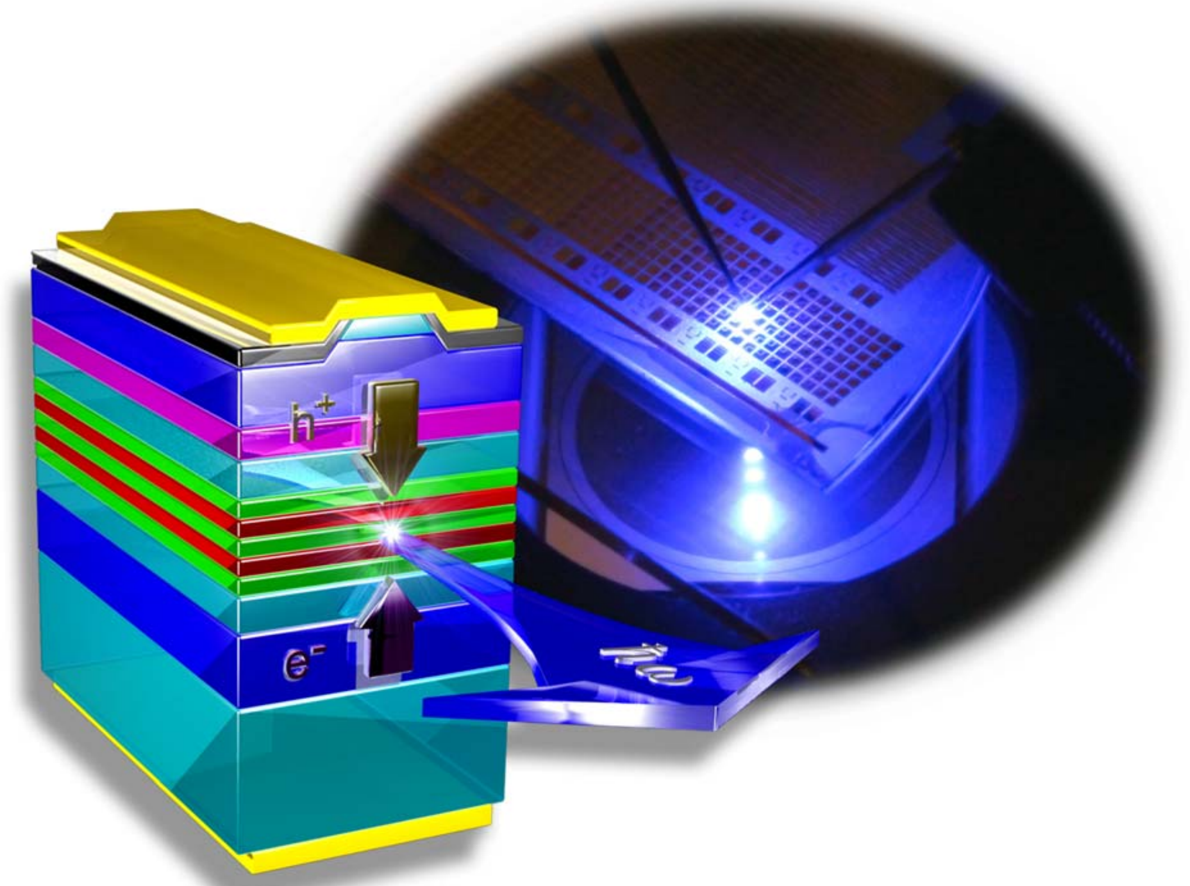
Technische Universität Berlin

Institute of Solid State Physics

Institut für Festkörperphysik

2005 - 2006



Technische Universität Berlin

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Institut für Festkörperphysik

2005 – 2006

Hardenbergstr. 36
D-10623 Berlin
Germany

Phone:	(30) 314-220 01
Fax:	(30) 314-220 64
E-Mail:	ifkp@physik.tu-berlin.de

Front Cover

Left: Schematic of a GaN-based ridge-waveguide laser heterostructure.
Right: Blue-violet emission from an InGaN multiple-quantum-well light emitting diode (LED) grown on sapphire substrate. The LED and laser structures on the wafer are results of the joint research of the Institute of Solid State Physics and Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH).

(Layout: Dipl.-Phys. R. Kremzow, Dipl.-Phys. J.-R. van Look, Dr. P. Vogt)

Back cover

Some of the larger projects and agencies funding our work, 2005 – 2006.

(Layout: Dipl.-Phys. A. Marent)

CONTENTS

1. PREFACE

The Institute of Solid State Physics presents its ninth biannual progress report. Founded in 1974 the Institute is located since 1985 at its site in Hardenbergstraße next to the center of Berlin, where it disposes of spacious lecture halls, seminar rooms and state-of-the-art laboratories. Our scientific work is focussed on epitaxial growth of narrow and wide-gap semiconductor hetero- and nanostructures, physics of nanostructures, novel materials research as well as physics and technology of nano-photonic devices and systems. In addition, development of nanoscopic measurement techniques, like cathodoluminescence, cross-section scanning tunneling microscopy, near field scanning optical microscopy, microphoto-luminescence, and micro-Raman are common subjects of the research activities of our four scientific departments.

In 2004 new “Center of NanoPhotonics” CNP of the institute was inaugurated by the Senator of Science of Berlin and the TUB President. In clean rooms up to class 10 most modern optical lithography, dry etching, oxidation, insulator and metal deposition systems, and ellipsometers for processing wafers up to 6 inch diameter are concentrated. Novel devices like Quantum Dot Vertical Surface Emitting Lasers, QD High Speed Emitters, QD Semiconductor Optical Amplifiers, QD VECSELs, Nanoflash memories, … are developed based on materials like InGaAsSb/GaAs or InAlGaN/Al_2O_3. Most modern education and research on devices and their technology can now be offered to our students and PhD candidates. In addition, the CNP provides assistance to small and medium size companies and acts as incubator for start-ups.

End of March 2005 our colleague Wolfgang Richter retired from his position at the Institute and moved to Rome. We owe him a lot as an internationally recognized expert in surface physics and growth related phenomena and wish him much good luck in the future.

In August 2005 Michael Kneissl, until that moment principal scientist at the Palo Alto Research Center, PARC, accepted his succession. In addition to his position at TUB he is responsible for the nitride-related research and optoelectronic device development at Ferdinand-Braun-Institute in Adlershof. At TUB he is just installing a new Close-Coupled-Showerhead Thomas Swan GaN MOCVD system purchased from Aixtron.

Two more faculty members joined us in the last two years: Prof. Bella Lake, formerly at Iowa State University, USA, and Prof. Alan Tennant, formerly at University of St. Andrews, UK. Both are in charge of research groups at Hahn-Meitner-Institute and teach at TUB.

Finally, it is a particular pleasure to welcome back Norbert Esser. He was jointly appointed as head of the Berlin-Adlershof branch of the Federal Government Institute of Applied Spectroscopy, ISAS, and TUB. The surface physics activities of Wolfgang Richters group, to which he belonged until 2003, will be continued by him to a large extent.

We continue to welcome Prof. Nikolai N. Ledentsov as a temporary faculty member at the institute. He continued his appointment at TU Berlin in 2006 as a DFG Mercator Professor and - as the first external member of the faculty - of our new “International Post Graduate School of Engineering and Advanced Technologies”.

The success of the institute and the large number of students, PhD candidates and postdocs we employ depend now since more than a decade on external financial resources. The funding from TUB and our state government in Berlin covers less than 20 % of cost of consumables and equipment. Our most important funding agency continued to be the German Research

Foundation (DFG). It sponsored the Center of Excellence ”Growth-Related Properties of Low-Dimensional Semiconductor Structures” (Sfb 296), hosted by the institute. Cooperation on nanostructure research with colleagues from four other institutions in Berlin (Humboldt University, Fritz-Haber-Institute, Max-Born-Institute, and Paul-Drude-Institute) continued to flourish. In addition, projects focussing on III-nitrides and on high frequency photonics were funded by DFG.

Further important work was financed by the Federal Ministry of Research and Technology (BMBF) within its Briolas and synchrotron radiation program, by the European Union, INTAS, NATO as well as the government of the State of Berlin in the frame work of its “Zukunftsfonds” and the ProFIT Program.

The bmb+f national competence center CC NanOp (Nano-Optoelectronics), established in October 1998, presented in the last years a very effective and successful means for initiating important European programs on nanomaterials and devices like DOTCOM, NATAL and TRIUMPH. Many of these projects emerged from small scale projects so called “Machbarkeitsstudien”, financed via NanOp. TUB therefore decided to continue its support of CC NanOp until end of 2010.

We are particularly proud of being initiator and member of the presently only EU 6th framework Center of Excellence in the field of semiconductor nanostructures “SANDiE”. Strong links to leading international optoelectronic and communication companies like Aixtron, Bookham, Infineon, NL Nanosemiconductors, Sentech and Siemens have been established within the framework of the above mentioned and other bilateral programs. In addition, regional and national collaborations, in particular with Siemens, are of largest importance for the progress reported here. Interdisciplinary research projects evolved with some of our own start-ups like LayTec or Lumics and our two joint start-ups with St. Petersburg’s Ioffe-Institute, NL Nanosemiconductors, and PCB Lasers which had an excellent take-off. We hope that our latest “child” VI systems will develop similarly.

Know-how was transferred, graduates were hired and joint development and research contracts were obtained in the areas of measurement technologies and photonic systems. In order to protect our intellectual property better than in the past and to have a better basis for cooperation with the industry, we filed and obtained an appreciable number of patents. The support by our local patent agency IPAL proved to be of outmost importance.

We are very grateful to all our funding agencies, their administrators and cooperating industry for their continuous help and encouragement.

The scientific part of the present report will certainly provide sufficient evidence that funding we received carried excellent results. Particular appreciation of our scientific achievements was expressed by the bestowal of a number of important awards listed in part 2 of the report.

We are particularly proud on the bestowal of an Alexander von Humboldt Award to Prof. Gadi Eisenstein who joined us in summer 2006, focussing his activities on high speed devices. Dr. Jungho Kim from South Korea and Dr. Leonid Karachinsky from the Ioffe Institute in St. Petersburg received in 2006 Alexander von Humboldt Fellowship and an additional Marie Curie Stipend.

Scientific contacts with institutions at many different locations in Europe, Japan or USA continued to flourish. Especially strong collaborations were exercised to research institutions and universities in Austin, Barcelona, Cambridge, Haifa, Minsk, Novosibirsk, St. Petersburg, Rome, South Carolina, Surrey, … to mention only a few.

Physics is a science not bound to a country or to borders. This ”discovery” led to an increasing number of our students and scientists in the past to pursue their research at foreign universities. We would like to thank particularly their local hosts. We will further encourage our co-workers to combine the challenge of different cultures and languages with high productivity in their scientific work.

Additional and particularly large burdens were taken over by all of the faculty staff of the institute in order to serve TUB and the scientific community as members or chairmen of committees on the local, national and international scale, e.g., within advisory or program committees.

The reelection of Prof. Christian Thomsen as Dean of the Faculty of Mathematics and Science in spring 2005 and his devotion for developing multimedia eLearning and eResearch should be particularly mentioned here. Additionally, he serves a two-year term as president of the Berlin Physics Society (2006-2007).

Finally, the enthusiasm and the dedication of our collaborators at the institute should be honoured, being fundamental to our success. The key element for future progress of the institute continues to be their motivation to generate new ideas and to work hard.

This report will

- give an overview of the formal structure of the institute and list staff and students
- summarize our teaching activities in order to provide information on our involvement in the education of young students and scientists
- summarize the scientific activities of our research groups, including lists of the approximately 200 scientific papers we published or which have been accepted for publication within the past 24 months, and of the numerous invited lectures we gave.

Dieter Bimberg

Executive Director

January 2007

2. PRIZES AND AWARDS

Particular appreciation of our scientific achievements was expressed by the bestowal of a number of important awards and prizes:

Prof. Dr. Dieter Bimberg	Max-Born-Prize and Medal 2006 of the German Physical Society and the Institute of Physics, U.K., “For his pioneering work in the field of quantum dot laser technology”, Institute of Physics, London, U.K., January 2006
Dr. Holger Eisele	Feodor Lynen Research Fellowship of the Alexander von Humboldt foundation, October 2006
Dipl.-Phys. Matthias Kuntz	Young Scientist Award for his paper: “10 Gb/s data modulation using 1.3 µm InGaAs quantum dot lasers” 13th International Symposium Nanostructures: Physics and Technology, St. Petersburg, Russia, June 2005
Dr. María Machón	Carl-Ramsauer-Preis, for her outstanding doctoral thesis, Berlin, November 2006
Dr. Janina Maultzsch	Feodor Lynen Research Fellowship of the Alexander von Humboldt foundation, August 2006
Dr. Sven Rodt, Dipl.-Phys. Andrei Schliwa, Dipl.-Phys. Robert Seguin	Nanowissenschaftspreis 2006 of the Hamburg Center of Competence for Nanotechnology (HanseNanoTec) for their achievements in the field of single quantum dot spectroscopy, awarded at the Conference ”nanoDe 2006”, Berlin, Germany, November 2006

3. STRUCTURE AND STAFF OF THE INSTITUTE

3.1 Office of the executive director (01.01.2006)

Prof. Dr. phil. nat. Dieter Bimberg (executive director)
Prof. Dr. rer. nat. Christian Thomsen (deputy executive director)
Prof. Dr. rer. nat. Mario Dähne (deputy executive director)
Prof. Dr. rer. nat. Michael Kneissl (deputy executive director)
Priv.-Doz. Dr. rer. nat. Axel Hoffmann (chief operating officer)
Ines Rudolph (administrative assistant)

3.2 Departments of the institute

Department I:	Prof. Dr. phil. nat. Dieter Bimberg
Department IIa:	Prof. Dr. rer. nat. Christian Thomsen
Department IIb:	Prof. em. Dr.-Ing. Dr. h.c. mult. Immanuel Broser Priv.-Doz. Dr. Axel Hoffmann
Department III:	Prof. Dr. rer. nat. Mario Dähne Prof. em. Dr.-Ing. Hans-Eckhart Gumlich
Department IV:	Prof. Dr. rer. nat. Michael Kneissl (as of 01.08.2005) Prof. Dr. rer. nat. Wolfgang Richter (retired since 01.04.2005)

3.3 Center of NanoPhotonics

Executive director
Prof. Dr. phil. nat. Dieter Bimberg

Chief operating officer
Priv.-Doz. Dr. Udo W. Pohl

Chief technology officers
Dr. Friedhelm Hopfer (processing, department I)
Dr. André Strittmatter (growth, department I)

Technical staff

Ilona Gründler (department I)

Christof Maerker (department IV)

Dipl.-Krist. Kathrin Schatke (department I)

Dipl.-Ing. Bernhard Tierock (department I)

The Center of Nano-Photonics provides support to institute departments by growth, processing and analysis of materials and structures. Growth facilities are based on metal-organic vapor phase epitaxy (MOCVD). They were recently amended by installing additional hydride lines at our AIX200/4 reactor, enabling improved doping and interface control. Processing facilities include dry etching, plasma deposition and optical lithography. An electrom beam evaporator and a sputter setup with multiple sources each were recently added to improve the performance of *p*-contacts.Growth and processing activities mainly focused on quantum-dot structures. MOCVD particularly aimed to realize InAs/GaAs dots with well-defined structure for fundamental studies, and InGaAs/GaAs dots with high areal density for edge- and surface-emitting lasers. The recently developed multimodal InAs/GaAs ensembles with quantum dots of shell-like increasing sizes was employed to fabricate samples for studying and controlling binding energies and fine-structure splitting of confined excitons. Structural properties of such dots were clarified and their formation and evolution was modeled using strain-driven kinetics. The performance of InGaAs quantum dots for lasers emitting at 1.3 μm was strongly improved by adjusting growth parameters for each of the stacked dot layer individually. A transparency current density of 66 A/cm^2 and 94% internal quantum efficiency were achieved for lasers emitting at 1.25 μm and strategies were developed to reach the 1.3 μm target. Electrically driven vertical-cavity surface-emitting QD-lasers grown using MOCVD were realized, featuring cw ground state lasing at RT with 1.45 mW output power and 45% external efficiency.

Device processing comprised fabrication of narrow ridge-waveguide lasers, a fast procedure for broad area test-lasers, HR facet coating, and VCSEL fabrication with selectively oxidized AlOx/GaAs mirrors and intracavity contacts. MBE wafers of edge-emitting InGaAs QD lasers were processed into deeply etched narrow ridge two section devices for mode locking and into semiconductor optical amplifiers. Amplification with low bias for mode-locked pulses was proved up to 80 GHz. PIN diodes with embedded InAs dot ensembles of a low areal density were successfully processed with a tiny oxide current-aperture to allow for an electrical excitation of only a single dot. Photon correlation measurements of such devices proved single-photon emission.

3.4 Workshops

Chief operating officer

Priv.-Doz. Dr. Axel Hoffmann

3.4.1 Mechanical workshop

Werner Kaczmarek (head)
Rainer Noethen
Wolfgang Pieper
Lothar Kroll
Daniela Beiße (as of 31.05.2006)
Jürgen Hoppe (until 31.12.2005)

3.4.2 Electronic workshop

Norbert Lindner

3.4.3 Glasstechnical workshop

Norbert Zielinski

3.5 Affiliated scientific units

3.5.1 Center of Excellence (Sfb 296) of the National Science Foundation DFG "Growth Correlated Properties of Low-Dimensional Semiconductor Structures"

Chairman

Prof. Dr. Dieter Bimberg

Vice chairmen

Prof. Dr. Thomas Elsässer, Max-Born-Institute
Prof. Dr. Andreas Knorr, Technical University Berlin
Prof. Dr. Roland Zimmermann, Humboldt University Berlin

Chief operating officer

Dipl.-Phys. Andrei Schliwa

Administrative assistant

Doreen Nitzsche

3.5.2 National Competence Center on NanoOptoelectronics of the Federal Ministry of Education and Research (bmb+f)

Chairman

Prof. Dr. Dieter Bimberg

Vice chairmen

Prof. Dr. Alfred Forchel, University of Würzburg

Dr. Norbert Grote, Heinrich-Hertz-Institute, Berlin

Dr. Jörg Kropp, Infineon Technologies GmbH, Berlin (until 31.12.2005)

Dr. Klaus Schulz, Merge Optics GmbH, Berlin

Chief operating officer

Dr. Matthias Kuntz

Deputy chief operating officer

Dipl.-Phys. Oliver Schulz

Administrative assistant

Susanne El-Badawi (until 30.09.2006)

3.5.3 Multimedia Center for eLearning and eResearch (MuLF)

Executive director

Prof. Dr. Chistian Thomsen

Prof. Dr. Sabina Jeschke

Staff

Dipl.-Phys. Dirk Heinrich

Dipl.-Math.Olivier Pfeiffer

Dipl.-Chem. Tilman Rassy

Dipl.-Inf. Uwe Sinhar

cand. Dipl.-Phys. Carola Nisse

Sabine Morgner

The Multimedia Center for E-teaching and E-research (MuLF) as a center in our faculty is responsible for central tasks in the area of information technology-based support of teaching. Achievements are, e.g., the information system for students (ISIS), the introduction of electronic chalk, the management system for examinations (MOSES), the electronic eprint server, or the electronic management system for the "Lange Nacht der Wissenschaften". Severeal thousands of students across the university are using these services. MuLF advises newcomers to E-teaching and offers training for the optimal use of the new media at the university. Furthermore, MuLF coordinated the multimedia equipment in the lecture rooms at the university. Scientifically the center coordinates projects, like, e.g., Nemesis, a large university-wide teaching and research project.

3.6 External and retired faculty members of the institute

Priv.-Doz. Dr. Norbert Ernst, Fritz-Haber-Institute (FHI) Berlin (until 31.03.2006)

S-Prof. Dr. Norbert Esser, Institute for Analytical Sciences (ISAS) Berlin (since 01.05.2006)

apl. Prof. Dr. Rudolf Germer, University of Applied Sciences (FHTW) Berlin

apl. Prof. Dr. Holger Grahn, Paul-Drude-Institute (PDI) Berlin

Priv.-Doz. Dr. Thorsten U. Kampen, Fritz-Haber-Institute (FHI) Berlin

S-Prof. Dr. Bella Lake, Hahn-Meitner-Institute (HMI) Berlin (since 01.08.2006)

apl. Prof. Dr. Hans-Joachim Lewerenz, Hahn-Meitner-Institute (HMI) Berlin

apl. Prof. Dr. Michael Meißner, Hahn-Meitner-Institute (HMI) Berlin

S-Prof. Dr. Ferenc Mezei, Hahn-Meitner-Institute (HMI) Berlin

Priv.-Doz. Dr. Norbert Nickel, Hahn-Meitner-Institute (HMI) Berlin

Priv.-Doz. Dr. Harm-Hinrich Rotermund, Fritz-Haber-Institute (FHI) Berlin

Priv.-Doz. Dr. Konrad Siemensmeyer, Hahn-Meitner-Institute (HMI) Berlin

S-Prof. Dr. Michael Steiner, Hahn-Meitner-Institute (HMI), Berlin

S-Prof. Dr. Alan Tennant, Hahn-Meitner-Institute (HMI) Berlin

apl. Prof. Dr. Wolfgang Treimer, University of Applied Sciences (TFH) Berlin

3.7 Honorary, adjunct and guest professors, Humboldt awardees and fellows

Prof. Dr. Alexander M. Bradshaw, executive director, Max-Planck-Institut für Plasmaphysik München, Germany, Honorary Professor

Prof. Dr. Gadi Eisenstein, Technion – Israel Institute of Technology, Haifa, Israel, Humboldt Award

Prof. Dr. Vladimir Haisler, Russian Academy of Sciences, Novosibirsk, Russia, Guest Professor

Prof. Dr. Diana Huffaker, University of New Mexico, Albuquerque, USA, Humboldt Fellow

Dr. Leonid Karachinsky, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia, Humboldt Fellow

Dr. Jungho Kim, National University, Seoul, Republic of Korea, Humboldt Fellow

Prof. Dr. Nikolai N. Ledentsov, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia, DFG Mercator-Professor

Dr. Mikhail Maximov, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia, Humboldt Fellow

Dr. Vitaly A. Shchukin, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia, DLR Fellow

Dr. Yuncai Wang, Taiyuan University of Technology, Shanxi, China, Guest Professor

4. FOREIGN GUESTS

Department I

M.Sc. Amélia **Ankiewicz**, University of Aveiro, Portugal
29.10. - 17.12.2006

Dr. Nina **Aulchenko**, Institute of Semiconductor Physics, Novosibirsk, Russia
16.10. - 30.11.2005

Dr. Sergej **Blokhin**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
12.11. - 28.12.2006

Dr. Ceyhun **Bulutay**, Bilkent University, Istanbul, Turkey
24.01. - 31.01.2005

Shanna **Crankshaw**, University of California, Berkeley, USA
04.12. - 08.12.2006

M.Sc. Francois **Doré**, Institut National des Sciences Appliquées de Rennes, France
12.06. - 16.06.2006

M.Sc. Christophe **Gosset**, LPN-CNRS, Marcoussis, France
01.07. - 16.07.2006

Dr. Leonid **Karachinsky**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
10.02. - 17.02.2005, 19.05. - 19.06.2005, 11.08. - 13.11.2005, 30.10. - 31.12.2006

Anastasia **Karkatzinou**, University of Athens, Greece
11.10.2006 - 30.09.2007

M.Sc. Vlastimil **Krapek**, Masaryk University Brno, Czech Republic
01.10.2006 - 31.07.2007

Dr. Natalia **Kryzhanovskaya**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
05.05. - 26.05.2005, 04.07. - 19.08.2005

Prof. Dr. Christophe **Labbé**, Institut National des Sciences Appliquées de Rennes, France
12.06. - 16.06.2006

Dr. Maria **Lifshits**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
21.03. - 05.05.2005, 26.05. - 19.06.2005

Juan G. **Lozano** and David **Sales**, University of Cadiz, Spain
08.12. - 12.12.2005

M.Sc. Vladan **Mlinar**, University of Antwerp, Belgium
04.04. - 30.05.2005

Vincent **Peron-Lührs**, Institut National des Sciences Appliquées de Rennes, France
12.06. - 16.06.2006

Dr. Anna **Rodina**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
05.08. - 31.08.2006

M.Sc. Artem **Savelyev**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
02.03. - 30.04.2006, 30.10. - 25.12.2006

Dr. Vitaly A. **Shchukin**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
01.01.2005 – 31.12.2006

Department II

Dr. Dimitry **Azamat**, A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
01.01.-31.05.2005

Prof. Dr. Wolfgang S. **Bacsa**, Laboratoire de Physique des Solides, Université Paul Sabatier, Toulouse, France
23.05. – 28.05.2005, 19.09.-25.09.2005

Prof. Dr. Milan **Damnjanović**, University of Belgrade, Belgrade, Serbia
21.11.-26.11.2005

Prof. Dr. Nikolaus **Dietz**, Georgia State University, Atlanta, USA
03.07.-11.07.2006

Gijs **Franssen**, Unipress, Warschau, Poland
23.09.-25.09.2005

Prof. Dr. Konstantin **Gartsmann**, Weizmann Institute of Science, Electron Microscopy Unit, Rehovot, Israel
13.02.-20.02.2005, 12.06.-26.06.06

Prof. Dr. Jean **Geurts**, Julius-Maximilians-Universität Würzburg, Germany
03.11.-05.11.2006

Prof. Dr. Alejandro **Goñi**, Institut de Ciència de Materials de Barcelona, Bellaterra, Spain
23.08. – 30.08.2005, 21.11.-26.11.2005, 01.06.-17.2006. 2006, 22.11.-29.11.2006

Dr. Jos **Haverkort**, Eindhoven University of Technology, Eindhoven, The Netherlands
24.04.-28.04.2006

Matthew **Kane**, Georgia State University, Atlanta, USA
31.01.-05.03.2006

Prof. Dr. Oleg **Kibis**, State Technical University, Novosibirsk, Russia
20.07.-02.08.2006

Prof. Dr. Herbert Willi **Kunert**, University of Pretoria, South Africa
01.04.-30.06.2006

Andrei **Magyarov**, Belarusian State University, Minsk, Belarus
01.04.-31.05.2005 and 01.05.-30.06.2006

Prof. Dr. Sergey **Maksimenko**, Belarusian State University, Minsk, Belarus
01.04.-31.05.2005; 01.04.-31.05.2006 and 03.12.-24.12.2006

Enno **Malguth**, University of Technology, Sydney, Australia
27.03.-02.04.2006

Prof. Dr. Bruno K. **Meyer**, Justus-Liebig-Universität Gießen, Germany
18.12.-20.12.2005 and 06.06.-08.06.2006

Robert **McKenna**, University of Technology, Sydney, Australia
21.11.-05.12.2005 and 01.02.-11.04.2006

Pablo Jesús **Ordejón Rontome**, Universitat Autònoma de Barcelona, Spain
06.06.-08.06.2006

Prof. Dr. Dimitra **Papadimitriou**, University of Athens, Greece
15.04.-30.04.2006

Prof. Dr. Matthew **Philips**, University of Technology, Sydney, Australia
27.05. – 29.05.2005

Dipl.-Phys. Pascal **Puech**, Laboratoire de Physique des Solides, Université Paul Sabatier, Toulouse, France
19.09.-25.09.2005

Dr. Peter **Rafailov**, Bulgarian Academy of Sciences, Sofia, Bulgaria
25.10. – 11.11.2006

Prof. Dr. Stephanie **Reich**, Massachusetts Institute of Technology, Cambridge, USA
08.04.-17.04.2005, 01.08.-30.09.2005, 01.06.-09.06.2006

Veronika **Rinnerbauer**, Johannes-Kepler-Universität Linz, Austria
24.10.-28.10.2006

Dr. Gregory **Slepyan**, Belarusian State University, Minsk, Belarus
01.04.-30.04.2005; 01.04.-30.04.2006 and 03.12.-24.12.2006

Prof. Dr. Vasili **Strazhau**, Belarusian State University, Minsk, Belarus
19.04.-21.04.2006

Prof. Dr. Tadeusz **Suski**, Unipress, Warschau, Poland
23.09.-25.09.2005

Prof. Joe **Troedahl**, Victoria University, Wellington, New Zealand
19.09.-25.09.2005

Department III

Ganesh **Balakrishnan**, University of New Mexico, Albuquerque, USA
07.05. – 11.05.2005

Dr. Giovanni **Costantini**, MPI für Festkörperforschung, Stuttgart, Germany
14. – 15.12.2006

Dr. Hazem **Abu-Farzakh**, MPI für Eisenforschung, Düsseldorf, Germany
11. – 12.04.2006

Prof. Dr. Karl **Jacobi**, Fritz-Haber-Institut, Berlin, Germany
16.08. – 20.08.2005

Dr. Max **Migliorato**, University of Sheffield, UK
11. – 12.05.2006

Dr. Susanne **Siebentritt**, Hahn-Meitner-Institut, Berlin, Germany
24.02.2006

Dr. Denis **Vyalikh**, Technische Universität Dresden, Germany
25.11.2005

Department IV

Balliou **Aggeliki**, National Technical University of Athens, Greece
01.10.2005 – 30.09.2006

Dr. Sandhya **Chandola**, Trinity College, Dublin, Ireland
01.01.2005 – 31.12.2006

Prof. Dr. Anatoli **Chkrebtii**, Institute of Technology, University of Ontario, Canada
01.-08.08.2006

Dott. Roberto **Jakomin**, Università degli studi di Parma, Italy
01.09.-31.12.2006

MSc Georgios **Karras**, National Technical University of Athens, Greece
01.08.-30.09.2005

Dr. Stacia **Keller**, Electrical & Computer Engineering Dept. University of California, Santa Barbara, USA
05.-08.12.2005

Phd Georgios **Manolis**, National Technical University of Athens, Greece
01.08.-01.12.2005

Dr. David **Martin**, University of Liverpool, UK
21. – 26.08.2006

Dr. Thomas **Oates**, Institut für Ionenstrahlung und Materialforschung, Forschungszentrum Rossendorf, Dresden
14.11.2005

Dr. Dimitra **Papadimitriou**, National Technical University of Athens, Greece
07.-25.02.2005, 01.08.-30.09.2005, 15.-26.02.2006, 01.08.-31.8.2006

Phd Sofia **Theodoropoulou**, National Technical University of Athens, Greece
01.08.-30.9.2005

Dr. Georgios **Tzamalis**, National Technical University of Athens, Greece
01.08.-30.9.2005

Prof. Dr. **Weng Chow**, Sandia National Laboratories, Albuquerque, NM, USA
20.11. – 08.12.2006

4.1 Talks by Guests

Department I

Prof. Dr. Zhores I. Alferov	**Einstein and the development of quantum electronics** 18.10.2005 A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
Prof. Dr. Claus Ascheron	**Science citation index and impact factors - Gebrauch und Missbrauch - Ist der Science Citation Index das ultimative Maß für die Qualität wissenschaftlicher Veröffentlichungen?** 13.07.2005 Executive Editor Physics, Springer-Verlag, Heidelberg, Germany
Prof. Dr. Claus Ascheron	**Scientific publishing: How to write a good scientific paper and submit it successfully** 26.10.2005 Executive Editor Physics, Springer-Verlag, Heidelberg, Germany
Dr. Fariba Hatami	**Novel light emitters based on InP/GaP nanostructures** 11.12.2006 Humboldt-Universität zu Berlin, Germany
Prof. Dr. Ortwin Hess	**Modelling of photonic nano-materials and ultrafast optoelectronic devices** 26.01.2006 School of Electronics and Physical Sciences, University of Surrey, Guildford, UK
Dr. Wolfgang Huhn	**Ökonomie der Halbleiterproduktion in Deutschland** 30.06.2005 McKinsey & Co. Inc., Frankfurt, Germany
Dr. Leonid Ya. Karachinsky	**Single mode cw operation of InAs/InGaAs quantum dot lasers on GaAs substrate s emitting near 1.5 µm** 15.02.2005 A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

Dr. Natalia Kryzanovskaya	**Optical studies of asymmetrical waveguide InGaAs quantum dot microdisks formed by selective wet oxidation and time-resolved study of enhancement of spontaneous emission rates of InAs quantum dots in the tilted cavity laser** 16.08.2005 A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
M.Sc. Vladan Mlinar	**Quantum dot electronic states in a magnetic field** 26.05.2005 University of Antwerp, Belgium
Prof. Dr. Gerd O. Müller	**Nitride auf dem Weg zu Solid State Lighting** 11.07.2005 Lumileds Lighting, San Jose, USA
M.Sc. Artem Savelyev	**Spontaneous emission and waveguiding modes in VCSEL and AVCSEL structures** 25.04.2006 A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia
Prof. Dr. Ruben P. Seisyan	**The concept of EUV-lithography tool for scientific applications** 23.01.2006 A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

Department II

Dipl.-Phys. Klaus Anhalt	**Eutektische Metall-Kohlenstoff Legierungen als Hochtemperatur-Fixpunkte in Strahlungsthermometrie und Radiometrie** 21.02.2005 Physikalisch-Technische Bundesanstalt, Berlin, Germany
Dr. Johan Carlsson	**Theoretical study of curvature effects in defective Nanotubes** 23.05.2005 Fritz-Haber-Institut, Berlin, Germany
Prof. Dr. Nikolaus Dietz	**High pressure MOVCD growth and in-situ characterization of InN** 13.06.2005 Georgia State University, Atlanta, USA

Dipl.-Phys. Fabian Jachmann	**Transport of vortices in superconductors** 21.05.2006 Paul-Drude-Institut, Berlin, Germany
Prof. Dr. Jean Geurts	**Dimensional and doping dependence of the exchange energy in diluted magnetic II-VI compounds** 03.11.2006 Julius-Maximilians-Universität Würzburg, Germany
Dr. Katlin Kamarás	**Optical spectroscopy on carbon nanotubes** 06.06.2005 Hungarian Academy of Science, Budapest, Hungary
Dr. Markus Kraft	**Nanotubes and remote experiments** 11.08.2005 University of Cambridge, UK
Dr. Ralf Krupke	**Separation of metallic from semiconducting carbon nanotubes, optical spectroscopy and electron transport** 18.11.2005 Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Germany
Dipl.-Phys. Holger Lange	**Stimulated emission from single ZnO nanorods** 29.05.2006 Hahn-Meitner-Institut, Berlin, Germany
Prof. Dr. Bruno K. Meyer	**Defects and doping in ZnO** 19.12.2005 Universität Gießen, Germany
Cand. Dipl.-Phys. Jörg Polte	**Eindimensionale Anordnung von endohedralen Fullerenen** 17.07.2006 Freie Universität, Berlin, Germany
Dr. Riccardo Rurali	**Surface reconstructed silicon nanowires: A theoretical study** 21.11.2005 Université Paul Sabatier, Toulouse, France

Department III

Ganesh Balakrishnan	**Manipulation of 3-D Quantum Structures using Strain and Surface** 09.05.2005 University of New Mexico, Albuquerque, USA
Wolfgang Benten	**Kollektive Anregungen von oxidgetragenen Edelmetallpartikeln** 18.02.2005 Fritz-Haber-Institut, Berlin, Germany
Dr. Giovanni Costantini	**Self-organized semiconductor quantum dots: Growth capping and composition** 14.12.2006 MPI für Festkörperforschung, Stuttgart, Germany
Prof. Dr. Norbert Esser	**Optische Charakterisierung von Oberflächen und Grenzflächen** 23.08.2006 ISAS, Berlin, Germany
Dr. Hazem Abu-Farzakh	**Incorporation of N at GaAs and InAs surfaces: An ab-initio study** 12.04.2006 MPI für Eisenforschung, Düsseldorf, Germany
Prof. Dr. Karl Jacobi	**Atomare Struktur von Quantenpunkten** 18.08.2005 Fritz-Haber-Institut, Berlin, Germany
Dr. Max Migliorato	**Atomistic Simulations using realistic models of Semiconductor Quantum Dots** 11.05.2006 University of Sheffield, UK
Antonio Rueda	**Untersuchung der Mikrostruktur und des Fließverhaltens binärer thixotroper Legierungen mit Synchrotronstrahlung** 28.04.2006 Hahn-Meitner-Institut, Berlin, Germany
Dr. Susanne Siebentritt	**Chalkopyrite - ternäre Halbleiter mit einzigartigen Eigenschaften (nicht nur) für Solarzellen** 24.02.2006 Hahn-Meitner-Institut, Berlin, Germany
Dr. Denis Vyalikh	**Quantum well states in metallic bilayers** 25.11.2005 Technische Universität Dresden, Germany

Department IV

Prof. Dr. Anatoli Chkrebtii	**Symmetry in optical properties: Surface sensitive effect of injection current and temperature dependent optical dielectric function** 07.08.2006 University of Ontario, Canada
Dr. Stacia Keller	**Group-III Nitrides for Light Emitting Devices – A Discussion of Remaining Challenges** 07.12.2005 University of California, St. Barbara, USA
Dr. Thomas Oates	**In situ spectroscopic ellipsometry of metallic nanoparticulate thin films** 14.11.2005 Forschungszentrum Rossendorf, Dresden
Dr. Bert Voigtländer	**Formation and Decay of Si/Ge Nanostructures at the Atomic Level** 11.01.2006 Forschungszentrum Jülich
Prof. Dr. Weng Chow	**Emission from an active photonic lattics: Is greater than blackbody intensity possible?** 06.12.2006 Sandia National Lab., Albuquerque, USA

5. PARTICIPATION IN COMMITEES

5.1 Program and Advisory Committee

Dieter Bimberg

Member of the Program Committee of the “Nanoelectronics and Novel Materials” at
17th Indium Phosphide and Related Materials Conference (IPRM 2005),
Glasgow, Scotland, UK, May 8 - 12, 2005

Member of the Program Committee of the Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures, Kühlungsborn, Germany, June 9 - 12, 2005

Member of the Program Committee of the 12th Int. Conf. on Modulated Semiconductor Structures (MSS 12), Albuquerque, New Mexico, USA, July 10 - 15, 2005

Member of the Program Committee of the IEEE Nano-Optoelectronics and Nano-Photonics Technical Committee of Nanotechnology Council, IEEE Nano Conference 2005, Nagoya, Japan, July 11 - 15, 2005

Workshop “Quanteninformation und Quantenpunkte” (Chairman),
Institut für Festkörperphysik, TU Berlin, Germany, November 14, 2005

Member of the Program Committee of the Int. Workshop on Semiconductor Quantum Dot based Devices and Applications, Institut Curie, Paris, France, March 16 - 17, 2006

DPG - spring meeting of the Division Condensed Matter, EPS - 21st General Conference of the Condensed Matter Division (Session Chair), Dresden, Germany, March 26 - 31, 2006

Member of the Program Committee of the “Semiconductor Lasers and Laser Dynamics II”
at Photonics Europe, 2006, Strasbourg, France, April 3 - 7, 2006

Member of the Program Committee of the 8th Int. Workshop on Expert Evaluation & Control of Compound Semiconductor Materials & Technologies (EXMATEC ’06) Cadiz, Spain, May 14 - 17, 2006

Member of the International Advisory Board of the Special Symposium “Disclosing Materials at Nanoscale” at CIMTEC 2006, Acireale, Sicily, Italy, June 4 - 9, 2006

Special Symposium “Disclosing Materials at Nanoscale” (Co-Chairman), CIMTEC 2006, Acireale, Sicily, Italy, June 4 - 9, 2006

Member of the Program Committee of the Workshop on Photonic Components for Broadband Communication, Stockholm, Sweden, June 28 - 29, 2006

Member of the International Advisory Board of the 28th Int. Conference on the Physics of Semiconductors (ICPS 28), Vienna, Austria, July 24 - 28, 2006

Member of the International Advisory Board of the 14th Int. Conference on Superlattices, Nano-Structures and Nano-Devices (ICSNN 2006), Istanbul, Turkey, July 30 - August 14, 2006

Organizing and Program Committee, (Chairman), Int. Symp. on Semiconductor Nanostructures, Berlin, Germany, September 7 - 8, 2006

Mario Dähne

Member of the Program Committee of the European Conference on Surface Science, Berlin, Germany, September 4 - 9, 2005 (ECOSS 2005)

Axel Hoffmann

Member of the Program Committee of the “SPIE 2005”, San Diego, California, U.S.A., February 2005

Member of the Program Committee of the “Frühjahrstagung der Deutschen Physikalischen Gesellschaft” (DPG 2005), Berlin, Germany, March 2005

Chairman of the “E-MRS Spring Meeting 2005” (E-MRS 2005), Strasbourg, France, May 2005

Member of the Organisation Committee and Program Chair of the “ICNS-6 The Six’th International Conference On Nitride Semiconductors”, Bremen, Germany, August 2005

Member of the Program Committee of the “9th International Conference on the Optics of Excitons in Confined Systems”, Southampton, United Kingdom, September 2005

Member of the Program Committee of the “SPIE 2006”, San Jose, California, U.S.A., January 2006

Member of the Program Committee of the “Frühjahrstagung der Deutschen Physikalischen Gesellschaft” (DPG 2006), Berlin, Germany, March 2006

Program Chair of the “ISBLLED 2006, Montpellier, France, May 2006

Member of the Program Committee of the “IWN 2006”, Kyoto, Japan, October 2006

Michael Kneissl

Member of the Program Committee of the SPIE Photonics West Conference, Symposium on Novel In-Plane Laser Diodes, San Jose, USA, 2002 until present

Member of the International Advisory Committee, International Workshop on Nitride Semiconductors, Kyoto, Japan, October 2006

Member of the Organizing Committee of the DFG-Workshop on “Laserdioden im blauen Spektralbereich und nahen UV: neue Strukturen und dynamische Eigenschaften“, Regensburg, Germany, March 2006

Nikolai Ledentsov

Member of the Program Committee of the Integrated Optoelectronic devices, OPTO 2006, San Jose, California, USA, January 21 – 26, 2006

Member of the Program committee of the "Physics and Simulation of Optoelectronic Devices XIV", Photonics West, San Jose, California, USA, January 21 – 26, 2006

Udo Pohl

Member of the Scientific Committee of the DGKK/ PTWK 2006, Workshop of the German Association for Crystal Growth (DGKK) and the Polish Association for Crystal Growth (PTWK), Berlin, Germany, March 6 – 8, 2006

Wolfgang Richter

Organizing Committee of the Optics of Surfaces and Interfaces (OSI-VI) in Aalborg, Danmark, June 2005

Program Committee of the European Workshop on Metal Organic Vapour Phase Epitaxy, EW MOVPE XI (2005), Lausanne, Schweiz

Advisory Committee of the 13th international Conference on Metal Organic Vapour Phase Epitaxy, IC MOVPE XIII (2006), Miyazaki, Japan,

Christian Thomsen

Member of the Board of "International Winterschool on the Electronic Properties of Novel Materials" 2005 and 2006, Kirchberg, Austria

5.2 Editorial duties / Boards of institutes and companies

Dieter Bimberg

Co-Editor of Springer Series “NanoScience and Technology”, Springer Verlag GmbH, Heidelberg, Germany

Editorial Chair for Nanophysics in “Nanoscale Research Letters”

Editorial Advisory Board "OPTO-ELECTRONICS REVIEW" (O-ER)

International Board of Editors “Semiconductor News”

Guest Editor of IEEE Journal of Quantum Optics, Selected Topics

Mario Dähne

Referee of Journal of Vacuum Science and Technology, Physical Review, Journal of Applied Physics, Applied Physics Letters, Physical Review Letters, Surface Science, Thin Solid Films, Surface and Interface Analysis

Holger Eisele

Referee of Journal of Crystal Growth, Surface Science and Journal of Vacuum-Science and Technology

Hans-Eckhart Gumlich

Referee of Semiconductor Science and Technology, Nanotechnology and Journal of Applied Physics

Axel Hoffmann

Editorial Board of “physica status solidi (c)”, WILEY-VCH, Weinheim, Germany

Michael Kneissl

Guest Editor of the Japanese Journal of Applied Physics, “Selected Topics in Applied Physics- Physics of UV Materials and Devices and Their Applications” (2005).

Nikolai Ledentsov

Editorial Board of Semiconductors and Semiconductor Science and Technology

Udo Pohl

Organizer of the Nano Research Society

Wolfgang Richter

Board of Editors of Journal Applied Physics A

Christian Thomsen

Editorial board of physica status solidi (b), Solid Sate Communications, physica status solidi (rrl)

Scientific Advisory Board; Laser und Medizintechnik GmbH Berlin, LMTB (until 2005)

Scientific Advisory Board of the Max-Born-Institute Berlin (since 2003)

Member of the Council of the Physikalische Gesellschaft zu Berlin e.V.

President of the Physikalische Gesellschaft zu Berlin e.V. (2006-2007)

6. EXTERNAL COLLABORATIONS

Department I

- Universität Linz, **Austria**, Prof. Dr. G. Bauer, Dr. A. Darhuber
- Belarus State University Minsk, **Belarus**, Dr. M.V.P. Kalosha
- University of Antwerp, **Belgium**, Prof. J.T. Devreese, Prof. F. Peeters
- Denmark Technical University, Lyngby, **Denmark**,
  Prof. M.J. Hvam and Prof. D. Birkedal
- Humboldt Universität zu Berlin, **Germany**,
  Prof. Dr. O. Benson, Prof. Dr. F Henneberger, Prof. Dr. R. Köhler, Prof. Dr.W. Neumann
  Prof. Dr. M. von Ortenberg, Prof. Dr. R. Zimmermann
- Siemens AG, Berlin, **Germany**, Dr. V. Lüthen
- NL Nanosemiconductors, Dortmund, **Germany**, Dr. A. Kovsh
- Universität Dortmund, **Germany**, Prof. Dr. U. Woggon, Dr. P. Borri
- Universität Karlsruhe, **Germany**, Prof. Dr. D. Gerthsen
- Universität Leipzig, **Germany**, Prof. Dr. M. Grundmann
- Universität Magdeburg, **Germany**, Prof. Dr. J. Christen, Prof. Dr. A. Krost
- National Technical University, Athens, **Greece**, Prof. Dr. Y. Raptis, Dr. A. Kontos
- University of Cork, Tyndall Center, **Ireland**, Prof. J.G. McInerney, Dr. S. Hegarty
- PCB Lasers Ltd., Tel Aviv, **Israel**, Dr. A. Sharon
- Universita di Roma „La Sapienza", **Italy**, A. Polimeni, M. Capizzi
- University of Tokyo, **Japan**, Prof. Y. Arakawa
- Katholieke Universiteit Leuven, **The Netherlands**, Prof. V. Moshchalkov, Dr. M. Hayne
- Warsaw University of Technology, Faculty of Physics, **Poland**, Prof. R. Bacewicz
- Universidad de Aveiro, **Portugal**, Prof. N. Sobolev
- Institute of Semiconductor Physics, Novosibirsk, **Russia**, Prof. V.A. Haisler
- A.F. Ioffe Physico-Technical Institute, St. Petersburg, **Russia**,
  Prof. Zh. I. Alferov, Prof. N.T. Bagraev, Prof. V.M. Ustinov
- Siberian Physico-Technical Institute, Tomsk, **Russia**,
  Prof. V.G. Voevodin, O.V. Voevodina
- University of Cambridge, **UK**, Prof. I. White, Dr. R. Penty
- University of Glasgow, **UK**, Prof. J. Marsh and Dr. C. Bryce
- University of Nottingham, **UK**, Prof. L. Eaves, Dr. M. Henini
- University of Sheffield, **UK**, Prof. M. Skolnick, Prof. D. Mowbray
- University of Cincinnati, Ohio, **USA**, Prof. Dr. H.-P. Wagner
- University of Southern California, **USA**, Prof. Dr. A. Madhukar
- National Institute of Standards and Technology, Gaithersburg, **USA**, Dr. M. Hanke
- University of Michigan, **USA**, Prof. P.K. Bhattacharya
- University of New Mexico, **USA**, Prof. D.L. Huffaker
- University of Texas, **USA**, Prof. D.G. Deppe

Department II

- Centro Atomico, Bariloche, **Argentina**, Prof. Dr. Alex Fainstein
- University of Technology Sydney, **Australia**, Dr. Matthew Phillips
- Belarus State University, Minsk, **Belarus**, Dr. M.V.P. Kalosha
- Institute for Nuclear Problems, Minsk, **Belarus**, Prof. S. Maksimenko, Dr. G. Ya. Slepyan
- University of Sofia, **Bulgaria**, Dr. Miroslav Abrashev
- CNRS Université Montpellier, **France**, Prof. Bernier, Prof. B. Gil, Dr. B. Daudin
- Laboratoire de Physique des Solides, Université Paul Sabatier, Toulouse, **France**, Prof. Dr. Wolfgang Bacsa
- Aixtron AG, Aachen, **Germany**, Priv. Doz. Dr. M. Heuken
- Humboldt Universität zu Berlin, **Germany**, Prof. R. Zimmermann
- Hahn-Meitner-Institut Berlin, **Germany**, Prof. Dr. Michael Steiner, Dr. Bernd Meißner
- Paul-Drude-Institut, Berlin, **Germany**, Prof. K. Ploog, Dr. H.T. Grahn
- Frauenhofer-Institut für Festkörperforschung, Freiburg, **Germany**, Dr. F. Fuchs
- Universität Gießen, **Germany**, Prof. B.K. Meyer
- Otto-von-Guericke Universität, Magdeburg, **Germany**, Prof. J. Christen
- Siemens AG, München, **Germany**, Dr. C. Fricke
- Walter Schottky Institut München, **Germany**, Prof. M. Stutzmann
- Gesamthochschule Paderborn, **Germany**, Prof. Lischka
- Max-Planck-Institut für Festkörperforschung, Stuttgart, **Germany**, Dr. Siegmar Roth
- Weizmann Institute of Science, Rehovot, **Israel**, Prof. Dr. Konstantin Gartsmann, Prof. Dr. Reshef Tenne
- Mie University, **Japan**, Prof. K. Hiramatsu
- University of Tokyo, **Japan**, Prof. Yasuhiko Arakawa
- Novosibirsk State Technical University, **Russia**, Prof. O. V. Kibis
- A.F. Ioffe Physico-Technical Institute, St. Petersburg, **Russia**, Prof. Zh.I. Alferov
- University of Belgrade, **Serbia and Montenegro**, Prof. Dr. Zoran Popović, Prof. Dr. Milan Damnjanović
- Instituto de Cienca de materiales, Consejo, Barcelona, **Spain**, Prof. Dr. Alejandro Goñi, Prof. Dr. Pablo Ordejón
- University of Valencia, **Spain**, Dr. Andres Cantarero
- University of Cambridge, Cambridge, **UK**, Prof. Dr. John Robertson
- University of Exceter, **UK**, Dr. A. Plaut, Dr. M. E. Portnoi
- National Center for Electron Microscopy, Berkley, California, **USA**, Dr. Christian Kieselowski
- Massachusetts Institute of Technology, Cambridge, **USA**, Prof. Dr. Stephanie Reich
- North Carolina State University, Raleigh, **USA**, Dr. James L. Oblinger
- Georgia State University, Atlanta, **USA**, Dr. Carl V. Patton, Dr. Lauren Adamson

Department III

- Freie Universität Berlin, **Germany**, Prof. G. Kaindl
- Fritz-Haber-Institut, Berlin, **Germany**, Prof. K. Horn, Prof. K. Jacobi, Prof. M. Scheffler
- Technische Universität Dresden, **Germany**, Prof. C. Laubschat, Dr. S. Molodtsov
- Forschungszentrum Jülich, **Germany**, Dr. P. Ebert
- Infineon Technologies, **Germany**, Dr. L. Geelhaar
- Max-Planck-Institut für Festkörperforschung, Stuttgart, **Germany**, Dr. G. Costantini, Dr. A. Rastelli
- Universidad del País Vasco, San Sebastián, **Spain**, Prof. J.E. Ortega
- University of New Mexico, **USA**, Prof. D.L. Huffaker
- University of Texas, Austin, **USA**, Prof. C.K. Shih

Department IV

- Aixtron AG, Aachen, **Germany**, Dr. F. Schulte
- Ferdinan-Braun-Institut für Höchstfrequenztechnik, Berlin, **Germany**, Prof. Dr. G. Tränkle
- Institute for Analytical Sciences, Dept. Berlin, **Germany**, Prof. Dr. N. Esser
- LayTec GmbH, Berlin, **Germany**, Dr. T. Zettler
- IV. Physikalisches Insitut der Universität Göttingen, **Germany**, Dr. Martin Wenderoth,
- National Technical University, Athens, **Greece**, Prof. Dr. Papadimitriou
- Università degli studi di Parma, **Italy**, Prof. L. Tarricone
- Università degli Studi di Roma "Tor Vergata", **Italy**, Prof. Dr. Wolfgang Richter
- Palo Alto Research Center, Califonia, **USA**, Dr. Noble M. Johnson
- Yale University, New Haven, **USA**, Prof. Dr. Richard K. Chang
- Sandia National Laboratories, Albuquerque, New Mexcio, **USA**, Prof. Weng Chow

7. TEACHING

Internal faculty members

Applied Physics I + II, Lectures
D. Bimberg, U.W. Pohl, A. Hoffmann, M. Weyers

Lab Course in Advanced Experimental Physics
D. Bimberg, M. Dähne, C. Thomsen, M. Kneissl

Lab Course in Methods of Applied Physics I and II
D. Bimberg

Seminar on Photonics: Materials, Devices, Systems
D. Bimberg, A. Hoffmann, F. Hopfer, U.W. Pohl, A. Strittmatter

Advanced Experimental Physics II: Solid State Physics
M. Dähne, H. Eisele

Experimental Physics I + II
M. Dähne

Introduction to Physics I + II for Chemistry Students
M. Dähne, H. Eisele

Seminar on Surfaces, Interfaces and Nanostructures
M. Dähne, H. Eisele, J. Grabowski, K. Hodeck, L. Ivanova, A. Lenz, R. Timm, M. Wanke

Introduction to the Basics of Magnetic Resonance Spectroscopy
W. Gehlhoff

Advanced Optoelectronic Devices for Telecom and Quantum Cryptography Applications
V. A. Haisler

Macroscopic Quantum Phenomena in Solid State Physics
A. Hoffmann

Modern Methods of Solid State Physics
A. Hoffmann

Exercises to Solid State Physics I + II
M. Kneissl, P. Vogt

Seminar "Moderne Konzepte der Optoelektronik"
M. Kneissl, M. Pristovsek

Seminar "Physics of Semiconductor Interfaces and Heterostructures"

M. Kneissl, W.Richter, P.Vogt, M. Pristovsek

Solid State Physics I + II
M. Kneissl, P. Vogt, M. Pristovsek

Nanoepitaxy – Nanooptoelectronics, Lectures
N.N. Ledentsov

Introduction to Physics for Engineering Students I +II
C. Thomsen

Introduction to Physics: Problems Solving for
Graduate students and Advanced Diploma Students
C. Thomsen

Physikalisches Kolloquium
C. Thomsen, A. Knorr

Special Topics in Physics for Engineering Students
C. Thomsen

Special Topics in Semiconductor and Nanotube Research
C. Thomsen

External faculty members

Experimental Surface Physics
N. Ernst

Introduction to Physics I + II for Chemistry Students
N. Esser, T.U. Kampen, N. Nickel

Physics of Electronic Devices
R. Germer

Physics of Organs of Perception
R. Germer

Ultrasonics and Phonons
R. Germer

Electrochemical Nanotechnology
H.-J. Lewerenz

Photo-Electro Chemical Solar Energy Conversion
H.-J. Lewerenz

Photovoltaic Solar Cells
H.-J. Lewerenz

Surface Physical Research on Energy Converted Semiconductor Structures
H.-J. Lewerenz

Neutron Scattering
F. Mezei

Hydrogen in Solid States
N. Nickel

Applied Surface Physic
H.-H. Rotermund

Neutron Scattering and Dynamics of Condensed Matter
K. Siemensmeyer, B. Lake

Neutrons as an Efficient Tool to Investigate Condensed Matter
K. Siemensmeyer, B. Lake

Advanced Magnetism
A. Tennant

Neutron Scattering (Statics and Dynamics of Magnetic Model Systems)
A. Tennant

Neutron Interferences
W. Treimer

X-ray Interferences and Applications I + II
W. Treimer

X-ray and Neutron Computed Tomography
W. Treimer

X-ray and Neutron Optics
W. Treimer

8. PATENTS

Verfahren zur Epitaxie von (Indium, Aluminium, Gallium)-Nitridschichten auf nicht-planaren Si-Substraten
Deutsche Patentanmeldung Nr. 102005010821.0 (07.03.2005)
Internationale Anmeldung Nr. PCT/DE2006/000399 (01.03.2006)
Dieter Bimberg, André Strittmatter, Lars Reißmann

Contact structure for an electrically operated II/VI semiconductor element and a process for the production thereof
US. Pat. 6,893,950 B1 (17.5.2005)
Matthias Straßburg, Oliver Schulz, Udo W. Pohl, Dieter Bimberg

Method for improving the efficiency of epitaxially produced quantum dot semiconductor components
US-Patent Nr. 6,942,731, B2 (13.09.2005)
Roman Sellin, Nikolai N. Ledentsov, Dieter Bimberg

Elektrisch betriebene Einzelphotonenquelle auf einer VCSEL Struktur
Deutsche Patentanmeldung Nr. 102005057800.4 (23.11.2005)
Dieter Bimberg, Anatol Lochmann, Vladimir Gaysler

Verfahren zum Bestimmen eines Frequenzverhaltens eines elektrischen Bauelements und Anordnung zur Durchführung des Verfahrens
Patent-Nr. 10349368.9 / IPC: G01R 15/24 (2006.1)
Dieter Bimberg, Dieter Huhse, Olaf Reimann

Terabit optical burst sampling
Verfahren und Aufbau für Einzelschuss Optical Sampling
Deutsche Patentanmeldung Nr. 102006045835.4 (22.09.2006)
Holger Quast, Dieter Bimberg

Verfahren zur Verbesserung der Effizienz von epitaktisch hergestellten Quantenpunkt-Halbleiterbauelementen
EU-Patent-Anmeldung Nr. 011976169.1-2203 (27.10.2006)
Roman Sellin, Nikolai N. Ledentsov, Dieter Bimberg

Speicherzelle und Verfahren zum Speichern von Daten
Deutsche Patentanmeldung Nr. 10 2006 059 110.0 (08.12.2006)
Martin Geller, Andreas Marent, Dieter Bimberg

Data transmission optoelectronic device
angemeldet bei KPL, 11.10.06
TUB-Az: 06060/TUB
Ipal-Az: 06126HPV/TUB
Nikolai N. Ledentsov, Vitaly A. Shchukin, Dieter Bimberg

9. SCIENTIFIC ACTIVITIES

9.1 Department I

Prof. Dr. phil. nat. Dieter Bimberg

9.1.0 Staff

Secretary

Ulrike Grupe

Technical staff

Jörg Döhring
Ilona Gründler
Dipl.-Ing. Bernd Ludwig
Dipl.-Krist. Kathrin Schatke
Dipl.-Ing. Bernhard Tierock

Permanent guest scientists

Prof. Dr. Jürgen Christen
Priv.-Doz. Dr. Armin Dadgar
Prof. Dr. Vladimir A. Haisler
Dr. Leonid Ya. Karachinsky
Dr. Jungho Kim
M. Sc. Vlastimil Krapek
Prof. Dr. Alois Krost
Prof. Dr. Nikolai N. Ledentsov
Dr. Vitaly A. Shchukin

Principal scientists

Prof. Dr. Wolfgang Gehlhoff
Priv.-Doz. Dr. Udo Pohl
Dr. André Strittmatter
Dr. Friedhelm Hopfer

Senior scientists

Dr. Matthias Kuntz
Dr. Matthias Lämmlin
Dr. Holger Quast
Dr. Sven Rodt

PhD candidates

Dipl.-Phys. Sebastian Bognár (until 31.01.2005)
Dipl.-Phys. Vadim Eisner (until 28.02.2005)
Dipl.-Phys. Gerrit Fiol
Dipl.-Phys. Martin Geller
Dipl.-Phys. Thorsten Kettler
Dipl.-Phys. Marc Anatol Lochmann
Dipl.-Phys. Andreas Marent
Dipl.-Phys. Christian Meuer
Dipl.-Phys. Alex Mutig
Dipl.-Phys. Konstantin Pötschke
Dipl.-Phys. Kristijan Posilovic
Dipl.-Phys. Lars Reißmann (until 31.05.2005)
Dipl.-Phys. Andrei Schliwa
Dipl.-Phys. Oliver Schulz (until 30.09.2006)
Dipl.-Phys. Robert Seguin
Dipl.-Phys. Erik Stock
Dipl.-Phys. Till Warming
Dipl.-Phys. Momme Winkelnkemper

Diploma and teacher students

Anja Brostowski (until 30.06.2005)
David Feise (until 31.12.2006)
Max Feucker
Tim Germann
Anastasia Karkatzinou
Sven Liebich
Martin Schubert, HHI (until 31.10.2006)
Carola Szewc (until 28.02.2006)
Witlef Wieczorek (until 30.09.2005)
Clemens Wündisch

9.1.1 Summary of activities

The activities of the department are grouped in five mutually connected research areas with complementary objectives:

- epitaxy of novel nano- and heterostructures,
- physics of nanostructures,
- nanophotonics,
- high frequency photonics, and
- magnetic resonance investigations.

The **Center of Nanophotonics** which was officially inaugurated in summer 2004 went step by step fully into operation during the last two years after enormous efforts had gone into debugging. Now complete processing of most complex devices like vertical cavity emitters can be performed (see below).

Theoretical studies of growth focused on **stability analysis of coherently strained arrays of faceted surface ridges**. Ridge arrays were found to be unstable for all surface coverages, having important implications, e.g. for annealing of any nanostructure with elongated geometry. Modeling and experimental studies of MOCVD growth of AlGaInP on misoriented (or in other terms high index) surfaces based thereupon led to the development of advanced **photonic band gap laser** structures based on quantum wires in corrugated superlattices showing very little beam divergence.

Evolution of Gaussian distribution of InAs QD sizes to a **multimodal distribution of truncated pyramids** differing by exactly one monolayer in size with sharp interfaces upon precisely controlled growth interruption enhanced by an Sb surfactant was discovered. This new type of QD system proved to be decisive for detailed experimental and theoretical studies of few particle interactions and exciton fine structure as a function of QD size. The observed strong variations of the few-particle (X, X^+, X^-, XX, XX^+) energy positions could be attributed to variations of the degree of correlation. Correlation effects are reduced in smaller QDs.

The same type of QDs was employed to study **size-dependent fine-structure splitting** (FSP). A systematic variation from +520 μeV to –80 μeV was observed. Previously no reports of such large values, of zero splitting or negative values, did exist for the InAs/GaAs QD system. Piezoelectricity is pinpointed as the main effect reproducing the observed trend. Ex-situ annealing of QD-structures was subsequently discovered to allow systematic variation of FSP. Our development of single polarized photon emitting diodes (**Q-bit emitters**) and emitters of entangled photon pairs is based on these discoveries. A first attempt to fabricate a Q-bit emitter was immediately successful. Across the whole wavelength range of QD emission highly efficient electroluminescence of one QD below an oxide aperture was observed.

Previous theoretical work on interrelating structural and electronic properties based on **eight-band k·p theory** was extended from zincblende QDs to **wurtzite** ones. Strain effects, piezo- and pyroelectricity, spin-orbit and crystal field splitting were incorporated. For InGaN QDs, which were studied in detail, the piezo- and pyroelectric fields were found to cause a spatial separation of electron and hole parts of the exciton wavefunction and a redshift of the exciton transition.

Cathodoluminescence investigations of **single InGaN/GaN QDs on Si substrate** revealed exceptional emission features. Up to five emission lines per QD were observed with all the emission lines being polarized along one of two orthogonal directions. Calculations with the newly developed wurtzite-type eight-band k•p scheme and the Hartree method revealed transitions involving the A- and B- valence bands as origin of the **strict polarization**.

QDs might become some day the template of ultimate storage of information, where one bit is represented by one or a few charge carriers. One first important step towards a realistic **QD-based memory** was made. A special AlGaAs barrier below the QDs resulted in a thermal activation energy of 560 meV and a 300 K storage time of 5 ms for holes. This is precisely the present standard DRAM refresh time. Yet unpublished work will report storage times in the minute range.

In **spectral hole burning** experiments negative and positive trions in QDs were observed, leading to charging of spectrally selected subensembles with single carriers. Using circularly polarized excitation in an applied magnetic field the spin of single electrons could be addressed and spin flip of electrons was observed. Such studies are fundamental to explore alternative roads to QD-based memories.

Alternative precursor **MOCVD based InGaAs/GaAs edge and vertical cavity emitting lasers** reached new record values. For 1.25 µm emission wavelength transparency current densities of 10 A/cm^2 and internal quantum efficiencies of 94 % have been realized for edge emitters. VCSELs with 3 x 3 QD layers placed in the field intensity antinodes of the 4λ cavity formed by selectively oxidized Bragg reflectors demonstrated a minimum threshold of 85 µA for a 1 µm aperture and 1.45 mW cw output power for slightly larger apertures at 1.1 µm wavelength.

VCSELs based on dense arrays of stacked **submonolayer grown InGaAs QDs** emitting near 980 nm demonstrated a modulation band width of 10.5 GHz, a high modulation efficiency factor of 14 GHz/√mA and a side mode suppression ratio of > 40 dB, which are presently the best values reported in literature for QD VCSELs. These results present an important step forward towards the realisation of a Terabus.

Other breakthroughs were achieved in the field of novel **high brightness QW-lasers** with 5° beam divergence of the farfield and for degradation robust QD-lasers near 1.5 µm showing 800 mW of simple transverse mode emission.

Large emphasis of our work was on **high speed** properties of **directly modulated** and **mode-locked QD-lasers** and **QD semiconductor optical amplifiers**. For directly modulated lasers digital modulation showed open eyes up to 12 Gbit/s and a bit error rate below 10^{-12} at 10 Gbit/s. Passively mode-locked lasers operated at frequencies of 5 – 80 GHz with ps time jitter, whereas hybrid mode-locked lasers show pulse half-widths below 1 ps. QD-SOAs demonstrate gain recovery times of 120 – 140 fs and a net gain larger than 0.4 dB/mm x QD-layer demonstrating the large potential of QD SOAs for novel types of booster amplifiers and Mach-Zehnder interferometers.

Finally we would like to report a culmination of our work on fs-laser pulses with arbitary repetition rates. A modified photon injection set-up led to output pulses of 310 fs width and 540 fs timing jitter after compression in comb-like dispersion profiled fibres for a dual laser system with 100 fs scanning steps. Such a system might present the basis for future **ultrafast pump-probe** or **electro-optical sampling** systems.

TM-doped chalcopyrites such as $ZnGeP_2$ and the III-V compound GaN showing **ferro-magnetism** above room temperature (RTFM) are promising candidates for future **spintronic** devices. However, the described results on the origin of TM-induced FM in these compounds are contradictory. It is therefore highly important to thoroughly carry out experimental studies suitable to elucidate the **microscopic origin of FM** in these materials. By means of EPR we determined the TM-induced local change of the free parameter x_f describing the position of the anion sites for Mn^{2+} on Zn sites in $ZnGeP_2$ and $ZnSiP_2$ as well as for Fe^{3+} on Ge^{4+} site in $ZnGeP_2$. The incorporation of TMs on Ge site in $ZnGeP_2$, which is important according to theoretical predictions for the formation of FM, was detected for Fe^{3+} and Cr^{4+}. The creation of antiferromagnetically coupled Mn_{Zn}^{2+}-Mn_{Zn}^{2+} pairs was confirmed by the characteristic hyperfine coupling of such pairs.

New results on the structural, optical and electronic **properties of Fe-doped GaN** were obtained. We observed the charge state Fe^{2+} and Fe^{3+} and identified for the first time Fe-Ga pairs. A preferential incorporation of Fe^{3+} on one type of Ga site corresponding to the ABAB stacking sequence of the hexagonal GaN structure was observed. In addition to the incorporation of Mn in MOCVD epilayers we could show that the recharging of Mn is correlated with the occurrence of FM detected by SQUID.

9.1.2 Publications

The abstracts of papers marked by* are reprinted in section 9.1.6

a) Novel Nano- and Heterostructures

1. **Deep levels in Osmium doped p-type GaAs grown by metal organic chemical vapor deposition**
M. Zafar Iqbal, A. Majid, A. Dadgar, and D. Bimberg
AIP Conf. Proc. of ICPS-27, Flagstaff, USA, 2004,
J. Menéndez and Ch. G. Van de Walle (Eds.) **772** (a), 147 (2005)

2. **Deep levels in Ruthenium doped p-type MOCVD GaAs**
A. Majid, M. Zafar Iqbal, A. Dadgar, and D. Bimberg
AIP Conf. Proc. of ICPS-27, Flagstaff, USA, 2004,
J. Menéndez and Ch. G. Van de Walle (Eds.) **772** (a), 143 (2005)

3.* **Evolution of a multimodal distribution of self-organized InAs/GaAs quantum dots**
U.W. Pohl, K. Pötschke, A. Schliwa, F. Guffarth, and D. Bimberg, N.D. Zakharov and P. Werner, M.B. Lifshits and V.A. Shchukin, D.E. Jesson
Phys. Rev. B **72**, 245332 (2005)

4. **InAs quantum dots on GaAs($\bar{2}\,\bar{5}\,\overline{11}$)B: an STM and PL study**
Y. Temko, T. Suzuki, M.C. Xu, K. Pötschke, D. Bimberg, K. Jacobi
Phys. Rev. B **71**, 045336 (2005)

5. **Indium redistribution in an InGaN quantum well induced by electron-beam irradiation in a transmission electron microscope**
T. Li, E. Hahn, and D. Gerthsen, A. Rosenauer, A. Strittmatter, L. Reißmann, and D. Bimberg
Appl. Phys. Lett. **86**, 241911 (2005)

6.* **Instability to Ostwald ripening of an array of coherently strained faceted ridges**
V.A. Shchukin, T.P. Munt, D.E. Jesson, and D. Bimberg
Phys. Rev. B **71**, 113407 (2005)

7. **Many-particle states in single InGaN/GaN quantum dots grown on Si-substrates**
R. Seguin, S. Rodt, M. Winkelnkemper, A. Schliwa, A. Strittmatter, L. Reißmann, D. Bimberg, E. Hahn, and D. Gerthsen
AIP Conf. Proc. of ICPS-27, Flagstaff, USA, 2004,
J. Menéndez and Ch. G. Van de Walle (Eds.) **772** (a), 767 (2005)

8. **Novel growth mechanism of strained islands: Multimodal closed-shell distribution of quantum dots**
M.B. Lifshits, V.A. Shchukin, D. Bimberg, D.E. Jesson
Proc. of 13th Int. Symp. on Nanostructures: Physics and Technology,
St. Petersburg, Russia, 308 (2005)

9. **Onion-like growth of and inverted many-particle energies in quantum dots**
A. Schliwa, S. Rodt, K. Pötschke, F. Guffarth, and D. Bimberg
AIP Conf. Proc. of ICPS-27, Flagstaff, USA, 2004,
J. Menéndez and Ch. G. Van de Walle (Eds.) **772** (a), 769 (2005)

10. **Onion-like growth of and inverted many-particle energies in quantum dots**
Dieter Bimberg, Florian Guffarth, Konstantin Pötschke, Sven Rodt, and Andrei Schliwa
Current Trends in Nanoscience - From Materials to Applications (reprinted from: Materials Science & Engineering: C), M. Stoneham, H. Grimmeiss, G. Marletta (Eds.) **25** (5-8), 698 (2005)

11. **Osmium impurity-related deep levels in n-type GaAs**
A. Majid, M. Zafar Iqbal, A. Dadgar, and D. Bimberg
J. Appl. Phys. **98,** 83709 (2005)

12. **Shape transitions of metastable surface nanostructures**
D.J. Vine, D.E. Jesson, M.J. Morgan, V.A. Shchukin, and D. Bimberg
Phys. Rev. B **72**, 241304 (2005)

13. **Shell-like formation of self-organized InAs/GaAs quantum dots**
R. Heitz, F. Guffarth, K. Pötschke, A. Schliwa, D. Bimberg, N.D. Zakharov, and P. Werner
Phys. Rev. B **71**, 45325 (2005)

14. **Stability of an hexagonal array of coherently strained conical islands against Ostwald ripening**
V.A. Shchukin, D. Bimberg, T.P. Munt, D.E. Jesson
Annals of Physics **320,** 237 (2005)

15. **Temperature stability of optical properties of InAs quantum dots overgrown by AlAs/InAlAs layers**
N.V. Kryzhanovskaya, A.G. Gladyshev, S.A. Blokhin, A.P. Vasil`ev, E.S. Semenova, A.E. Zhukov, M.V. Maximov, N.N. Ledentsov, V.M. Ustinov, D. Bimberg
Proc. of 13th Int. Symp. on Nanostructures: Physics and Technology,
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16. **The optical properties of heterostructures with quantum-confined InGaAsN layers on GaAs substrate and emitting at 1.3-1.55 µm**
N.V. Kryzhanovskaya, A.Yu. Egorov, V.V. Mamutin, N.K. Polyakov, A.F. Tsatsul`nikov, A.R. Kovsh, N.N. Ledentsov, V.M. Ustinov, D. Bimberg
Semiconductors (Fizika i tekhnika poluprovodnikov) **39** (6), 703 (2005)

17. **1.3-1.5 µm quantum dot lasers on foreign substrates: Growth using defect reduction technique, high-power CW operation, and degradation resistance**
N.N. Ledentsov, A.R. Kovsh, V.A. Shchukin, S.S. Mikhrin, I.L. Krestnikov, A.V. Kozhukhov, L.Ya. Karachinsky, M.V. Maximov, I.I. Novikov, Yu.M. Shernyakov, I.P. Soshnikov, A.E. Zhukov, Yu.G. Musikhin, V.M. Ustinov, N.D. Zakharov, P. Werner, T. Kettler, K. Posilovic, D. Bimberg, M. Hu, H.K. Nguyen, K. Song and Chung-en Zah
Proc. of SPIE: Novel In-Plane Semiconductor Lasers V, C. Mermelstein, D.P. Bour (Eds.) **6133,** 61330S (2006)

18. **Control of structural and excitonic properties of self-organized InAs/GaAs quantum dots**
U.W. Pohl, R. Seguin, S. Rodt, A. Schliwa, K. Pötschke, D. Bimberg
Physica E **35** (2), G. Bauer, W. Jantsch, F. Kuchar (Eds.), 285 (2006)

19. **Electric-field-enhanced thermal emission from Osmium-related deep level in n-GaAs**
M. Zafar Iqbal, A. Majid, A. Dadgar, and D. Bimberg
Advances in Science and Technology **46,** 73 (2006)

20. **Formation and evolution of multimodal size distributions of InAs/GaAs quantum dots**
U.W. Pohl, K. Pötschke, A. Schliwa, M.B. Lifshits, V.A. Shchukin, D.E. Jesson, D. Bimberg
Physica E **32,** 9 (2006)

21. **Growth, atomic structure, and electronic properties of GaSb/GaAs nanostructures: Quantum wells, dots, and rings**
Rainer Timm, Andrea Lenz, Holger Eisele, Lena Ivanova, Ganesh Balakrishnan, Diana Huffaker, Konstantin Pötschke, Udo W. Pohl, Dieter Bimberg, Randall M. Feenstra, and Mario Dähne
AIP Conf. Proc. of ICPS-28, Vienna, Austria, 2006 in print

22. **InAs/GaAs quantum dots grown with Sb impurities**
Andrea Lenz, Rainer Timm, Holger Eisele, Tai Y. Kim, Ferdinand Streicher, Konstantin Pötschke, Udo W. Pohl, Dieter Bimberg, and Mario Dähne
AIP Conf. Proc. of ICPS-28, Vienna, Austria, 2006 in print

23. **InAs/InP quantum dots: From single to coupled dots applications**
C. Cornet, A. Schliwa, M. Hayne, N. Chauvin, F. Doré, J. Even, V. V. Moshchalkov, D. Bimberg, G. Bremond, C. Bru-Chevallier, M. Gendry, and S. Loualiche
Phys. stat. sol. (c) **3** (11), 4039 (2006)

24.* **Nanofaceting and alloy decomposition: From basic studies to advanced photonic devices**
Vitaly A. Shchukin, Nikolai N. Ledentsov, and D. Bimberg
Microelectronics Journal **37,** 1451 (2006)

25. New method for the in situ determination of $Al_xGa_{1-x}N$ composition in MOVPE by real-time optical reflectance
H. Hardtdegen, N. Kaluza, Z. Sofer, Y.S. Cho, R. Steins, H.L. Bay, Y. Dikme, H. Kalisch, R.H. Jansen, M. Heuken, A. Strittmatter, L. Reißmann, D. Bimberg, and J.-T. Zettler
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Phys. stat. sol. (c) **3** (11), 3971 (2006)

27. Self-organized formation of shell-like InAs/GaAs quantum dot ensembles
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Physica E **32,** 25 (2006)

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S. Rodt, A. Schliwa, K. Pötschke, F. Guffarth, and D. Bimberg
Phys. Rev. B **71**, 155325 (2005)

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31. Local phonon modes in InAs/GaAs quantum dots
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J. Menéndez and Ch. G. Van de Walle (Eds.) **772** (a), 689 (2005)

32. Nonequilibrium room-temperature carrier distribution in InAs quantum dots overgrown with thin AlAs/InAlAs layers
N.V. Kryzhanovskaya, A.G. Gladyshev, S.A. Blokhin, M.V. Maksimov, E.S. Semenova, A.P. Vasil'ev, A.E. Zhukov, N.N. Ledentsov, V.M. Ustinov, and D. Bimberg
Semiconductors (Fizika i tekhnika poluprovodnikov) **39** (10), 1188 (2005)

33. Quantum structures in semiconductors
Udo W. Pohl and Dieter Bimberg
Encyclopedia of Physics, R.G. Lerner and G.L. Trigg (Eds.) **2,** 2138 (2005)

34. Redistribution of excitons localized in InGaN quantum dot structures
M. Dworzak, T. Bartel, M. Strassburg, A. Hoffmann, A. Strittmatter, and D. Bimberg
AIP Conf. Proc. of ICPS-27, Flagstaff, USA, 2004,
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35.* **Size-dependent fine-structure splitting in self-organized InAs/GaAs quantum dots**
R. Seguin, A. Schliwa, S. Rodt, K. Pötschke, U.W. Pohl, D. Bimberg
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36. **Spectral hole burning by storage of electrons or holes**
T. Warming, W. Wieczorek, M. Geller, A.E. Zhukov, V.M. Ustinov, and D. Bimberg
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37. **Ultrafast gain recovery dynamics of the excited state in InGaAs quantum dot amplifiers**
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V.I. Zubkov, C.M.A. Kapteyn, A.V. Solomonov and D. Bimberg
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39. **5 ms storage time at room temperature in InGaAs quantum dots**
M. Geller, A. Marent, A.P. Vasi'ev, E.S. Semenova, A.E. Zhukov, V.M. Ustinov,
and D. Bimberg
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P. Rinke, A. Qteish, M. Winkelnkemper, D. Bimberg, J. Neugebauer, and M. Scheffler
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M. Geller, E. Stock, A. Marent, A.E. Zhukov, V.M. Ustinov, and D. Bimberg
Phys. stat. sol. (c) **3** (3)**,** 504 (2006)

43.* **Carrier storage time of milliseconds at room temperature in self-organized quantum dots**
A. Marent, M. Geller, and D. Bimberg, A.P. Vasi'ev, E.S. Semenova,
A.E. Zhukov, and V.M. Ustinov
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44.* **Charge and spin storage in self- organized quantum dots**
W. Wieczorek, T. Warming, M. Geller, D. Bimberg, G.E. Cirlin, A.E. Zhukov,
V.M. Ustinov
Appl. Phys. Lett. **88,** 182107 (2006)

45.* **Control of fine-structure splitting and excitonic binding energies in selected individual InAs/GaAs quantum dots**
R. Seguin, A. Schliwa, T.D. Germann, S. Rodt, M. Winkelnkemper, K. Pötschke,
A. Strittmatter, U.W. Pohl, T. Hammerschmidt, P. Kratzer, and D. Bimberg
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46. **Der Zoo der Quantenpunkte - Mit Halbleiter-Quantenpunkten zu neuartigen Bauelementen**
Dieter Bimberg
Physik Journal **5** (8/9), 43 (2006)

47. **Direct observation of tunneling emission to determine localization energies in selforganized quantum dots**
M. Geller, E. Stock, R. Sellin, D. Bimberg
Physica E **32,** 171 (2006)

48. **DRAM storage time of milliseconds demonstrated in selforganized quantum dots**
Andreas Marent, Martin Geller, Alexey P. Vasiev, Elisaveta S. Semenova, Alexey E. Zhukov, Victor M. Ustinov, and Dieter Bimberg
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49. **Ex-situ control of fine-structure splitting and excitonic binding energies in single InAs/GaAs quantum dots**
Robert Seguin, Andrei Schliwa, Sven Rodt, Konstantin Pötschke, Udo W. Pohl, and Dieter Bimberg
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50.* **Interrelation of structural and electronic properties of InxGaN1-x/GaN quantum dots using an eight-band k·p model**
Momme Winkelnkemper, Andrei Schliwa, and Dieter Bimberg
Phys. Rev. B **74,** 153322 (2006)

51. **Quantum-dot size dependence of exciton fine-structure splitting**
R. Seguin, A. Schliwa, S. Rodt, K. Pötschke, D. Bimberg
Physica E **32,** 101 (2006)

52. **Size-dependence of anisotropic exchange interaction in InAs/GaAs quantum dots**
R. Seguin, S. Rodt, A. Schliwa, K. Pötschke, U.W. Pohl, and D. Bimberg
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53. **Size-dependent binding energies and fine-structure splitting of excitonic complexes in single InAs/GaAs quantum dots**
S. Rodt, R. Seguin, A. Schliwa, F. Guffarth, K. Pötschke, U.W. Pohl, D. Bimberg
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54. **Spin storage and readout in self-organized quantum dots**
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55. **Symmetry breaking and fine structure splitting in self-assembled zincblende quantum dots: Atomistic simulations of long-range strain and piezoelectric field**
Muhammad Usman, Shaikh Ahmed, Clemens Heitzinger, Rajib Rahman, Andrei Schliwa, and Gerhard Klimeck
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56. Systematic size-dependence of anisotropic exchange interaction in InAs/GaAs quantum dots
R. Seguin, A. Schliwa, S. Rodt, K. Pötschke, U.W. Pohl, D. Bimberg
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57. The origin of the broad distribution of exciton lifetimes in InGaN quantum dots
Matthias Dworzak, Momme Winkelnkemper, Thomas Stempel, Axel Hoffmann, and Dieter Bimberg
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58. Theory and experiment of InAs/InP quantum dots: From calculations to laser emission
Charles Cornet, Manus Hayne, Andrei Schliwa, François Doré, Christophe Labbé, Hervé Folliot, Jacky Even, Dieter Bimberg, Victor Moshchalkov, and Slimane Loualiche
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59. Theory of excitation transfer in coupled nanostructures - From quantum dots to light harvesting complexes
Marten Richter, Kwang Jun Ahn, Andreas Knorr, Andrei Schliwa, Dieter Bimberg, Mohamed El-Amine Madjet, and Thomas Renger
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M. Geller, E. Stock, C. Kapteyn, R.L. Sellin, and D. Bimberg
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62. Size-tunable exchange interaction in InAs/GaAs quantum dots
U.W. Pohl, A. Schliwa, R. Seguin, S. Rodt, K. Pötschke, D. Bimberg
Adv. in Sol. Stat. Phys. Vol. **46** (2006).

63. Ultrafast carrier dynamics in InGaAs quantum dot materials and devices
Paola Borri, Stephan Schneider, Wolfgang Langbein, and Dieter Bimberg
J. of Optics A: Pure Appl. Physics **8,** 33 (2006)

c) Nanophotonics

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T. Kettler, L.Ya. Karachinsky, A. Lochmann, O. Schulz, L. Reissmann, N.Yu. Gordeev, I.I. Novikov, M.V. Maximov, Yu.M. Shernyakov, N.V. Kryzhanovskaya, A.E. Zhukov, A.P. Vasil'ev, E.S. Semenova, V.M. Ustinov, N.N. Ledentsov, A.R. Kovsh, V.A. Shchukin, S.S. Mikhrin, and D. Bimberg
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L.Ya. Karachinsky, T. Kettler, N.Yu. Gordeev, I.I. Novikov, M.V. Maximov, Yu.M. Shernyakov, N.V. Kryzhanovskaya, A.E. Zhukov, E.S. Semenova, A.P. Vasil'ev, V.M. Ustinov, N.N. Ledentsov, A.R. Kovsh, V.A. Shchukin,
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W. Gehlhoff, D. Azamat, U. Haboeck, A. Hoffmann
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E. Malguth, A. Hoffmann, M. Phillips, and W. Gehlhoff
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E. Malguth, A. Hoffmann, W. Gehlhoff, O. Gelhausen, M.R. Philips, X. Xu,
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128. Electron Paramagnetic Resonance Characterization of Mn- and Co-doped ZnO Nanowires
A. Ankiewicz, W. Gehlhoff, A. Rahm, M. Lorenz, M. Grundmann, M.C. Carmo, and N.A. Sobolev
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130. Optical Studies of Transition Metal doped GaN Thin Films grown by Metalorganic Chemical Vapor Deposition
M.H. Kane, E. Malguth, S. Gupta, W.E. Fenwick, Y. Wang, C.J. Summers, W. Gehlhoff, A. Hoffmann, and I. T. Ferguson
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A. Ankiewicz, M.C. Carmo, and N.A. Sobolev, W. Gehlhoff, E. M. Kaidashev, A. Rahm, M. Lorenz, and M. Grundmann
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9.1.3 Invited talks

D. Bimberg | **Halbleiter-Nanostrukturen**
Physikzentrum Bad Honnef, Germany, February 2005

D. Bimberg | **Auf dem Weg zu den kleinsten Dingen – Nanos für das Jahrhundert der Photonik und Medizin**
Präsenzabend des Lions Club Berlin-Sanssouci,
Berlin, Germany, February 2005

D. Bimberg | **Quantum Dot Lasers: Novel sources for picosecond high frequency pulses**
Int. Symposium on Quantum Dots and Photonic Crystals 2005,
Tokyo, Japan, March 2005

D. Bimberg | **Quantum dots for lasers, amplifiers and photonic systems**
OFC Optical Fiber Communication Conference 2005
Anaheim, California, USA, March 2005

D. Bimberg | **Geometry, many-particle effects and quantum onions**
Int. Symp. on Science and Society,
St. Petersburg, Russia, March 2005

D. Bimberg | **Quantum dot lasers: Novel sources of picosecond high frequency pulses**
Intern. Symp. on Nanoscience and – Technology,
Mauterndorf, Austria, March 2005

D. Bimberg | **Nanophotonic devices and systems**
PHASE 2005, Int. Workshop on Physics & Applications of Semiconductor Lasers
Metz, France, March 2005

D. Bimberg | **Physik der Nanomaterialien – Von der Nanostruktur zum photonischen Bauelement**
Forschungsschwerpunkt Photonik,
TU Berlin, Germany, April 2005

D. Bimberg | **Quantum dot nanostructures: Paradigm changes in semiconductor physics**
Physics Colloquium of the Van der Waals-Zeeman Institute
Amsterdam, Netherlands, April 2005

D. Bimberg | **Quantum dot nanostructures: Paradigm changes in semiconductor physics**
Int. School of Quantum Electronics
"Photonic Metamaterials: From Micro to Nano Scale",
Erice, Italy, August 2005

D. Bimberg

Self-organised quantum-dots for optoelectronic applications
Summerschool on Semiconductor QD's: Physics and Devices,
Monte Veritá, Switzerland, September 2005

D. Bimberg

Quantum dots for semiconductor amplifiers and high speed lasers
Optical Amplifiers and their Applications (OSA 2005),
Budapest, Hungary, September 2005

D. Bimberg

Nanophotonics: Quantum dots for lasers and amplifiers
Gemeinsames Kolloquium Elektrotechnik und Physik,
Universität Karlsruhe, Germany, September 2005

D. Bimberg

21st century: The age of nanotechnologies – Applications of nanostructures in optoelectronics
NATO Parliamentary Assembly: 'Science and Technology'
Deutscher Bundestag, Berlin, October 2005

D. Bimberg

Abram Ioffe and Germany
Physics to Humankind
Int. Conf. devoted to the 125th Anniversary of
Abram F. Ioffe's Birthday,
St. Petersburg, Russia, October 2005

D. Bimberg

21st century: The age of nanotechnologies – Applications of nanostructures in optoelectronics
Presse-Seminar: "Wissenschaft im Dienst der Nanotechnik"
TELI und VDI,
Berlin, November 2005

D. Bimberg

Bulk versus quantum-well versus QD SOAs
Workshop „The Future of SOAs" at OFC/NFOEC 2006,
Anaheim, California, USA, March 2006

D. Bimberg

Quantum dots: Genesis, the excitonic zoo and its applications
Preisträger-Vortrag, DPG-Frühjahrestagung,
Dresden, Germany, March 2006

D. Bimberg

Quantum dots: Genesis, the excitonic zoo and its applications for high speed photonics, quantum cryptography and single carrier memories
Nanotechnology in Northern Europe,
Helsinki, Finland, May 2006

D. Bimberg

Quantum dot amplifiers for 100 Gbit ethernet
8th Int. Conf. on Transparent Optical Networks (ICTON 2006),
Nottingham, U.K., June 2006

D. Bimberg

On the road to the terabus: High speed 980 nm VCSELs with submonolayer quantum dots
COST 288 Meeting,
Nottingham, U.K., June 2006

D. Bimberg

High speed ultrashort pulse generation by QD-lasers at communication wavelengths
XII. Int. Conf. on Laser Optics,
St. Petersburg, Russia, June 2006

D. Bimberg

High speed quantum dot photonics
Int. Conf. on Superlattices, Nano-Structures and Nano-Devices,
Istanbul, Turkey, July/August 2006

D. Bimberg

History, highlights, challenges
Int. Symposium: "Semiconductor Nanostructures",
TU Berlin, Germany, September 2006

D. Bimberg

Von der Invention zu Innovation
nanoDe 2006 – Strategien für Produkte von Morgen,
Dritte BMBF-Nanotechnologietage,
Berlin, Germany, November 2006

D. Bimberg

Auf dem Weg zu den kleinsten Dingen: Nanos für das Jahrhundert der Photonik und Medizin
Auricher Wissenschaftstage,
Aurich, Germany, November 2006

W. Gehlhoff

Site selectivity of Fe^{3+} on Ga site in hexagonal GaN
Workshop Low Dimensional Structure of Semiconductors:
Growth, Properties and Applications,
Aveiro, Portugal, January 2006

W. Gehlhoff

Magnetische Resonanzverfahren zur Charakterisierung von magnetischen Halbleitern und Nanoclustern für Spintronik-Anwendungen
Kolloquium „Innovation durch Integration“,
Humboldt-Universität zu Berlin,
Berlin, Germany, February 2006

M.P. Geller

Charge carrier storage in self-organized quantum dots
Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures,
Kühlungsborn, Germany, June 2005

M.P. Geller

Carrier storage and confinement in GaAs-based self-organized quantum dots
32nd Int. Symp.on Compound Semiconductors (ISCS-2005),
Freiburg, Germany, September 2005

M.P. Geller **Self-organized quantum dots for future memory devices**
14th Int. Workshop on Heterostructure Technology (HETECH 05),
Smolenice, Slovakia, October 2005

F. Hopfer **Quantum dot photonics: Edge emitter, amplifier and VCSEL**
Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures,
Kühlungsborn, Germany, June 2006

F. Hopfer **Quantum dot photonics: Edge emitter, amplifier and VCSEL**
Int. Conf. on Advanced Optoelectronics (CAOL 2005),
Yalta, Crimea, Ukraine, September 2005

F. Hopfer **High speed quantum dot VCSELs**
XII. Int. Conf. on Laser Optics,
St. Petersburg, Russia, June, 2006

F. Hopfer **20 Gb/s direct modulation of 980 nm VCSELs based on submonolayer deposition of quantum dots**
Workshop on Photonic Components for Broadband Communication,
Stockholm, Sweden, June 2006

F. Hopfer **Nanostructures for nanoelectronics: No potential for room temperature applications ?**
Japan - Germany JST-DFG Joint Workshop,"Nano-Electronics",
Tokyo, Japan, October/November 2006

M. Kuntz **10 Gb/s data modulation and 50 GHz mode locking using 1.3 µm InGaAs quantum dot lasers**
13th Int. Symp. Nanostructures: Physics and Technology,
St. Petersburg, Russia, June 2005

M. Kuntz **Quantum dots for high speed photonic devices**
9th Int. Symp.on Contemporary Photonics Technology, CPT 2006,
Tokyo, Japan, January 2006

M. Kuntz **Faszination Nanotechnologie**
Tage der Naturwissenschaften,
Blankenfelde, Germany, February 2006

M. Kuntz **High-speed quantum dot lasers and amplifiers for optical data communication**
IEEE Nanotechnology Conference 2006,
Cincinnati, USA, June 2006

N.N. Ledentsov **Edge and surface-emitting tilted cavity lasers**
Photonics West 2005,
San Jose, California, USA, January 2005

N.N. Ledentsov	**Nanotechnologies: The present status and the perspectives** Int. Symp. on Science and Society, St. Petersburg, Russia, March 2005
N.N. Ledentsov	**Quantum dots for degradation-robust 1.3-1.5 µm lasers on GaAs** Nano-Optoelectronic Workshop (NOW 2005) University of California, Berkely, USA, August 2005
N.N. Ledentsov	**1.3-1.5 µm quantum dot lasers on foreign substrates: Growth using defect reduction technique, high-power CW operation, and degradation resistance** Photonics West, San José, California, USA, January 2006
N.N. Ledentsov	**Longitudinal photonic bandgap crystal laser diodes with ultra-narrow vertical beam divergence** Photonics West, San José, California, USA, January 2006
N.N. Ledentsov	**Quantum-dot lasers** Korean-German Workshop on "Nanophotonics", Cheju Island, Korea, March 2006
N.N. Ledentsov	**Merging nanoepitaxy and nanophotonics** 2006 Advanced Research Workshop (FTM-5) Future Trends in Microelectronics: Up to the Nano Creek, Crete, Greece, June 2006
N.N. Ledentsov	**MBE-grown metamorphic lasers for applications at telecom wavelengths** 14th Int. Conf. on Molecular Beam Epitaxy (MBE2006), Tokyo, Japan, September 2006
N.N. Ledentsov	**MBE-grown metamorphic lasers for applications at telecom wavelengths** New York State University, Buffalo, USA, September 2006
N.N. Ledentsov	**High speed surface emitting lasers** Int. Symp. "Semiconductor Nanostructures", TU Berlin, Germany, September 2006
U.W. Pohl	**Self-organized formation of multimodal InAs/GaAs quantum dots** Seminar der Exp. Abt. II, Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany, March 2005

U.W. Pohl	**Dynamics of multimodal InAs/GaAs quantum dot formation** Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures, Kühlungsborn, Germany, June 2006
U.W. Pohl	**Self-organized quantum dots: Change of paradigm in solid state physics** Faculty-Colloquium on Electron Transfer in Biology, Chemistry and Physics; dedicated to Nobel-price laureate Prof. Dr. R. A. Marcus, TU Berlin, Germany, June 2005
U.W. Pohl	**Evolution of a multimodal InAs/GaAs quantum dot size distribution** Physics Seminar, University of New Mexico, Albuquerque, USA, July 2005
U.W. Pohl	**Control of structural and excitonic properties of self-organized InAs/GaAs quantum dots** 14th Int. Winterschool on New Developments in Solid State Physics, Mauterndorf, Austria, February 2006
U.W. Pohl	**Size-tunable exchange interaction in InAs/GaAs quantum dots** General Conf. of the European Physical Society, Dresden, Germany, March 2006
U.W. Pohl	**Impact of InAs/GaAs quantum-dot size on the exciton fine-structure splitting** Institut National des Sciences Appliquées, Rennes, France, June 2006
U.W. Pohl	**Impact of quantum dot size on the optical properties of confined exciton complexes** Int. Symp. "Semiconductor Nanostructures", TU Berlin, Germany, September 2006
U.W. Pohl	**Self-organized epitaxial quantumdots - Growth, optical properties, and applications** MRS Fall Meeting, Boston, Mass., USA, November 2006
H. Quast	**Jitterarmes Kurzpuls Doppel-Lasersystem** FSP Seminar, TU Berlin, Germany, January 2005
S. Rodt	**The excitonic zoo in single quantum dots: Excitons, trions and more** 14th Int. Conf. on Luminscence (ICL'05), Peking, China, July 2005

S. Rodt	**Semiconductor quantum dots: Small objects with high potential** NanoScience and NanoTechnology 2006 Ankara, Turkey, May 2006
A. Schliwa	**Electronic properties of self-organized quantum dots** Quantum Dots Workshop, University of Antwerp, Belgium, January 2005
A. Schliwa	**Shape and order of wavefunctions in uncapped InAs/GaAs quantum dots** SANDiE Meeting “Characterization and Modelling of Self-assembled Semiconductor Nanostructures” Eindhoven University of Technology, The Netherlands, November 2005
A. Schliwa	**Theory of excitons in low dimensions** Int. Symposium: "Semiconductor Nanostructures", TU Berlin, Germany, September 2006
V.A. Shchukin	**Tunable metastability of surface nanostructure arrays** Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures, Kühlungsborn, Germany, June 2005
V.A. Shchukin	**Tunable metastability of self-organized surface nanostructures** Summer School: Self-Organised Nanostructures Cargese, Corsica, France, July 2005
V.A. Shchukin	**Nanofaceting and alloy decomposition: From basic studies to advanced photonic devices** 6th Int. Workshop on Epitaxial Semiconductors on Patterned Substrates and Novel Index Surfaces (ESPS-NIS 06), Nottingham, U.K., April 2006
V.A. Shchukin	**High brilliance photonic bandgap crystal lasers** Workshop on Photonic Components for Broadband Communication, Stockholm, Sweden, June 2006
T. Warming	**Trions in Quantum Dots: A probe for the electronic structure and a tool for information storage** Int. Workshop on Growth, Electronic and Optical Properties of Semiconductor Nanostructures, Kühlungsborn, Germany, June 2005

9.1.4 PhD theses

Bognár, Sebastian	**Elektrolumineszenzuntersuchungen an InGaAs/GaAs-Quantenpunkten – Gewinn und Polarisation von Kantenemittern** 22.03.2005
Weber, Alexander	**Optische Untersuchungen von Intersubniveau-Übergängen in selbstorganisierten InGaAs/GaAs-Quantenpunkten** 13.07.2005
Kuntz, Matthias	**Modulated InGaAs/GaAs Quantum Dot Lasers** 09.11.2005
Rodt, Sven	**Exzitonische Komplexe in einzelnen III-V Quantenpunkten** 15.11.2005
Kaiander, Ilia	**MOCVD growth of InGaAs/GaAs QDs for long wavelength lasers and VCSELs** 20.12.2005
Quast, Holger	**Semiconductor Laser Systems with Advanced Pulse Compression for High-Frequency Measurement Applications** 18.12.2006
Lämmlin, Matthias	**GaAs-Based Semiconductor Optical Amplifiers with Quantum Dots as an Active Medium** 21.12.2006

9.1.5 Diploma theses

Meuer, Christian	**Elektro-optisches Sampling** 19.05.2005
Brostowski, Anja	**Grundlegende Eigenschaften von optischen Verstärkern mit Quantenpunkten** 30.06.2005
Wieczorek, Witlef	**Polarization Phenomena in the Spectroscopy of Quantum Dots** 27.09.2005
Posilovic, Kristijan	**Brillante Quantenpunktlaser** 14.01.2006
Marent, Andreas	**Kapazitätsspektroskopie an Quantenpunktstrukturen** 31.01.2006
Szewc, Carola	**Modengekoppelte Quantenpunktlaser** 21.02.2006

Schubert, Martin	**Pulskompression von phasen- und amplitudenmodulierten Datensignalen** 26.10.2006
Feise, David	**Quantenpunktstrukturen für zukünftige Speicherbauelemente** 14.12.2006

9.1.6 Abstracts of selected papers of department I

3. *Phys. Rev. B* ***72****, 245332 (2005)*

Evolution of a multimodal distribution of self-organized InAs/GaAs quantum dots

U. W. Pohl, K. Pötschke, A. Schliwa, F. Guffarth, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

N. D. Zakharov and P. Werner
Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

M. B. Lifshits and V. A. Shchukin
Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany and Abraham Ioffe Physical Technical Institute, St. Petersburg 194021, Russia

D. E. Jesson
School of Physics, Monash University, Victoria 3800, Australia

Formation and evolution of a multimodal InAs/GaAs quantum dot (QD) ensemble during a growth interruption prior to cap layer deposition is studied. These particular kinds of QDs form self-organized after deposition of an InAs layer close to the critical thickness for elastic relaxation and after a short growth interruption. The QDs consist of pure InAs with heights varying in steps of complete InAs monolayers, have well-defined, flat, top and bottom interfaces, and show indications for steep side facets in transmission electron micrographs. QDs with a common height represent a subensemble within the QD ensemble, showing anemission peak with small inhomogeneous broadening. The evolution occurs by an increased appearance of subensembles with higher QDs and disappearance of subensembles related to smaller QDs, which accordingly dissolve. Dissolution proceeds essentially by a decrease of height, and only to a small amount by lateral shrinking. Thickness and composition of the wetting layer do not change during this process; growth and dissolution originate solely from material exchange between different QD subensembles. The evolution slows down for prolonged growth interruption, but the QD ensemble does not attain equilibrium within a time scale of minutes being eventually limited by the onset of plastic relaxation. Formation and dynamics of the observed evolution of the multimodal QD size distribution is theoretically well described by a kinetic approach, which implies strain-controlled adatom kinetics in the mass exchange between the QDs mediated by the adatom sea.

6. *Phys. Rev. B* ***71**, 113407 (2005)*

Instability to Ostwald ripening of an array of coherently strained faceted ridges

V. A. Shchukin,[1] T. P. Munt,[2] D. E. Jesson,[3] and D. Bimberg[1]
[1]*Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany*
[2]*Department of Physics, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom*
[3]*School of Physics and Materials Engineering, Monash University, Victoria 3800, Australia*

A linear stability analysis is presented for the exchange of mass between a coherently strained array of faceted surface ridges. We demonstrate that the ridge array is unstable for all surface coverages. This has direct implications for the processing annealing of coherently strained surface nanostructures with an elongated geometry, such as quantum nanowires.

24. *Microelectronics Journal* ***37**, 1451 (2006)*

Nanofaceting and alloy decomposition: From basic studies to advanced photonic devices

V.A. Shchukin[a,b], N.N. Ledentsov[a,b], I.P. Soshnikov[a,b], N.V. Kryzhanovskaya[b], M.V. Maximov[b], N.D. Zakharov[c], P. Werner[c], D. Bimberg[a]
[a] *Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany*
[b]*Abraham Ioffe Physical Technical Institute, Politekhnicheskaya 26, 194021 St. Petersburg, Russia*
[c]*Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany*

Most of the modern epitaxial structures for semiconductor lasers serving the needs of optical storage and fiber pumping are grown on misoriented GaAs (0 0 1) substrates. It has been found in metal-organic vapor-phase epitaxy that surface misorientation helps to achieve better epitaxial quality of the alloy layers. On the other hand, these misoriented or, in other definition, high-index surfaces are known to undergo phase transformations, depending on the misorientation angle, from nanofaceting (like (3 1 1)A, (3 1 1)B, (3 3 1), (2 1 1)B GaAs surfaces) to arrays of step bunches (like (7 7 5) GaAs, etc.). In the present paper, we consider growth-related effects during growth of both standard and advanced laser structures on GaAs (1 1 8) substrates which are typically used for growth of 650 nm GaAlInP devices. We show that the active region of the laser structures represents a corrugated superlattice with a ~25nm in-plane periodicity, while the surrounding layers are natural superlattices with a ~5 nm vertical periodicity. Corrugated superlattice used as an active region manifests itself through a strong modification of optical properties. Strong in-plane polarization evidences the formation of arrays of quantum wires. Both standard and advanced red laser have been grown and processed. The advanced lasers have demonstrated a vertical beam divergence of only 7–8° full-width at half-maximum (FWHM).

The advanced lasers with 10 μm-wide stripes demonstrate continuous wave (CW) power up to ~200 mW and the lateral beam divergence of 4º, and those with 4 μm-wide stripes show CW power up to ~120 mW and the lateral beam divergence of 6.5º. No facet passivation has been applied and the power is limited by the catastrophic optical mirror damage (COMD). 20 W pulsed power has been achieved in 100 μm-wide stripes for the advanced design and 6 W has been obtained for the standard design. The advantage comes from the design optimization of the laser waveguide using the concept of the longitudinal photonic bandgap crystal. We believe that also the optimization of the active region with better utilization of the nanofaceting effects may enable, in addition, a dramatic extension of the emission wavelength towards bright red (620–630 nm) and, probably, yellow (~580 nm) spectral ranges.

29. *Phys. Rev. B **71**, 155325 (2005)*

Correlation of structural and few-particle properties of self-organized InAs/GaAs quantum dots

S. Rodt, A. Schliwa, K. Pötschke, F. Guffarth, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

Charged (X^+,X^-,$XX^{+)}$ and neutral (X,XX) exciton complexes in single InAs/GaAs quantum dots (QDs) are investigated by cathodoluminescence spectroscopy. The relative spectral positions of the few-particle transition energies compared to the X transition are shown to be strongly correlated to the QD size. Starting from an unprecedented detailed knowledge about the size, shape, and composition of the investigated quantum dots these energies are calculated using an eight-band $\mathbf{k}\cdot\mathbf{p}$ theory for the single-particle states and the configuration interaction method for the few-particle states. The observed strong variation of the few-particle energy positions is found to originate from a depletion of the number of excited states in the QDs when they become smaller. Then the degree of correlation is reduced. From a detailed comparison of the numerical results with the experimental data we identify the number of hole states bound in the QD to be the key parameter for size and sign variations of the relative few-particle energies.

35. *Phys. Rev. Lett.* ***95****, 257402 (2005)*

Size-Dependent Fine-Structure Splitting in Self-Organized InAs/GaAs Quantum Dots

R. Seguin, A. Schliwa, S. Rodt, K. Pötschke, U.W. Pohl, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

A systematic variation of the exciton fine-structure splitting with quantum dot size in single InAs/GaAs quantum dots grown by metal-organic chemical vapor deposition is observed. The splitting increases from -80 to as much as 520 μeV with quantum dot size. A change of sign is reported for small quantum dots. Model calculations within the framework of eight-band k•p theory and the configuration interaction method were performed. Different sources for the fine-structure splitting are discussed, and piezoelectricity is pinpointed as the only effect reproducing the observed trend.

40. *Appl. Phys. Lett.* ***89****, 161919 (2006)*

Band gap and band parameters of InN and GaN from quasiparticle energy calculations based on exact-exchange density-functional theory

P. Rinke and M. Scheffler
Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany
A. Qteish
Department of Physics, Yarmouk University, 21163-Irbid, Jordan
M. Winkelnkemper[b)] and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany
J. Neugebauer
Department of Computational Materials Design, Max-Planck-Institut für Eisenforschung, D-40237 Düsseldorf, Germany

The authors have studied the electronic structure of InN and GaN employing G_0W_0 calculations based on exact-exchange density-functional theory. For InN their approach predicts a gap of 0.7 eV. Taking the Burnstein-Moss effect into account, the increase of the apparent quasiparticle gap with increasing electron concentration is in good agreement with the observed blueshift of the experimental optical absorption edge. Moreover, the concentration dependence of the effective mass, which results from the nonparabolicity of the conduction band, agrees well with recent experimental findings. Based on the quasiparticle band structure the parameter set for a 4 x 4 **k·p** Hamiltonian has been derived.

***43**. Appl. Phys. Lett. **89,** 72103 (2006)*

Carrier storage time of milliseconds at room temperature in self-organized quantum dots

A. Marent, M. Geller, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

A. P. Vasi'ev, E. S. Semenova, A. E. Zhukov, and V. M. Ustinov
A. F. Ioffe Physico-Technical Institute, Russian Acadamy of Sciences 26 Polytekhnicheskaya, St. Petersburg 194021, Russia

Thermally activated hole emission from differently charged InAs/GaAs quantum dots (QDs) was investigated by using deep level transient spectroscopy. In a sample with an additional AlGaAs barrier below the QD layer, a thermal activation energy of 560 meV for hole emission from the QD ground states over the AlGaAs barrier is obtained. This large activation energy leads to a hole storage time at room temperature of about 5 ms, which is in the order of magnitude of a typical dynamic random access memory (DRAM) refresh time.

***44.** Appl. Phys. Lett. **88,** 182107 (2006)*

Charge and spin storage in self-organized quantum dots

W. Wieczorek, T. Warming, M. Geller, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

G. E. Cirlin, A. E. Zhukov, and V. M. Ustinov
A. F. Ioffe Physico-Technical Institute, Russian Acadamy of Sciences, 26 Polytekhnicheskaya, St. Petersburg 194021, Russian Federation

We demonstrate optical charging of spectrally selected subensembles of self-organized quantum dots with single charge carriers. In spectral hole burning experiments negative and positive trions are observed, representing quantum dots charged with single electrons and holes. By circularly polarized excitation in an applied magnetic field we are able to address the spin of single electrons. A spin flip of the electron is observed after excitation in the upper Zeeman level.

45. *Appl. Phys. Lett.* ***89,*** *263109 (2006)*

Control of fine-structure splitting and excitonic binding energies in selected individual InAs/GaAs quantum dots

R. Seguin, A. Schliwa, T. D. Germann, S. Rodt, K. Pötschke,
A. Strittmatter, U. W. Pohl, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany

M. Winkelnkemper
Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany and Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany

T. Hammerschmidt
Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany

P. Kratzer
Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany and Fachbereich Physik, Universität Duisburg-Essen, D-47048 Duisburg, Germany

A systematic study of the impact of annealing on the electronic properties of single InAs/GaAs quantum dots (QDs) is presented. Single QD cathodoluminescence spectra are recorded to trace the evolution of one and the same QD over several steps of annealing. A substantial reduction of the excitonic fine-structure splitting upon annealing is observed. In addition, the binding energies of different excitonic complexes change dramatically. The results are compared to model calculations within 8-band k•p theory and the configuration interaction method, suggesting a change of electron and hole wave function shape and relative position.

50. *Phys. Rev. B **74**, 153322 (2006)*

Interrelation of structural and electronic properties in $In_xGa_{1-x}N/GaN$ quantum dots using an eight-band k·p model

Momme Winkelnkemper,[1,2] Andrei Schliwa,[1] and Dieter Bimberg[1]
[1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany
[2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany

We present an eight-band **k·p**-model for the calculation of the electronic structure of wurtzite semiconductor quantum dots (QDs) and its application to indium gallium nitride ($In_xGa_{1-x}N$) QDs formed by composition fluctuations in $In_xGa_{1-x}N$ layers. The eight-band **k·p**-model accounts for strain effects, piezoelectricity and pyroelectricity, and spin-orbit and crystal-field splitting. Exciton binding energies are calculated using the self-consistent Hartree method. Using this model, we studied the electronic properties of $In_xGa_{1-x}N$ QDs and their dependence on structural properties, i.e., their chemical composition, height, and lateral diameter. We found a dominant influence of the built-in piezoelectric and pyroelectric fields, causing a spatial separation of the bound electron and hole states and a redshift of the exciton transition energies. The single-particle energies as well as the exciton energies depend heavily on the composition and geometry of the QDs.

61. *Phys. Rev. B **73**, 205331 (2006)*

Tunneling emission from self-organized In(Ga)As/GaAs quantum dots observed via time-resolved capacitance measurements

M. Geller, E. Stock, C. Kapteyn, R. L. Sellin†, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

The observation of tunneling emission of electrons and holes from In(Ga)As/GaAs quantum dots in timeresolved capacitance measurements is reported. The electron and hole ground-state localization energies are determined as (290±30) meV and (210±20) meV, respectively. These energies are in excellent agreement with predictions from eight-band **k·p** theory. Based on the localization energies, we estimate the escape time for thermal excitation at room temperature as ~200 ns for electrons and ~0.5 ns for holes in case of a zero-electric-field situation. The electric-field dependence of the tunneling emission is investigated in detail.

69. *Optics Communications* ***248*** *(1-3), 211 (2005)*

On gain saturation in quantum dot semiconductor optical amplifiers

A.V. Uskov [a,b], E.P. O'Reilly [a], M. Laemmlin [c], N.N. Ledentsov [c,d,e], D. Bimberg [c]

[a] *NMRC, University College Cork, Lee Maltings, Prospect Row, Cork, Ireland*
[b] *P.N. Lebedev Physical Institute, Leninsky pr. 53, 117924 Moscow, Russia*
[c] *Institut für Festkörperphysik TU Berlin, Hardenbergstrasse 36, D-10623 Berlin, Germany*
[d] *Ioffe Physical-Technical Institute, Politekhnicheskaya 26, 194021 St. Petersburg, Russia*
[e] *NL-Nanosemiconductor GmbH, 44227 Dortmund, Germany*

We show for quantum dot (QD) semiconductor optical amplifiers (SOAs) operating in the regime where the gain is maximized, that gain saturation due to carrier depletion can be eliminated by increasing the SOA pump current density. At high pump currents, gain saturation in QD SOAs is then due to spectral hole burning. As a result, the saturation power for cw amplification can be enhanced by two orders in magnitude in QD SOAs. On the other hand, the increase of the saturation pulse energy in single pulse amplification depends strongly on the pulse duration. For pulse durations of order 100 ps, the saturation pulse energy can be increased by one order of magnitude, while a significantly smaller increase is expected for pulses of duration less than 10 ps. Simple approximate formulas are given for the gain saturation characteristics in these different regimes.

74. *J. Phys. D: Appl. Phys.* ***38*** *(15), 2055 (2005)*

Quantum dots for lasers, amplifiers and computing

Dieter Bimberg
Institut für Festkörperphysik TU Berlin, Hardenbergstrasse 36, D-10623 Berlin, Germany

For InAs-GaAs based quantum dot lasers emitting at 1300 nm, digital modulation showing an open eye pattern up to 12 Gb/s at room temperature is demonstrated, at 10 Gb/s the bit error rate is below 10^{-12} at −2 dBm receiver power. Cut-off frequencies up to 20 GHz are realised for lasers emitting at 1.1μm. Passively mode-locked QD lasers generate optical pulses with repetition frequencies between 5 and 50 GHz, with a minimum Fourier limited pulse length of 3 ps. The uncorrelated jitter is below 1 ps. We use here deeply etched narrow ridge waveguide structures which show excellent performance similar to shallow mesa structures, but a circular far field at a ridge width of 1μm, improving coupling efficiency into fibres. No beam filamentation of the fundamental mode, low a-factors and strongly reduced sensitivity to optical feedback are observed. QD lasers are thus superior to QW lasers for any system or network. Quantum dot semiconductor optical amplifier (QD SOAs) demonstrate gain recovery times of 120–140 fs, 4–7 times faster than bulk/QW SOAs, and a net gain larger than 0.4 dB/(mm*QD-layer) providing us with novel types of booster amplifiers and Mach–Zehnder interferometers. These breakthroughs became possible due to systematic development of self-organized growth technologies.

76. *Appl. Phys. Lett.* ***88,*** *262104 (2006)*

Alternative precursor metal-organic chemical vapor deposition of InGaAs/GaAs quantum dot laser diodes with ultralow threshold at 1.25 µm

A. Strittmatter, T. D. Germann, Th. Kettler, K. Posilovic, U. W. Pohl, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Sekretariat PN 5-2, Hardenbergstrasse 36,D-10623 Berlin, Germany

Laser diodes based on InGaAs quantum dots (QDs) operating at 1250 nm with ultralow threshold current densities of 66 A/cm^2, transparency current densities of 10 A/cm^2 per quantum dot layer, and high internal quantum efficiencies of 94% have been realized using alternative precursor metal-organic chemical vapor deposition. Photoluminescence of the active QD stacks clearly indicates the requirement of varying growth parameters for subsequently deposited QD layers. The excellent performance of the QD lasers was obtained by adjusting the number of stacked QD layers to a limit given by the In content of the InGaAs strain-reducing layers grown on the QDs and individual durations of the growth interruption after deposition for each QD layer.

79. *Appl. Phys. Lett.* ***89,*** *41113 (2006)*

Degradation-robust single mode continuous wave operation of 1.46 µm metamorphic quantum dot lasers on GaAs substrate

T. Kettler, L. Ya. Karachinsky, N. N. Ledentsov, V. A. Shchukin, G. Fiol, M. Kuntz, A. Lochmann, O. Schulz, L. Reissmann, K. Posilovic, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, PN5-2, Hardenbergstr. 36, D-10623 Berlin, Germany

I. I. Novikov, Yu. M. Shernyakov, N. Yu. Gordeev, M. V. Maximov, N. V. Kryzhanovskaya, A. E. Zhukov, E. S. Semenova, A. P. Vasil'ev, and V. M. Ustinov
Ioffe Physico-Technical Institute, Politekhnicheskaya 26, 194021, St. Petersburg, Russia

A. R. Kovsh
NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

Narrow ridge lasers of 1.5 µm range based on InAs/InGaAs quantum dots grown on metamorphic (In,Ga,Al)As layers deposited on GaAs substrates using defect reduction technique are studied. It is shown that the lasers operate continuous wave (cw) in a single transverse mode. Single-mode 800 mW output power in the pulsed regime is obtained for a 6 µm ridge width. The dynamic studies of the lasers show a modulation bandwidth of ~3 GHz. Aging tests demonstrate >800 h of cw operation at ~50 mW at 10 °C (60 °C) and >200 h at 20 °C (70 °C) heat sink (junction) temperature without noticeable degradation.

80. *Electr. Lett.* ***42*** *(13), 774 (2006)*

Electrically driven single quantum dot polarised single photon emitter

A. Lochmann, E. Stock, O. Schulz, F. Hopfer, D. Bimberg,
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
V.A. Haisler, A.I. Toropov, A.K. Bakarov and A.K. Kalagin
Institute of Semiconductor Physics, Lavrenteva Avenue 13, 630090 Novosibirsk, Russia

A report is presented of a subminiature solid-state emitter structure, which allows electrical pumping of only one single InAs quantum dot (QD) grown in the Stranski-Krastanow mode. The emitter demonstrates a strongly monochromatic polarised emission of a single QD exciton. No other emission is observed across 500 nm. The structure is thus attractive for practical implementation as an effective single photon source for quantum cryptography.

88. *Phys. stat. sol. (c)* ***3*** *(3)***,** *391 (2006)*

Quantum dot based photonic devices at 1.3 µm: Direct modulation, mode-locking, SOAs and VCSELs

M. Laemmlin, G. Fiol[1], M. Kuntz[1], F. Hopfer[1], A. Mutig[1], N.N. Ledentsov[2], A.R. Kovsh[2], C. Schubert[3], A. Jacob[4], A. Umbach[4], and D. Bimberg[1]
[1] *Institut für Festkörperphysik, Technische Universität Berlin, PN5-2, Hardenbergstr. 36, 10623 Berlin, Germany*
[2] *NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany*
[3] *Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, Einsteinufer 37, 10587 Berlin, Germany*
[4] *u^2t Photonics AG, Reuchlinstrasse 10/11, 10553 Berlin, Germany*

We present results on directly modulated lasers with high-reflectivity coating, mode-locked lasers with a gain and absorber section, and semiconductor optical amplifiers (SOA) with anti-reflection coating, all based on InGaAs/GaAs quantum dot (QD) material emitting at 1.3 µm. Error free 8 and 10 Gb/s data modulation is presented. 80 GHz passive mode-locking of two-section QD lasers is reported. Hybrid mode-locking was achieved at 40 GHz. The minimum pulse width at 80 GHz was 1.5 ps, with a timebandwidth product of 1.7. QD SOAs are shown to have a chip gain larger than 26 dB. Modeling of the gain characteristics of these devices predicts 40 dB amplification under ideal biasing and input power. QD-VCSEL with 17 p-modulation doped QD layers placed in 5 field intensity antinodes and fully doped GaAs/AlGaAs DBRs show a peak multimode RT cw output power of 1.8 mW and differential efficiency of 20 %. The maximum -3dB bandwidth is 3 GHz.

93. *Electr. Lett.* ***42*** *(20)**,*** *1157 (2006)*

Single transverse mode 850nm GaAs/AlGaAs lasers with narrow beam divergence

T. Kettler, K. Posilovic, O. Schulz, V.A. Shchukin,
N.N. Ledentsov, U.W. Pohl and D. Bimberg
Institut für Festkörperphysik, and Center for NanoPhotonics, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

L.Ya. Karachinsky, I.I. Novikov, Yu.M. Shernyakov, S.M. Kuznetsov,
N.Yu. Gordeev, M.V. Maximov and P.S. Kop'ev
A.F.Ioffe Physico-Technical Institute, Russian Academy of Sciences, 26 Polytekhnicheskaya, St. Petersburg 194021, Russia

U. Ben-Ami and A. Sharon
PBC Lasers Ltd, P.O. Box 186, Kibbutz Einat 49910, Israel

S.S. Mikhrin and A.R. Kovsh
NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

GaAs/AlGaAs 850 nm range lasers based on a longitudinal photonic bandgap crystal waveguide show narrow vertical far-field pattern. Vertical and lateral beam divergence with FWHM below 10º and 5º, respectively, is demonstrated for 4 µm stripe width, being independent on injection current. Excellent beam quality with $M^{2=}1.4$, low internal losses of 1.4 cm^{-1} and high differential quantum efficiency of 83% are observed.

94. *Appl. Phys. Lett.* ***89,*** *141106 (2006)*

Single-mode submonolayer quantum-dot vertical-cavity surface-emitting lasers with high modulation bandwidth

F. Hopfer, A. Mutig, M. Kuntz, G. Fiol, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

N. N. Ledentsov and V. A. Shchukin
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
and Ioffe Physical Technical Institute, Politekhnicheskaya 26, 194021 St. Petersburg, Russia

S. S. Mikhrin, D. L. Livshits, I. L. Krestnikov, and A. R. Kovsh
NL-Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

N. D. Zakharov and P. Werner
Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Single-mode vertical-cavity surface-emitting lasers based on dense arrays of stacked submonolayer grown InGaAs quantum dots, emitting near 980 nm, demonstrate a modulation bandwidth of 10.5 GHz. A low threshold current of 170 μA, high differential efficiency of 0.53 W/A, and high modulation current efficiency factor of 14 GHz/√mA are realized from a 1 μm oxide aperture single-mode device with a side mode suppression ratio of >40 dB and peak output power of >1 mW. The lasers are also suitable for high temperature operation.

96. *Appl. Phys. Lett.* ***89,*** *061105 (2006)*

Vertical-cavity surface-emitting quantum-dot laser with low threshold current grown by metal-organic vapor phase epitaxy

F. Hopfer, I. Kaiander, A. Lochmann, A. Mutig, S. Bognar, M. Kuntz, U. W. Pohl, V. A. Haisler, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Ground state lasing of electrically driven vertical-cavity surface-emitting lasers with a quantum-dot (QD) gain medium grown using metal-organic vapor phase epitaxy was realized. The devices use stacked InGaAs QD layers, placed in the field intensity antinodes of the cavity formed by selectively oxidized distributed Bragg reflectors. Devices with 3 x 3 QD layers demonstrate at 20 °C a cw output power of 1.45 mW at 1.1 μm emission wavelength. The peak external efficiency was 45%, limited by lateral carrier spreading within the 4λ cavity and a reduction of the internal efficiency above 60 °C. A minimum threshold current of 85 μA was obtained from a device with a 1 μm aperture.

98. *Electr. Lett.* ***41*** *(5), 244 (2005)*

10 Gbit/s data modulation using 1.3 µm InGaAs quantum dot lasers

M. Kuntz, G. Fiol, M. Lämmlin and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
C. Schubert
Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut, Einsteinufer 37, 10587 Berlin, Germany
A.R. Kovsh
NL Nanosemiconductors GmbH, Joseph-von-Fraunhofer-Str. 13, 44227 Dortmund, Germany
A. Jacob and A. Umbach
u^2t photonics AG, Reuchlinstrasse 10-11, 10553 Berlin, Germany

Error-free 8 and 10 Gbit/s data modulation with quantum dot lasers emitting at 1.3 µm is presented. 12 Gbit/s open eye patterns are observed. An integrated fibre-optic QD laser module yields errorfree data modulation at 10 Gbit/s at a receiver power of -2 dBm.

101. *Electr. Lett.* ***41*** *(5), 248 (2005)*

Colliding-pulse modelocked quantum dot lasers

M.G. Thompson, C. Marinelli, X. Zhao, R.L. Sellin, R.V. Penty and I.H. White
Engineering Department, University of Cambridge, Trumpington St, CB2 1PZ, U.K.
I.N. Kaiander and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
D.-J. Kang and M.G. Blamire
Nanoscience Centre, University of Cambidge, 11 JJ Thomson Avenue, Cambridge CB3 0FF, U.K.
D.-J. Kang
also with Department of Physics, Sungkyunkwan University, Suwon, 440-746 Korea

Colliding pulse modelocking is demonstrated for the first time in quantum dot lasers. Using 3.9 mm-long devices with a 245 µm-long central absorber, 7 ps pulses at a repetition rate of 20 GHz is obtained. For Gaussian pulses a time-bandwidth product close to the Fourier transform limit is determined. These results confirm the potential of quantum dot lasers for high repetition rate harmonic modelocking.

103. *Electr. Lett.* ***41*** *(20), 1127 (2005)*

Low jitter femtosecond semiconductor laser system with arbitrary repetition rate

H. Quast, O. Reimann, V. Eisner, C. Meuer, and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A modified photon injection setup to generate low jitter singlemode laser pulses from a gain-switched Fabry-Perot laser diode at arbitrary repetition rates is presented. The output pulses show sub-picosecond timing jitter and, upon nonlinear compression in comb-like dispersion profiled fibre, pulse widths (FWHM) below 500 fs.

106. *Electr. Lett.* ***42*** *(12), 41 (2006)*

Distortion-free optical amplification of 20–80 GHz modelocked laser pulses at 1.3 µm using quantum dots

M. Laemmlin, G. Fiol, C. Meuer, M. Kuntz, F. Hopfer, N.N. Ledentsov and D. Bimberg
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A.R. Kovsh and N.N. Ledentsov
NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

Distortion-free amplification of modelocked laser pulses at 20, 40 and 80 GHz with a minimum pulse width of 710 fs is reported. The modelocked lasers and the semiconductor optical amplifiers are based on identical quantum dot material emitting at 1.3 µm.

107. *Phot. Tech. Lett.* ***18*** *(22)****,*** *2338 (2006)*

Dual Semiconductor Laser System With Rapid Time-Delay for Ultrafast Measurements

Holger Quast, Christian Meuer, Olaf Reimann, Dieter Huhse,
and Dieter Bimberg, Member, IEEE
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We present a dual semiconductor laser system at 1.55 µm with femtosecond pulse widths and very low timing jitter for rapid pump-probe measurements. Synchronizing the two lasers to the same low-noise radio frequency-oscillator allows the use of an electrical phase shifter for the relative time delay between the lasers. This leads to a large scanning window that nearly matches the pulse period of 2.5 ns, as well as achieving a discrete time step of below 100 fs. The timing jitter of the complete dual laser system including all electronics is only 540 fs across the whole time delay. The nonlinear pulse compression using especially designed comb-like dispersion profiled fiber leads to autocorrelation widths of 310 fs. The system performance, i.e., the high time resolution is demonstrated by optical cross correlation of the pump and probe pulse, showing a very low full-width at half maximum of 1.3 ps.

115. *Defect and Diffusion Forum* ***237-240****, 1049-1054 (2005)*

Fractal Self-Assembled Nanostructures on Monocrystalline Silicon Surface

N.T.Bagraev[1], A.D.Bouravleuv[1], W.Gehlhoff[2], L.E.Klyachkin[1],
A.M.Malyarenko[1], V.V.Romanov[3] and S.A.Rykov[3]
[1] *A.F.Ioffe Physico-Technical Institute, St.Petersburg, Russia*
[2] *Institut fuer Festkoerperphysik, Technische Universitaet Berlin, Berlin, Germany*
[3] *St.Petersburg State Technical University, St.Petersburg, Russia*

We present ultra-shallow diffusion profiles performed by short-time diffusion of boron from the gas phase using controlled surface injection of self-interstitials and vacancies into the n-type Si(100) wafers. The diffusion profiles of this kind are found to consist of both longitudinal and lateral silicon quantum wells of the p-type that are self-assembled between the layers of microdefects, which are produced by previous oxidation. These layers appear to be passivated during short-time diffusion of boron thereby forming neutral δ - barriers. The fractal type selfassembly of microdefects is found to be created by varying the thickness of the oxide overlayer, which represents the system of microcavities embedded in the quantum well plane.

122. *Physica B* ***376-377****, 790-794 (2006)*

Transition metals in $ZnGeP_2$ and other II–IV–V_2 compounds

W. Gehlhoff [a], D. Azamat[a], A. Hoffmann[a], N. Dietz[b], O.V. Voevodina[c]
[a] *Institute for Solid State Physics, Technical University Berlin, D-10623 Berlin, Germany*
[b] *Department of Physics and Astronomy, Georgia State University, Atlanta, GA 3030, USA*
[c] *Siberian-Physico-Technical Institute, 634050 Tomsk, Russia*

Semiconductors that exhibit room-temperature ferromagnetism are central to the development of semiconductor spintronics. Transition metal (TM)-doped $A^{II}B^{IV}C^{V}{}_2$ are a promising class of such system. These ternary compound semiconductors have two metal sites A and B that can be substituted by the TMs. A site preference for TM incorporation is crucial for a possible explanation of ferromagnetism since dependent on the TM valent state holes or electrons can be released. For low Fe- and Cr-doped $ZnGeP_2$, our EPR investigations revealed in addition to the well-known native defects the presence of substitutional Fe^{2+} ($3d^6$, S = 2) on Zn site, Fe^{3+} ($3d^5$, S = 5/2) and Cr^{4+} ($3d^2$, S = 1) on Ge site. A photo-induced recharging of Fe^{2+} to Fe^{+} is observed. The Cr^{4+} center exhibits a well resolved phosphorus ligand hyperfine splitting. For Fe^{2+} and Fe^{3+}, the magnetic site inequivalence of each of the both Zn and Ge sites, respectively, has been detected. Moreover, anti-ferromagnetically coupled $Mn_{Zn}{}^{2+}$–$Mn_{Zn}{}^{2+}$ pairs have been observed in Mn-doped $ZnGeP_2$.

126. *Phys. stat. sol. (b)* ***243****, 1687-1691 (2006)*

Site selectivity of $Fe_{Ga}{}^{3+}$ and the formation of $Fe_{Ga}{}^{3+}$-Ga_i pairs in GaN

W. Gehlhoff, D. Azamat, and A. Hoffmann
Institute for Solid State Physics, Technical University Berlin, 10623 Berlin, Germany

The electron paramagnetic resonance (EPR) spectra of Fe-related defects in high quality thick freestanding hydride vapor phase (HVPE) grown GaN have been studied in the X- and Q-band. The dominating part of the complex resonance pattern is due to isolated Fe^{3+} ($3d^5$, S = 5/2) on the two equivalent Ga sites A and B with C_{3V} point symmetry in the hexagonal GaN unit cell. These two physically equivalent sites, caused by the ABAB stacking sequence of the wurtzite structure, can be distinguished by EPR for electron spin systems $S \geq 2$. We found a preferential incorporation of Fe in one of the two types of Ga sites. Moreover, despite the strong overlap with the intensive Fe^{3+} transitions we could identify the main part of the additional observed very weak lines as $Fe_{Ga}{}^{3+}$–Ga_i pairs.

127. *Phys. Rev. B **74**, 165202 (2006)*

Structural and electronic properties of Fe^{3+} and Fe^{2+} centers in GaN from optical and EPR experiments

E. Malguth, A. Hoffmann, and W. Gehlhoff
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

O. Gelhausen and M. R. Phillips
Microstructural Analysis Unit, University of Technology, Sydney, Broadway, NSW 2007 Australia

X. Xu
Cree, Inc., 4600 Silicon Drive, Durham, North Carolina 27703, USA

This work provides a consistent picture of the structural, optical, and electronic properties of Fe-doped GaN. A set of high-quality GaN crystals doped with Fe at concentrations ranging from 5 x 10^{17} cm^{-3} to 2 x 10^{20} cm^{-3} is systematically investigated by means of electron paramagnetic resonance and various optical techniques. Fe^{3+} is shown to be a stable charge state at concentrations from 1 x 10^{18} cm^{-3}. The fine structure of its midgap states is successfully established, including an effective-mass-like state consisting of a hole bound to Fe^{2+} with a binding energy of 50±10 meV. A major excitation mechanism of the $Fe^{3+}(^4T_1\rightarrow{}^6A_1)$ luminescence is identified to be the capture of free holes by Fe^{2+} centers. The holes are generated in a two-step process via the intrinsic defects involved in the yellow luminescence. The $Fe^{3+/2+}$ charge-transfer level is found 2.863±0.005 eV above the valence band, suggesting that the internal reference rule does not hold for the prediction of band offsets of heterojunctions between GaN and other III-V materials. The $Fe^{2+}(^5E\rightarrow{}^5T_2)$ transition is observed around 390 meV at any studied Fe concentration by means of Fourier transform infrared spectroscopy. Charge-transfer processes and the effective-mass-like state involving both Fe^{2+} states are observed. At Fe concentrations from 1 x 10^{19} cm^{-3}, additional lines occur in electron paramagnetic resonance and photoluminescence spectra which are attributed to defect complexes involving Fe^{3+}. With increasing Fe concentration, the Fermi level is shown to move from near the conduction band to the $Fe^{3+/2+}$ charge-transfer level, where it stays pinned for concentrations from 1 x 10^{19} cm^{-3}. Contrary to cubic II-VI and III-V materials, both electronic states are affected by only a weak Jahn-Teller interaction.

9.2. Department II

Prof. Dr. rer. nat. Christian Thomsen (Dept. IIa)
Prof. em. Dr.-Ing. Dr. h.c. mult. Immanuel Broser, Priv.-Doz. Dr. Axel Hoffmann (Dept. IIb)

9.2.a Department IIa

Prof. Dr. rer. nat. Christian Thomsen

9.2a.0 Staff

Secretary
Marianne Heinold

Technical staff
Michael Mayer (as of 09.10.2006)
Sabine Morgner
Ing.grad. Heiner Perls
Bernd Schöler (until 31.12.2006)

Senior scientists
Dr. Sabine Bahrs (until 31.10.2006)
Dr. Paula Giudici (until 31.12.2005)
Dr. Christian Kristukat (until 30.06.2006)
Dr. María Machón
Dr. Janina Maultzsch
Dr. Peter Rafailov (until 30.06.2005)

PhD candidates
Dipl.-Phys. Ute Haboeck
Dipl.-Phys. Dirk Heinrich
Dipl.-Phys. Holger Lange
Dipl.-Phys. Matthias Müller
Dipl.-Phys. Marcel Mohr
Dipl.-Phys. Harald Scheel
Dipl.-Phys. Normen Tschirner
Dipl.-Phys. Hagen Telg

Diploma students (status of 31.12.2006 - thesis completed = c)
Katharina Brose
David Eckhardt
Martin Fouquet
Sevak Khachadorian
Marcel Mohr (c)
Carola Nisse
Nils Rosenkranz
Thomas Stempel Pereira (c)

Students
Juri Brunnmeier
Ela Elsholz
Jan Ranglack
Kai Scheddin
Jan-Hindrick Schulze
Jörg Wittich

9.2a.1 Summary of activities

The activity of this group is centered on optical spectroscopy of carbon nanotubes, wide and narrow-gap semiconductors nanostructures, 2D electron gases, quantum dots, superconductor-semiconductor-hybrid structures, ferrofluids, and high-T_c superconductors. In both 2005 and 2006 the publications of the group were cited over 500 times in total.

Emphasis in the work on **carbon nanotubes** was put on the understanding of chirality-dependent properties of these tubes. In 2004 we were successful in assigning ~ 60 different chiral indices to nanotubes in solution, a publication which has resultet in over 60 citations in the last couple of years. We are now focussing on the physical properties of specific chirality nanotubes, e.g., the metallic or the semiconducting ones. Recent highlights in this field were the identification of the excitonic character of the optical transitions in semiconducting nanotubes *via* two-photon spectroscopy and their binding energies, a long-standing problem in nanotube spectrocopy. We also calculated and measured the strength of the electron-phonon coupling of various vibrational modes. As part of the investigations in the Cluster of Excellence "Catalysis" we expanded our investigations to functionalized carbon nanotubes. A further research topic was the electrochemical doping of carbon nanotubes and the determination of the full graphite phonon dispersion relation with inelastic x-ray scattering using the synchrotron source ESRF in Grenoble. We collaborate in the nanotube work with S. Reich, MIT, J. Maultzsch, Columbia University – both former graduate students in the group –, on *ab initio* work with P. Ordejón in Spain and on group theoretical work with M. Damnjanović in Belgrade.

In the **nanostructure**-related project of the Sonderforschungsbereich 296 investigations focused on Raman and fir-spectroscopy of quantum dots and their luminescence properties under pressure. Based on predictions by density-functional calculations of a spin-polarized phase in higher subbands of a **2D electron gas** in a single quantum well, we searched for such a phase in photoluminescence and inelastic light scattering. A sharp emission was observed and behaves under the influence of a magnetic field as predicted confirming the formation of spin polarized domains in the excited subband. We believe that we observed such a phase also in the inelastic scattering spectra.

We continued our studies on wide-gap semiconductors with studies of binary and ternary **group-III nitrides** as a part of the now completed special focus program of the DFG (Schwerpunktprogramm Nitride). Our ability to spatially resolve physical and structural properties allowed us to contribute significantly to the strain and luminescence characterisation of macroscopic samples. Finite-element calculations contributed to the consistent explanation of our results. We contributed to a new DFG initiative on **AlN-based materials**.

The behavior of oxygen atoms in the **$YBa_2Cu_3O_{7-\delta}$ superconductor** family when excited with visible light was investigated with Raman spectroscopy, high-resolution x-ray radiation and Monte Carlo simulations. We have developed a consistent picture of the involved physical processes and are able to connect the optical to transport properties in these fascinating materials.

Our work on surfacted **ferrofluids** continues. In this period we covered mostly the behavior of ion-stabilized ferrofluids in an applied magnetic field. These fluids - aside from physics research - are of interest for medical applications.

Our investigations of **Si nanowires** lead to the discovery that the thermal conductivity of gases determines the steady-state temperature of the nanowires under illumination, leading to a non-contact, nano-sized gas sensor.

As part of the OWL-initiative of the University (Offensive—Wissen—Lernen) we are in the process of setting up a laboratory with remotely controlled experiments (**remoteExperiments**) which are used in the education of – in particular – engineering students. These experiments are controlled over the internet and available on a 24/7 basis. Modern control and evaluation software allow experimenting from a remote location and contribute to the excellence in teaching at TU Berlin.

The newly founded **Multimedia Center for Teaching and Research** (MuLF) of TU Berlin headed jointly by C. Thomsen and S. Jeschke (also Faculty II) was responsible for a general renewal of electronically based media. Its most prominent activities include the electronic-chalk project available now in many of the lecture rooms at the University and the Information System for Students (ISIS), which actively reaches now over 8000 students and manages their examinations. Another project is the simultaneous electronic examination of tens to hundreds of students which is currently being introduced in the class “Introduction to Physics for Engineering Students.”

9.2a.2 Publications

The abstracts of papers marked by * are reprinted in section 9.2a.6.

1.* **Strength of radial breathing mode in single-walled carbon nanotubes**
M. Machón, S. Reich, J. Maultzsch, P. Ordejón, and C. Thomsen
Phys. Rev. B 71, 035416 (2005).

2. **Excited-state carrier lifetime in single-walled carbon nanotubes**
S. Reich, M. Dworzak, A. Hoffmann, C. Thomsen and M.S. Strano
Phys. Rev. B **71**, 033402 (2005).

3. **Effect of light on the reflectance anisotropy and chain-oxygen related Raman signal in untwinned, underdoped crystals of $YBa_2Cu_3O_{7-\delta}$**
S. Bahrs, A. Bruchhausen, A.R. Goñi, G. Nieva, A. Fainstein, K. Fleischer, and C. Thomsen
Journal of Physics and Chemistry of Solids **67**, 340 (2006).

4. **Chirality assignments in carbon nanotubes based on resonant Raman scattering**
C. Thomsen, H. Telg, J. Maultzsch, and S. Reich
phys. stat. sol. (b) **242**, 1802-1806 (2005).

5.* **Exciton resonances quench the photoluminescence of zigzag carbon nanotubes**
S. Reich, C. Thomsen, and J. Robertson
Phys. Rev. Lett. **95**, 077402 (2005).

6. **Raman spectroscopy on electrochemically doped carbon nanotubes**
P.M. Rafailov and C. Thomsen
Journal of Optoelectronics and Advanced Materials **7**, 461-464 (2005).

7. **A Raman spectroscopic study of defects in $Bi_4Ge_3O_{12}$ crystals**
P.M. Rafailov, T.I. Milenov, M.N. Veleva, C. Thomsen, and M.M. Gospodinov
Journal of Optoelectronics and Advanced Materials **7**, 473-476 (2005).

8. **High-energy vibrational modes in nitrogen-doped ZnO**
U. Haboeck, A. Hoffmann, C. Thomsen, A. Zeuner, and B.K. Meyer
phys. stat. sol. (b) **242**, R 21-R23 (2005).

9.* **Electronic band structure of high-index silicon nano wires**
H. Scheel, S. Reich, and C. Thomsen
phys. stat. sol. (b) **242**, 2474-9 (2005).

10.* **Electrochemical switching of the Peierls-like transition in metallic single-walled carbon nanotubes**
P.M. Rafailov, J. Mautzsch, C. Thomsen, and H. Kataura
Phys. Rev. B **72**, 045411 (2005).

11.* **Structural, electronic, and vibrational properties of (4,4) picotube crystals**
M. Machón, S. Reich, J. Maultzsch, H. Okudera, A. Simon, R. Herges, and C. Thomsen
Phys. Rev. B **72**, 155402 (2005).

12.* **Orientation dependence of the polarization of an individual WS_2 nanotube by resonant Raman spectroscopy**
P.M. Rafailov, C. Thomsen, K. Gartsmann, I. Kaplan-Ashiri, and R. Tenne
Phys. Rev. B **72**, 205436 (2005).

13.* **Raman response of magnetic excitations in cuprate ladders and planes**
K.P. Schmidt, A. Gössling, U. Kuhlmann, C. Thomsen, A. Löffert, C. Gross, and W. Assmus
Phys. Rev. B **72**, 094419 (2005).

14.* **Exciton binding energies in carbon nanotubes from two-phonon photoluminescence**
J. Maultzsch, R. Pomraenke, S. Reich, E. Chang, D. Prezzi, A. Ruini, E. Molinari, M.S. Strano, C. Thomsen, and C. Lienau
Phys. Rev. B **72**, 241402 (2005).

15. **Chirality dependence of the high-energy Raman modes in carbon nanotubes**
H. Telg, J. Maultzsch, S. Reich, and C. Thomsen
Electronic properties of novel nanostructures, eds. H. Kuzmany, J. Fink, M. Mehring, S. Roth, AIP Conference Proceedings **786**, (Melville, New York, 2005) p. 162

16. **Phonon and symmetry properties of (4,4) picotube crystals**
M. Machón, S. Reich, J. Maultzsch, R. Herges, and C. Thomsen
IBID P. 452

17. **Micro Raman investigation of WS_2 nanotubes**
K. Gartsmann, I. Kaplan-Ashiri, R. Tenne, P. Rafailov, and C. Thomsen
ibid p. 349

18. **Raman spectroelectrochemistry - a way of switching the Peierls transition in metallic single-walled carbon nanotubes**
P.M. Rafailov, J. Maultzsch, and C. Thomsen
ibid p. 182

19. **Chiral-index assignment of carbon nanotubes by resonant Raman scattering**
J. Maultzsch, H. Telg, S. Reich, and C. Thomsen
ibid p. 401

20.* **Raman scattering in carbon nanotubes**
C. Thomsen and S. Reich
Light Scattering in Solids IX, Topics in Applied Physics, Vol. **108**, ed. by M. Cardona and G. Güntherodt, (Springer Verlag, Heidelberg, 2006), 126 pages

21.* **Persistent photo-excitation in $GdBa_2Cu_3O_{6.5}$ in a simultaneous Raman and electrical-transport experiment**
S. Bahrs, J. Guimpel, A.R. Goñi, B. Maiorov, A. Fainstein, G. Nieva, and C. Thomsen
Phys. Rev. B **72**, 144501 (2005).

22. **„e"-Volution an deutschen Universitäten: Chancen und Herausforderungen durch eLearning, eTeaching & eResearch (B3)**
S. Jeschke, O. Pfeiffer, R. Seiler, and C. Thomsen
Medien in der Wissenschaft; Auf zu neuen Ufern! E-Learning heute und morgen, eds. D. Tavangarian, K. Nölting (Waxmann, Münster, 2005) pp 227-236.

23. **The experiment in eLearning: Magnetism in virtual and remote experiments (C4)**
S. Jeschke, T. Richter, H. Scheel, R. Seiler, and C. Thomsen
Conference Proceedings Interactive computer aided learning (ICL) 2005, (kassel university press, Kassel, 2005).

24. **„e"-Volution: eltr-technologies and their impact on traditional universities (E1)**
S. Jeschke, O. Pfeiffer, R. Seiler, and C. Thomsen
Conference Proceedings of the Educa Online, (ICWE GmbH, Berlin, 2005) pp. 172-176

25. **Das Experiment und die eLTR-Technologien: Magnetismus in virtuellen Laboren und Remote-Experimente (G4)**
S. Jeschke, T. Richter, H. Scheel, R. Seiler, and C. Thomsen
Lecture Notes in Informatics (LNI), eds. K.P. Jantke, K.-P. Fähnrich, W.S.Wittig (Bonner Köllen Verlag, 2005) P-72

26. **Remote experiments in experimental physics (T1)**
C. Thomsen, H. Scheel, and S. Morgner
Proceedings of the ISPRS working group VI/1 - VI/2, Tools and Techniques for E-Learning, Internatilnal Archives of Photogrammetry, Remote Sensing and Spatial Information Science, **Vol. XXXVI-6/W30**, 2005.

27.* **Coupling between charge-density excitations and polar optical phonons in single quantum wells revisited**
P. Giudici, A.R. Goñi, C. Thomsen, K. Eberl, and M. Hauser
Phys. Rev. B. **73**, 045315-7 (2006).

28. **Inelastic light scattering of hydrogen containing open-cage-fullerene ATOCF**
P.M. Rafailov, C. Thomsen, A. Bassil, K. Komatsu, and W. Bacsa
phys. stat. sol. (b) **242**, R106-R108 (2005).

29.* **Radial breathing mode of single-walled carbon nanotubes: Optical transition energies and chiral-index assignment**
J. Maultzsch, H. Telg, S. Reich, and C. Thomsen
Phys. Rev. B **72**, 205438 (2005).

30. **Raman spectroscopic study of Ru, (Ru+Mn), Fe and (al+Mn) doped $Bi_4Ge_3O_{12}$ crystals**
P.M. Rafailov, T.I. Milenov, M.N. Veleva, C. Thomsen, and M.M. Gospodinov
Comt. Rend. Acad. bulg. Sci **59**, Nr. 3, 255-260 (2006).

31.* **Double-resonant Raman process in germanium**
M. Mohr, M. Machón, J. Maultzsch, and C. Thomsen
Phys. Rev. B **73**, 035217 (2006).

32. **Vibrational properties of hexahelicene: DFT and Raman**
M. Machón, S. Bahrs, and C. Thomsen
Chemical Physics Letters, in preparation (2006).

33. **Anisotropic ultraviolet Raman resonance in underdoped $YBa_2Cu_3O_{6.7}$**
S. Bahrs, S. Müller, M. Rübhausen, B. Schulz, A.R. Goñi, G. Nieva, and C. Thomsen
Phys. Rev. B **74**, 024519 (2006).

34. **Two-photon photoluminescence and excition binding in single-walled carbon nanotubes: experiment and theory**
R. Pomraenke, C. Lienau, J. Maultzsch, S. Reich, E. Chang, D. Prezzi, A. Ruini, E. Molinari, M.S. Strano, and C. Thomsen
Conference Proceedings CLEO Mai 2006, USA

35.* **Raman scattering on silicon nanowires: The thermal conductivity of the environment determines the optical phonon frequency**
H. Scheel, S. Reich. A.C. Ferrari, M. Cantoro, A. Colli, and C. Thomsen
App. Phys. Lett. **88**, 233114-16 (2006).

36. **Networked experiments and scientific resource sharing in cooperative knowledges spaces**
S. Cikic, S. Jeschke, T. Richter, U. Sinha, and C. Thomsen
Proceedings of the Eight IEEE International Symposium on Multimedia (ISM2006). IEEE Computer Society Conference Publishing Services, Los Alamitos, CA, pp. 953-958 (2006)

37. **The Teutates-project: tablet-PCs in modern physics education**
N. Dahlmann, S. Jeschke, H. Scheel, and C. Thomsen
Conference Proceedings of the 34th SEFI Annual Conference.
official URL: http://www.sefi2006.com (2006).

38.* **Two-photon photoluminescence and exciton binding energies in single-walled carbon nanotubes**
R. Pomraenke, J. Maultzsch, S. Reich, E. Chang, D. Prezzi, A. Ruini, E. Molinari, M.S. Strano, C. Thomsen, and C. Lienau
phys. stat. sol. (b) **243**, 2428-2435 (2006).

39.* **Resonant-Raman intensities and transition energies of the E_{11} transition in carbon nanotubes**
H. Telg. J. Maultzsch, S. Reich, and C. Thomsen
Phys. Rev. B **74**, 115415-5 (2006).

40. **Raman intensities of the first optical transitions in carbon nanotubes**
H. Telg, J. Maultzsch, S. Reich, F. Hennrich, and C. Thomsen
phys. stat. sol. (b) **243**, 3181-85 (2006).

41.* **Design and realization of multimedia-examinations for large numbers of participants in university education**
N. Tschirner, M. Müller, O. Pfeiffer, and C. Thomsen
International Journal of Emerging Technologies in Learning (iJET) Vol. **1**, (Nr. 2) 1-4 (2006).

42. **Electron-phonon coupling in carbon nanotubes**
M. Machón, S. Reich, and C. Thomsen
phys. stat. sol. (b) **243**, 3166-70 (2006).

43.* **Strong electron-phonon coupling of the high-energy modes of carbon nanotubes**
M. Machón, S. Reich, and C. Thomsen
Phys. Rev. B **74**, 205423 (2006).

44. **Excitons in carbon nanotubes**
J. Maultzsch, R. Pomraenke, S. Reich, E. Chang, D. Prezzi, A. Ruini, E. Molinari, M.S. Strano, C. Thomsen, and C. Lienau
phys. stat. sol. (b) **243**, 3204-08 (2006).

45. **Electronic examinations for undergraduates in large classes**
N. Tschirner, M. Müller, and C. Thomsen
Conference ICL 206, Sept. 27-29, Villach, Austria, veröffentlicht auf CD (2006).

46. **Special issue: Electronic Properties of Novel Nanostructures**
Hans Kuzmany, Peter Dinse, Siegmar Roth, Christian Thomsen
phys. stat. sol. (b) **243**, 2965 (2006).

47. **Probing residual strain in InGaAs/GaAs micro-origami tubes by mircro-Raman spectroscopy**
A. Bernardi, A.R. Goñi, M.I. Alonso, F. Alsina, H. Scheel, P.O. Vacarro, and N. Saito
J. App. Phys. **99**, 063512 (2006).

48. **XRD and Raman spectroscopic study of Ru and Os doped $Bi_{12}SiO_{20}$ crystals**
T.I. Milenov, P.M. Rafailov, A.V. Egorysheva, V.M. Skorikov, R. Petrova, M.N. Velena, T.D. Dudkina, A.Ya. Vasil'ev, C. Thomsen, and M.M. Gospodinov
Journal of Optoelectronics and Advanced Materials, in print (2007)

49. **On remote and virtual experiments in eLearning in statistical mechanics and thermodynamics**
S. Jeschke, T. Richter, C. Thomsen, and H. Scheel
The Second International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering /CISSR 2006), Advances in Systems, Computing, Sciences and Software (Springer, Berlin, 2007), in print

50. **Dynamics of magnetic-field induced clustering in ionic ferrofluides from Raman scattering**
D. Heinrich, A.R. Goñi, and C. Thomsen
J. Chem. Phys., in print (2007).

51. **Raman scattering at carbon nanotubes**
J. Maultzsch and C. Thomsen
Advanced Micro and Nanosystems, Vol. **8**: Nanosystems, eds. Baltes, Hierold, et. al. (WILEY, Weinheim, 2007), in print

52. **Dependence of the band-gap pressure coefficients of self-assembled InAs/GaAs quantum dots on the quantum dot size**
C. Kristukat, A.R. Goñi, K. Pötschke, D. Bimberg, and C. Thomsen
phys. stat. sol. (b), **244**, 53-58 (2007).

53. **Elasticity of single crystalline graphite**
A. Bosak, M. Krisch, J. Maultzsch, M. Mohr, and C. Thomsen
Phys. Rev.B, in print (2007).

54. **Mixing of the fully symmetric vibrational modes in carbon nanotubes**
M. Mohr, M. Machón, C. Thomsen, I. Milošević, and M. Damnjanović
Phys. Rev. B, in print (2007).

55. **Overcoming the gender gap: New concepts of study in technological areas**
N. Dahlmann, S. Jeschke, C. Thomsen, and M. Wilke
Conference Proceedings of the 2006 ASEE Annual Conference, in print (2007).

56. **Collaborative working environment for virtual and remote experiments in nanoscience and nanotechnology**
S. Jeschke, and C. Thomsen
Proceedings of the First International Conference on Interactive Mobile and Computer Aided Learning (ICML) 2006, Kassel University Press,
official URL: http://www. Imcl-conference.org.

57. **The experiment in eLearning: Magnetism in virtual and remote experiments**
S. Jeschke, T. Richter, H. Scheel, R. Seiler, and C. Thomsen
First WebALT Conference and Exhibition – WebALT2006, 5-6 Jan 2006, Eindhoven, NL.

9.2a.3 Invited talks

Sabine Bahrs
Ramanspektroskopie an Hochtemperatursupraleitern
Stipendiatinnen-Workshop des Berliner Chancengleichheits-programms, Berlin, Germany, Juni 2006

Ute Haboeck
Lattice dynamics of homoepitaxially grown ZnO and ZnO:Li layers
The 4th International Workshop on ZnO and Related Materials, 1st Physics Institute, Justus-Liebig-University Giessen, Germany October 2006

Dirk Heinrich
Dynamics of clustering in ionic ferrofluid from Raman scattering
7th German Ferrofluid Workshop , Benediktbeuern, Germany, September 2006

Holger Lange
Raman spectroscopy of CdSe nanowires
Workshop Nanodrähte und Nanoröhren: von der kontrollierten Synthese zur Funktion, Hirschegg-Kleinweisertal, Austria, September 2006

María Machón
Phonon and symmetry properties of (4,4) picotube crystals
XIX International Winterschool/Euroconference on Electronic Properties of Novel Materials, Electronic Properties of Nanostructures, Kirchberg, Austria, March 2005

María Machón
Picotube crystals: symmetry and vibrations
5. Tag der Fullerene Neue Kohlenstoffnanostrukturen, Rathen, Sächsische Schweiz, Germany, November 2005

María Machón	**Electron-phonon coupling in carbon nanotubes** 20th International Winterschool/Euroconference on Electronic Properties of Novel Materials, Electronic Properties of Novel Nanostructures, Kirchberg, Austria, March 2006
Janina Maultzsch	**Chiral-index assignment of carbon nanotubes by resonant Raman scattering** XIX International Winterschool/Euroconference on Electronic Properties of Novel Materials, Electronic Properties of Nanosttructures Nanostructures, Kirchberg, Austria, March 2005
Janina Maultzsch	**Optical transitions and excitonic effects in single-walled carbon nanotubes** 30th International Symposium on Dynamical Properies of Solids (DYPOSO 2005), Cesky Krumlov, Czech Republic, September 2005
Janina Maultzsch	**Optical spectroscopy of carbón nanotubes: chiral-index assignment and excitonic effects** NSEC, Seminar Columbia Universität New York, New York, USA, November 2005
Janina Maultzsch	**Micro- und Near-field Raman spectroscopy** Fraunhofer Institute for Reliablity and Microintegration Microintegration Microreliability Seminar, Berlin, Germany January 2006
Janina Maultzsch	**Excitons in carbon nanotubes** 20th International Winterschool/Euroconference on Electronic Properties of Novel Materials, Electronic Properties of Novel Nanostructures, Kirchberg, Austria, March 2006
Janina Maultzsch	**Electron-phonon coupling and Raman intensities for the E11 and E22 transitions of carbon nanotubes** Center for Nonlinear Studies at Los Alamod National Laboratory Electronic and Vibrational Interactions in carbon nanotubes, Santa Fe, USA, September 2006
Harald Scheel	**Remote Experiments and the NanoLab Approach** Online Educa Berlin 2005, Worshop16: Implementing Large-scale Blended Learning at Universities, Berlin, Germany, November 2005
Harald Scheel	**From Carnot and Bolzmann: Thermodynamic in action** Gesellschaft für Medien in der Wissenschaft Gesellschaft für Medien in der Wissenschaft (GMW) 2006, E-Learning - Alltagstaugliche Innovation? Virtuelle Labore & Remote Experimente, Zürich, Switzerland, September 2006

Harald Scheel	**Wrap-Up: Virtual Laboratories & remote-Experiments** Gesellschaft für Medien in der Wissenschaft Gesellschaft für Medien in der Wissenschaft (GMW) 2006, E-Learning - Alltagstaugliche Innovation? Virtuelle Labore und & Remote Experimente, Zürich, Switzerland, September 2006
Harald Scheel	**Large environmental dependence of the Raman spectrum of silicon nanowires** Materials Research Society 2006 MRS Fall Meeting of the Materials Research Society, Boston, USA, November 2006
Harald Scheel	**On remote and virtual experiments in eLearning in statistical mechanics and thermodynamics** CISSE 2006, International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering, Bridgeport, CT, USA, December 2006
Hagen Telg	**Chirality dependence of the high-energy Raman modes in carbon nanotubes** XIX International Winterschool/Euroconference on Electronic Properties of Novel Materials, Electronic Properties of Nanostructures, Kirchberg, Austria, March 2005
Hagen Telg	**Fano lineshape in metallic carbon nanotubes** 5. Tag der Fullerene Neue Kohlenstoffnanostrukturen, Rathen, Sächsische Schweiz, Deutschland, November 2005
Christian Thomsen	**Raman scattering in carbon nanotubes** AMN2 2nd Internatioanl Conference on Advanced Materials and Nanotechnology, Queenstown, Neuseeland, February 2005
Christian Thomsen	**Electronic transition energies and vibrational properties of carbon nanotubes** Physikalisches Kolloquium, Regensburg, Germany, April 2005
Christian Thomsen	**Raman spectroscopy of individual CNT** 25th GIF. Nanotubes and Nanowires, Dresden, Germany, June 2005
Christian Thomsen	**Opto-Electronic properties of Carbon Nanotubes** 4the IEE Seminar on Advances in Carbon Electronics, London, Grossbritannien und Nordirland, UK, November 2005
Christian Thomsen	**Elekronische Prüfungen und remote-Experimente** Universität Osnabrück Neue Medien in der Bildung, Osnabrück, Germany, November 2005
Christian Thomsen	**Determination of chiral indices and electronic trasition energies in carbon nanotubes** Workshop carbon nanotubes, Zürich, Switzerland, February 2006

Christian Thomsen **Von eLearning bis eResearch: Virtuelle Labore & Remote-Experimente in kooperativen virtuellen Wissensräumen**
e-Learning Symposium, Berlin, Germany, June 2006

Christian Thomsen **Spectroscopies: resonant Raman, fluorescence, optical absorbtion**
Summer School on Nanotubes, Cargese, Corsica, France, July 2006

Christian Thomsen **Raman and optical properties of SWNT**
Workwhop Carbon Nanotubes-Growth, Catalysis, Elecronics, Berlin, Germany, October 2006

Christian Thomsen **Excitons and chiral-index determination in carbon nanotubes: Two photon absorpton and resonant Raman scattering**
Workshop One-dimensional nanostructures: From Atomic desing to device applications, Tegernsee, Germany, October 2006

Christian Thomsen **From E-Learning to E-Research – Scientific IT Strategies for the Future**
Online Educa Berlin 2006, Berlin, Germany, November 2006

Christian Thomsen **Raman and optical properties of carbon and WS_2 nanotubes**
Workshop Nanotubes in science and technology, Tel Aviv, Israel, December 2006

Norman Tschirner **Electronic Examinations for Undergraduates in large Classes**
ICL Interacitve Computer Aided Learning, Villach, Germany, November 2006

Norman Tschirner **Multimedia Examination Concepts Used in University for a Large Number of Participants**
Online Educa Berlin 2006, Berlin, Germany, November 2006

9.2a.4 PhD theses

Fleischer, Karsten	**Optical anisotropy and vibrational properties of Sn, In, and Cs nanowires** 29.06.05
Kuhlmann, Uwe	**Phonon and spin dynamics of $(VO)_2P_2O_7$** 09.08.05
Nuzha, Hasan	**Aufbau einer Kernkühlstufe zur Untersuchung der kondensierten Materie bei ultratiefen Temperaturen und hohen Magnetfeldern** 20.10.05
Deniozou, Thalia	**Properties of the CuGaSe2(001) surface** 02.11.05
Bahrs, Sabine	**Persistent photo-induced effects in high-temperature superconducting $RBa_2Cu_3O_{7-\delta}$** 25.11.05
Laades, Abdelazize	Preparation and Characterization of Amorphous/Crystalline Silicon Heterojunctions (a-Si:H/c-Si) 14.12.05
Kronast, Florian	**Magnetic coupling in (GaMn)As ferromagnetic semiconductors – studied by soft x-ray spectroscopy** 20.12.05
Kristukat, Christian	**High-pressure study of the electronic structure of self-assembled InAS/GaAs and InP/GaP quantum dots** 10.02.06
Machón, Maria	**Electron-phonon coupling, vibrational, and optical properties of carbon nanotubes and picotubes** 07.06.06
Jachmann, Fabian	**Transport von Vortices in Supraleitern durch akustische Oberflächenwellen** 15.06.06
Kaczmarczyk, Georg	**Schwingungsverhalten lokaler Defekte in Breitband-Halbleitern** 16.06.06

9.2a.5 Diploma theses

Mohr, Marcel	**Double resonant Raman scattering in Germanium** 23.08.05
Stempel Pereira, Th.	**Relaxation und Rekombination in niederdimensionalen InGaN-Halbleiterstrukturen** 04.04.2006

9.2a.6 Abstracts of selected papers of department IIa

1. *Phys. Rev. B* ***71****, 035416 (2005)*

Strength of radial breathing mode in single-walled carbon nanotubes

M. Machón,[1] S. Reich,[2] H. Telg,[1] J. Maultzsch,[1] P. Ordejón,[3] and C. Thomsen[1]
[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany*
[2]*Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, United Kingdom*
[3]*Institut de Ciència de Materials de Barcelona, Campus de la Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain*

We show by *ab initio* calculations that the electron-phonon coupling matrix element $M_{e\text{-}ph}$ of the radial breathing mode in single-walled carbon nanotubes depends strongly on tube chirality. For nanotubes of the same diameter the coupling strength $|M_{e\text{-}ph}|^2$ is up to one order of magnitude stronger for zigzag tubes than for armchair tubes. For ($n1$, $n2$) tubes $M_{e\text{-}ph}$ depends on the value of ($n1-n2$) mod 3, which allows us to discriminate semiconducting nanotubes with similar diameter by their Raman scattering intensity. We show measured resonance Raman profiles of the radial breathing mode which support our theoretical predictions.

5. *Phys. Rev. Lett.* ***95****, 077402 (2005)*

Exciton Resonances Quench the Photoluminescence of Zigzag Carbon Nanotubes

Stephanie Reich,[1] Christian Thomsen,[2] and John Robertson[1]
[1]*Department of Engineering, University of Cambridge, Cambridge CB2 1PZ, United Kingdom*
[2]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany*

(Received 22 December 2004; published 12 August 2005)

We show that the photoluminescence intensity of single-walled carbon nanotubes is much stronger in tubes with large chiral angles—armchair tubes—because exciton resonances make the luminescence of zigzag tubes intrinsically weak. This exciton-exciton resonance depends on the electronic structure of the tubes and is found more often in nanotubes of the +1 family. Armchair tubes do not necessarily grow preferentially with present growth techniques; they just have stronger luminescence. Our analysis allows us to normalize photoluminescence intensities and find the abundance of nanotube chiralities in macroscopic samples.

9. *phys. stat. sol. (b), 1-6 (2005)*

Electronic band structure of high-index silicon nanowires

H. Scheel[1], S. Reich[2], and C. Thomsen[1]
[1] *Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany*
[2] *Department of Engineering, University of Cambridge, Cambridge CB2 IPZ, United Kingdom*

We calculated the electronic properties of high-index free-standing silicon nanowires. [112] nanowires are indirect semiconductors for diameters down to 0.8 nm; [110] wires have a direct band gap at the Γ-point, but the density of states is very small at the conduction band edge. Confinement arguments show that only [001] nanowires are expected to develop a direct gap with a large density of electronic states at the band edges for diameters in the nm range. The magnitude of the gap depends strongly on the wire growth direction, which is due to the different effective confinement length and effective masses for the ΓX -derived silicon states. Correcting for the extension of the wave functions we find our calculated energies to agree with recent scanning tunneling experiments.

10. *Phys. Rev. B* ***72****, 045411 (2005)*

Electrochemical switching of the Peierls-like transition in metallic single-walled carbon nanotubes

Peter M. Rafailov, Janina Maultzsch, and Christian Thomsen
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
Hiromichi Kataura
Nanotechnology Research Institute (NRI), National Institute of Advanced Industrial Science and Technology (AIST), Central 4, Higashi 1-1-1, Tsukuba, Ibaraki 305-8562, Japan

(Received 15 December 2004; revised manuscript received 14 April 2005; published 7 July 2005)

The high-energy vibrational modes of metallic carbon nanotubes are believed to be softened compared to the semiconducting ones by a Peierls-like transition. The Raman modes, when excited with a red laser to enhance the metallic tubes, were found to exhibit an exceptionally high sensitivity to electrochemical doping. Our data may be interpreted as controlling the Peierls-like instability in metallic tubes with the applied potential. We also discuss the limits of applicability of the double-layer charging model and show Raman evidence for a hysteretic transition to a chemical doping regime.

11. *Phys. Rev. B* ***72****, 155402 (2005)*

Structural, electronic, and vibrational properties of (4,4) picotube crystals

M. Machón,[1] S. Reich,[2] J. Maultzsch,[1] H. Okudera,[3] A. Simon,[3] R. Herges,[4] and C. Thomsen[1]
[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany*
[2]*Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, United Kingdom*
[3]*Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany*
[4]*Institut für Organische Chemie, Universität Kiel, Otto-Hahn-Platz 4, 24098 Kiel, Germany*

The picotube molecule is a highly symmetric hydrocarbon, closely related to a very short (4,4) carbon nanotube. We present a thorough experimental and theoretical study of the physical properties of picotube crystals. In x-ray diffraction experiments we find the picotube molecules to display D_{2d} symmetry. We identify the most intense Raman peaks as A_1 modes with polarization-dependent Raman measurements. *Ab initio* calculations of the structural, electronic, and vibrational properties of picotubes are in excellent agreement with our experiments. We assign the measured vibrations to displacement eigenvectors including those analogous to the nanotube high-energy mode, the *D* mode, and the radial-breathing mode.

12. *Phys. Rev. B* ***72****, 205436 (2005)*

Orientation dependence of the polarizability of an individual WS2 nanotube by resonant Raman spectroscopy

P. M. Rafailov,[1] C. Thomsen,[1] K. Gartsman,[2] I. Kaplan-Ashiri,[2] and R. Tenne[2]
[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany*
[2]*Weizmann Institute of Science, Rehovot, Israel*

We obtained a Raman signal from an individual WS_2 nanotube mounted on an atomic force microscopy cantilever tip. We discuss the implications for simultaneous investigations of the mechanical properties of WS_2 nanotubes by combining different experimental methods. From the orientation dependence of this nanotube's resonant Raman intensity, we estimate the ratio of the perpendicular to parallel polarizabilities $\alpha_{XX}/\alpha_{ZZ} \approx 0.16$. We compare the WS_2 nanotube with single-walled carbon nanotubes and expect a similarly strong depolarization effect for multiwalled carbon nanotubes.

13. *Phys. Rev. B* ***72****, 094419 (2005)*

Raman response of magnetic excitations in cuprate ladders and planes

K. P. Schmidt
Institut für Theoretische Physik, Universität zu Köln, Zülpicher Strasse 77, D-50937 Köln, Germany

A. Gössling
II. Physikalisches Institut, Universität zu Köln, Zülpicher Strasse 77, D-50937 Köln, Germany

U. Kuhlmann and C. Thomsen
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, D-10623 Berlin, Germany

A. Löffert, C. Gross, and W. Assmus
Physikalisches Institut, J.W. Goethe-Universität, Robert-Mayer-Strasse 2-4, D-60054 Frankfurt a. M., Germany

A unified picture for the Raman response of magnetic excitations in cuprate spin-ladder compounds is obtained by comparing calculated two-triplon Raman line shapes to those of the prototypical compounds $SrCu_2O_3$ (Sr123), $Sr_{14}Cu_{24}O_{41}$ (Sr14), and $La_6Ca_8Cu_{24}O_{41}$ (La6Ca8). The theoretical model for the two-leg ladder contains Heisenberg exchange couplings $J_\parallel$ and $J_\perp$ plus an additional four-spin interaction J_{cyc}. Within this model Sr123 and Sr14 can be described by $x{:=}J_\parallel/J_\perp=1.5$, $x_{\mathrm{cyc}}{:=}J_{\mathrm{cyc}}/J_\perp=0.2$, $J_\perp^{\mathrm{Sr123}}=1130$ cm^{-1} and $J_\perp^{\mathrm{Sr14}}=1080$ cm^{-1}. The couplings found for La6Ca8 are $x=1.2$, $x_{\mathrm{cyc}}=0.2$, and $J_\perp^{\mathrm{La6Ca8}}=1130$ cm^{-1}. The unexpected sharp two-triplon peak in the ladder materials compared to the undoped two-dimensional cuprates can be traced back to the anisotropy of the magnetic exchange in rung and leg direction. With the results obtained for the isotropic ladder, we calculate the Raman line shape of a two-dimensional square lattice using a toy model consisting of a vertical and a horizontal ladder. A direct comparison of these results with Raman experiments for the two-dimensional cuprates R_5CuO_4(R=La,Nd), $Sr_2\,CuO_2Cl_2$, and $YBa_2Cu_3O_{6+\delta}$ yields a good agreement for the dominating two-triplon peak. We conclude that short-range quantum fluctuations are dominating the magnetic Raman response in both ladders and planes. We discuss possible scenarios responsible for the high-energy spectral weight of the Raman line shape, i.e., phonons, the triple-resonance, and multiparticle contributions.

14. *Phys. Rev. B* ***72****, 241402(R) (2005)*

Exciton binding energies in carbon nanotubes from two-photon photoluminescence

J. Maultzsch,[1], R. Pomraenke,[2] S. Reich,[3] E. Chang,[4] D. Prezzi,[4] A. Ruini,[4] E. Molinari,[4] M. S. Strano,[5] C. Thomsen,[1] and C. Lienau[2]

[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*

[2]*Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, 12489 Berlin, Germany*

[3]*Department of Materials Science and Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge,Massachusetts 02139-4307, USA*

[4]*INFM National Research Center S3, and Physics Department, University of Modena and Reggio Emilia, 41100 Modena, Italy*

[5]*Deptartment of Chemistry and Biomolecular Engineering, University of Illinois, Urbana, Illinois 61801, USA*

Excitonic effects in the linear and nonlinear optical properties of single-walled carbon nanotubes are manifested by photoluminescence excitation experiments and *ab initio* calculations. One- and two-photon spectra showed a series of exciton states; their energy splitting is the fingerprint of excitonic interactions in carbon nanotubes. By *ab initio* calculations we determine the energies, wave functions, and symmetries of the excitonic states. Combining experiment and theory we find binding energies of 0.3–0.4 eV for nanotubes with diameters between 6.8 and 9.0 Å.

20. *Light Scattering in Solids IX, Topics in Applied Physics, Vol.* ***108***

Raman scattering in carbon nanotubes

C. Thomsen[1] and S. Reich[2]

[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*

[2] *Department of Materials Science and Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139-4307, USA*

The vibrational properties of single-walled carbon nanotubes reflect the electron and phonon confinement as well as the cylindrical geometry of the tubes. Raman scattering is one of the prime techniques for studying fundamental properties of carbon tubes and nanotube characterization. The most important phonon for sample characterization is the radial-breathing mode, an in-phase radial movement of all carbon atoms, in combination with resonant excitation it can be used to determine the nanotube microscopic structure. Metallic and semiconducting tubes can be distinguished from the high-energy Raman spectra. The high-energy phonons are remarkable because of their strong electron-phonon coupling, which leads to phonon anomalies in metallic tubes. A common characteristic of the Raman spectra in nanotubes and graphite is the appearance of Raman peaks that correspond to phonons from inside the Brillouin zone, the defect-induced modes. In this review we first introduce the vibrational, electronic, and optical properties of carbon tubes and explain important concepts such as the nanotubes' family behavior. We then discuss the Raman-active phonons of carbon tubes. Besides the vibrational frequencies and symmetries Raman spectroscopy also allows studying optical (excitonic) transitions, electron-phonon coupling and phase transitions in single-walled carbon nanotubes.

21. *Phys. Rev. B* ***72****, 144501 (2005)*

Persistent photo-excitation in GdBa2Cu3O6.5 in a simultaneous Raman and electrical-transport experiment

S. Bahrs,[1] J. Guimpel,[2] A. R. Goñi,[3] B. Maiorov,[4] A. Fainstein,[2] G. Nieva,[2] and C. Thomsen[1]
[1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
[2]Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, 8400 San Carlos de Bariloche, Río Negro, Argentina
[3]ICREA Research Professor, Institut de Ciència de Materials de Barcelona, Campus de la UAB, 08193 Bellaterra, Spain
[4]Superconductivity Technology Center, MS K763, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

We investigate the connection between persistent illumination-induced effects in underdoped RBa$_2$Cu$_3$O$_{7-\delta}$ known as persistent photoconductivity and Raman bleaching. Despite the long-standing assumption that the electrical and optical properties respond to the same light-induced change in the material, they have not been directly compared until now. We present a simultaneous experiment of Raman spectroscopy and electrical transport under visible illumination at low temperatures. The time dependence of the response in the two methods differs by two orders of magnitude, showing that the effects are connected but not identical. We discuss our results within the oxygen-vacancy reordering model of photobleaching and find that different Cu-O chain lengths affect the optical and the electrical response differently. Raman bleaching and persistent photoconductivity thus provide a different perspective on the microscopic oxygen vacancy distribution.

27. *Phys. Rev. B* ***73****, 045315 (2006)*

Coupling between charge-density excitations and polar optical phonons in single quantum wells revisited

P. Giudici,[1] A. R. Goñi,[2] C. Thomsen,[1] K. Eberl,[3] and M. Hauser[3]
[1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
[2]Institut de Ciència de Materials de Barcelona, Campus de la UAB, 08193 Bellaterra, Spain
[3]MPI für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

We report a detailed analysis of the coupling between the polar longitudinal optical (LO) phonon and intersubband charge-density excitations of a two-dimensional electron gas which forms in three GaAs single quantum wells of different thickness. Inelastic light scattering spectra exhibit different intersubband charge excitations depending on the number of occupied subbands (one or two). The coupling to the LO phonon was tuned by changing the electron density with a gate bias. Calculations of the coupled modes using a dielectric tensor formulated within the local density approximation allowed for a successful peak assignment. Among several striking coupling effects, we were able to identify a statically screened LO phonon mode.

29. *Phys. Rev. B* ***72****, 205438 (2005)*

Radial breathing mode of single-walled carbon nanotubes: Optical transition energies and chiral-index assignment

J. Maultzsch,[1] H. Telg,[1] S. Reich,[2] and C. Thomsen[1]

[1]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse. 36, D-10623 Berlin, Germany*

[2]*Department of Engineering, University of Cambridge, Cambridge CB2 1PZ, United Kingdom*

We present a comprehensive study of the chiral-index assignment of carbon nanotubes in aqueous suspensions by resonant Raman scattering of the radial breathing mode. We determine the energies of the first optical transition in metallic tubes and of the second optical transition in semiconducting tubes for more than 50 chiral indices. The assignment is unique and does not depend on empirical parameters. The systematics of the so-called branches in the Kataura plot are discussed; many properties of the tubes are similar for members of the same branch. We show how the radial breathing modes observed in a single Raman spectrum can be easily assigned based on these systematics. In addition, empirical fits provide the energies and radial breathing modes for all metallic and semiconducting nanotubes with diameters between 0.6 and 1.5 nm. We discuss the relation between the frequency of the radial breathing mode and tube diameter. Finally, from the Raman intensities we obtain information on the electron-phonon coupling.

31. *Phys. Rev. B* ***73****, 035217 (2006)*

Double-resonant Raman processes in germanium: Group theory and *ab initio* calculations

M. Mohr, M. Machón, J. Maultzsch, and C. Thomsen

Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We study the excitation-energy-dependent Raman peaks of germanium in terms of double-resonant scattering. In our analysis we combine group theory and ab initio calculations to select scattering processes and contrast them with the experimental data. A surface-driven k-selective mechanism explains not only the dependence of the peak shifts on surface orientation, but also their polarization dependence in a cubic system.

35. *App. Phys. Lett* ***88****, 233114 (2006)*

Raman scattering on silicon nanowires: The thermal conductivity of the environment determines the optical phonon frequency

H. Scheel, C. Thomsen
Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany
S. Reich
Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139-4307
A. C. Ferrari, M. Cantoro, and A. Colli
Department of Engineering, University of Cambridge, Cambridge CB3 OFA, United Kingdom

We studied the Raman spectra of silicon nanowires as a function of excitation power for various ambient gases. For a given excitation power, we find that the gas thermal conductivity determines the wire temperature, which can be detected by a change in phonon frequency. This shows that the redshift of the optical phonon in silicon nanowires compared to bulk silicon is mainly due to the lower thermal conductivity of nanowires and an increase in laser heating. The spectra of nanowires allow distinguishing gases on the basis of their thermal conductivity.

38. phys. stat. sol. (b) **243**, 2428-2435 (2006)

Two-photon photoluminescence and exciton binding energies in single-walled carbon nanotubes

R. Pomraenke[1], J. Maultzsch[2], S. Reich[3], E. Chang[4], D. Prezzi[4], A. Ruini[4], E. Molinari[4], M. S. Strano[5], C. Thomsen[2], and C. Lienau[1]

[1] Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2a, 12489 Berlin, Germany

[2] Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

[3] Department of Materials Science and Engineering, Massachusetts Institute of Technology,77 Massachusetts Avenue, Cambridge, MA 02139-4307, USA

[4] INFM National Research Center S3, and Physics Department, University of Modena and Reggio Emilia,via Campi 213/A, 41100 Modena, Italy

[5] University of Illinois, Department of Chemistry and Biomolecular Engineering, 600 South Mathews Avenue, Urbana, IL 61801, USA

We compare experimental one- and two-photon luminescence excitation spectra of single-walled carbon nanotubes at room temperature to *ab initio* calculations. The experimental spectra reveal a Rydberg-like series of excitonic states. The energy splitting between these states is a clear fingerprint of excitonic correlations in carbon nanotubes. From those spectra, we derive exciton binding energies of 0.3–0.4 eV for nanotubes with diameters between 6.8 Å and 9.0 Å. These energies are in quantitative agreement with our theoretical calculations, which predict the symmetries of the relevant excitonic wave functions and indicate that a low-lying optically dark excitonic state may be responsible for the low luminescence quantum yields in nanotubes.

39. *Phys. Rev. B* ***74****, 115415 (2006)*

Resonant-Raman intensities and transition energies of the E_{11} transition in carbon nanotubes

H. Telg,[1] J. Maultzsch,[1] S. Reich,[2] and C. Thomsen[1]

[1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

[2]Department of Materials Science and Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139-4307, USA

We observed the lowest optical transitions (E_{11}^S) in separated carbon nanotubes by resonant Raman spectroscopy. Radial breathing mode spectra were collected varying the excitation energy in the near-infrared from 1.15 to 1.48 eV. From resonance profiles we obtained the E_{11}^S energies of 11 nanotubes, extending the experimental Kataura plot. Strong Raman signal from tubes with ν =(n−m)mod3= +1 and from tubes that were absent in photoluminescence support the theory of exciton resonance. The measured Raman intensities agree well with the calculated optical absorption and electron-phonon coupling obtained with first-principles and empirical methods. A remaining factor of ~3 can be due to a higher abundance of armchairlike tubes or differences of the absorption and vibrational coupling between correlated (excitons) and uncorrelated electronhole pairs.

41. *iJET Vol. **1**, (Nr. 2) 1-4 (2006)*

Design and realization of multimedia-examinations for large numbers of participants in university education

N. Tschirner, M. Müller, O. Pfeiffer, and C. Thomsen

Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

We report on Multimedia Examinations successfully accomplished in a physics lecture for engineering freshmen. The use of New Media enables us to create new types of questions, including Java-based applets or those requiring internet-based in detail. Economically priced hardware solutions and user-friendly software for both teachers and students are realized in collaboration which Promethean Corporation. A first evaluation – which is very countenancing – is presented, our eAssessment finds general approval in the participants opinion.

43. *Phys. Rev. B **74**, 205423 (2006)*

Strong electron-phonon coupling of the high-energy modes of carbon nanotubes

M. Machón,[1] S. Reich,[2] and C. Thomsen[1]

[1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

[2]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139-4307, USA

We present ab initio calculations of electron-phonon coupling matrix elements of the totally symmetric high-energy vibrational modes of carbon nanotubes. The matrix elements depend on nanotube family (n_1-n_2)mod 3, chiral angle, and the particular optical transition, similarly to the radial-breathing mode. The strength of the matrix elements of the high-energy mode is up to 6 times higher than for the radial breathing mode. We discuss the implications of our results for the Raman spectrum of nanotubes and for charge carrier relaxation.

9.2.b Department IIb

Prof. em. Dr.-Ing. Dr. h.c. mult. Immanuel Broser
Priv.-Doz. Dr. Axel Hoffmann

9.2b.0 Staff

Secretary
Kathrin Haberland (part time)

Senior scientists
Dr. Dimitry Azamat (until 01.10.2005)

PhD candidates (status of 31.12.2006: thesis completed = c)
Dipl.-Phys. Til Bartel
Dipl.-Phys. Matthias Dworzak
Dipl.-Phys. Ute Haboeck
Dr. Georg Kaczmarczyk (c)
Dipl.-Phys. Enno Malguth
Dipl.-Phys. Tobias Schulze
Dipl.-Phys. Markus Wagner
Dipl.-Phys. Patrick Zimmer

Diploma students (status of 31.12.2006: thesis completed = c)
Max Bügler
Radowan Hildebrandt (c)
Benjamin Johnson (c)
Ronny Kirste
Rob McKenna (c)
Dirk Samberg (c)
Thomas Stempel-Pereira (c)
Kondi Santharaman Suresh (c)
Jhonny Vielses-Sotho (c)
Markus Wagner (c)
Stefan Werner
Patrick Zimmer (c)

9.2b.1 Summary of activities

The main research activities concern the optical properties of wide-band gap II-VI and III-V semiconductors with special emphasis on **ZnSe-, ZnO- and GaN-based structures**. The investigations are carried out on single crystals, epitaxially grown heterostructures and, especially, **low-dimensional structures like quantum wells and quantum dots**. In the last years new activities have been started like electro-optical effects in polymers, energy transfer investigations in organic light emitting diodes and non-linear optics in chalcopyrides. Cooperations have been established with many research groups in Germany, France, Russia, Belarus, United Kingdom, Israel, USA and Japan. The essential physical topics include:

- excitonic polaritons and bound excitons in bulk crystals and excitonic complexes in low dimensional structures based on **InGaN, InGaAs and InGaAsN**,
- shallow and deep centers,
- recombination dynamics and non-radiative processes,
- non-linear optical effects of pure and doped wide-gap semiconductors,
- coherent dynamics,
- optical gain mechanisms,
- analysis of doping and dopant compensation mechanisms, and
- electro-optical effects in polymers.

The experimental techniques used for these investigations include:

- photoluminescence (PL), PL excitation, and transmission spectroscopy over a wide range of temperatures and excitation densities,
- magneto-optical spectroscopy up to 15 Tesla using a split-coil magnet,
- time-resolved photoluminescence spectroscopy with down to femtosecond time resolution,
- two-colour time-resolved pump-and-probe spectroscopy in the ps and fs range using a modelocked and frequency tripled Nd-YAG laser system as well as a frequency doubled modelocked Ti: Sapphire laser,
- time-resolved degenerate four-wave mixing,
- Raman spectroscopy,
- CAS (calorimetric absorption spectroscopy) at mK temperatures in a He3/He4 cryostat,
- sputtering and evaporation methods for doping and contacting crystals and for the production of thin polycrystalline or amorphous layers.

An important field of our work concerns excitonic complexes, their excitation and relaxation mechanisms and the dynamics of these processes. The knowledge of the energetic structure and of the relaxation mechanisms of free and bound excitons allows a precise analysis of defects created during growth and doping procedures. An important method to study such phenomena is the measurement of the DTS-signal using the two colour pump-and-probe ps-spectroscopy. These investigations are carried out in close cooperation with national and international researchers involved in the development and optimization of new optoelectronic devices like **blue light emitting diodes and lasers**. Both wide-gap II-VI and III-V semiconductors are studied.

For GaN- and ZnO-based structures the problem of p-dopant compensation attracts a lot of interest. Intensive studies were dedicated to the behavior of donor-acceptor pair emissions of highly doped ZnO-layers. Our observation, that the broad luminescence band usually observed in highly doped material becomes much sharper at higher excitation levels, finally turning into the normal, low doping spectrum has triggered intensive investigations using optical spectroscopy as a function of intensity and temperature. Currently, two different models for this effect are discussed, **in highly compensated specimens** the formation of **high electric fields** or the existence of an exponentially structured continuum of low lying donors or acceptors. Quantitative calculations have been performed to distinguish between the two different methods. This work has been carried out with the groups of Jürgen Christen, Alois Krost (Otto-von-Guericke University of Magdeburg and Bruno Meyer (Justus-Liebig University of Gießen).

Our work on binary and ternary group-III nitrides has been concentrated to the experimental determination of basic band structure parameters of this as yet poorly known material. The thesis of Jens Holst has led to a complete understanding of the measured optical properties. A further focus has been on high density effects, like **biexciton annihilation, exciton-exciton scattering or plasma creation** which have been identified. Also, gain mechanisms in epitaxial group-III nitride layers and quantum wells were studied. All these investigations are of great interest for the development of blue emitting semiconductor laser diodes. In addition to these experiments, a comprehensive study of Raman scattering processes has been performed in cooperation with the group of C. Thomsen.

An important topic of our work is **the determination of radiationless energy relaxation and recombination** in semiconductors by calorimetric absorption spectroscopy (CAS). By measuring the yield of radiative transitions in a CAS experiment and the lifetimes of the corresponding excited states using time-resolved spectroscopy, the radiative and non-radiative transition rates of the energy relaxation processes involved can be determined quantitatively. Therefore, CAS is a powerful and sensitive tool, e.g., to understand the complicated cascade processes in deep centers. It is also especially useful to elucidate the electronic structures of localized excitons in low dimensional semiconductors.

The study of **coherent processes** especially at localized excitations are a further issue in our research. Coherent lifetimes react very sensitively to defect structures and can thus help to optimize growth techniques for blue light-emitting devices. Four wave mixing techniques could be applied to epitaxial layers of different II-VI compounds to receive non-linear quantum beats. We have shown that they originate either from zero-field split excited states of one complex or from interference between two different bound excitons. Coherent lifetimes of some hundred fs were observed.

The purpose of the Sfb 296 project headed by Axel Hoffmann and Christian Thomsen is to study the influence of the electron-phonon interaction in low dimensional semiconductor systems. Here, our main focus is the investigation of the dynamical properties of excitonic states in II-VI and III-V quantum dots. International cooperations with A.F. Ioffe Institute and the University of South California, Los Angeles, were very helpful for the understanding of the excitonic fine structure.

In a cooperation wih the Siemens AG experiments to measure the electro-optical coefficients of polymers and the electro-optical properties of **organic light emitting diodes and bio-chip readers** were continued. The resuls are important to create new optical communication and signal processing systems on the basis of organic materials.

9.2b.2 Publications

The abstracts of papers marked by* are reprinted in section 9.2.6

1. **On the composition dependence ZnO1-xSx**
Bruno K. Meyer, A. Polyty, B. Farangis, Y. He, D. Hasselkamp, T. Krämer, C. Wang, U. Haboeck, A. Hoffmann
phys. stat. sol. (c), 694 (2005)

2. **Valence band ordering and magneto-optical properties of free and bound excitons in ZnO**
A.V. Rodina, M. Strassburg, M. Dworzak, U. Haboeck, A. Hoffmann, H.R. Alves, A. Zeuner, D.M. Hofmann, B.K. Meyer
in Zinc oxide- a material for micro- and optoelectronic applications,3-14, eds. by N.H. Nickel and E. Terukov, Nato Series II: Mathematics, Physics and Chemestry- Vol. 194, 2005 Springer, printed in the Netherlands, (2005) 159 ISBN 1-4020-3474-1

3. **Excitonic Rabi oscillations in a quantum dot: local field impact**
G.Ya. Slepyan, S.A. Maksimenko, A.V. Magyarov, A. Hoffmann, D. Bimberg
Proc. of the EMRS Symposium L 2004: “InN, GaN, AlN and Related Materials, their Heterostructures and Devices” Superlattices and Microstructures 36, Europ. Mat. Res. Society, (2005) 773

4*. **Reconciliation of luminescence and Hall measurements on the ternary semiconductor CuGeSe2**
S. Siebentritt, I. Beckers, T. Riemann, J. Christen, M. Dworzak, and A. Hoffmann
Appl. Phys. Lett. 86, (2005) 091909

5. **Excited-state carrier lifetime in single-walled carbon nanotubes**
S. Reich, M. Dworzak, A. Hoffmann, C. Thomsen, M.S. Strano
Phys. Rev. B 71, (2005) 33402

6*. **High-energy vibrational modes in nitrogen-doped ZnO**
U. Haboeck, A. Hoffmann, C. Thomsen, A. Zeuner, B.K. Meyer
phys. stat. sol. (b) 242, (2005) R 21

7. **Site inaquivalence for Mn2+ substitution on Zn sites in ZnGeP2 and ZnSiP2**
W. Gehlhoff, D. Azamat, V.G. Voevodin, A. Hoffmann
phys. stat. sol. (b) 242, (2005) R 14

8. **Raman photoluminescence and absorption studies on high quality AlN single crystals**
J. Senawiratne, M. Strassburg. N. Dietz, U. Haboeck. A. Hoffmann, V. Noveski, R. Dalmau, R. Schlesser, Z. Sitar
phys. stat. sol. (c) 2(7), (2005) 2774

9. **Strong-light matter coupling in a quantum dot: local field effects**
G.Ya. Slepyan, A.V. Magyarov, S.A. Maksimenko, A. Hoffmann, and D. Bimberg
phys. stat. sol. (c) 2, (2005) 850

10. **Growth of high quality AlN single crystals and their optical properties**
M. Strassburg, J. Senawiratne, N. Dietz, U. Haboeck. A. Hoffmann, V. Noveski, R. Dalmau, R. Schlesser, Z. Sitar
Proceedings 27th Int. Conf. on the Physics of Semiconductors, Flagstaff, USA, AIP, J. Menéndez and Ch. G. Van de Walle (Eds.) 772 (1), (2005) 211

11. **Dephasing and energy relaxation processes in self-assembled In(Ga)As/GaAs quantum dots**
M. Dworzak, P. Zimmer, H. Born, A. Hoffmann
Proceedings 27th Int. Conf. On the Physics of Semiconductors, Flagstaff, USA, AIP, J. Menéndez and Ch. G. Van de Walle (Eds.) 772 (1), (2005) 633

12. **Local Phonon Modes in InAs/GaAs Quantum Dots**
A. Paarmann, F. Guffarth, T. Warming, A. Hoffmann, D. Bimberg
Proceedings 27th Int. Conf. on the Physics of Semiconductors, Flagstaff, USA, AIP, J. Menéndez and Ch. G. Van de Walle (Eds.) 772 (1), (2005) 689

13. **Redistribution of excitons localized in InGaN quantum dot structures**
M. Dworzak, T. Bartel, M. Strassburg, A. Hoffmann, A. Strittmatter, D. Bimberg
Proceedings 27th Int. Conf. on the Physics of Semiconductors, Flagstaff, USA, AIP, J. Menéndez and Ch. G. Van de Walle (Eds.) 772 (1), (2005) 701

14. **Development of dual MQW region LEDs for general illumination**
D.B. Nicol, A. Asghar, M. Strassburg, M. Tran, M. Pan, H. Kang, I.T. Ferguson, M. Alevi, J. Senawiratne, Ch. Hums, N. Dietz, and A. Hoffmann
Materials Research Society Proceedings, vol. 831, ISBN 1-55899-779-2, E9.5.1-E8.5.7, 2005

15. **Optical and structural investigations on Mn-ion states in MOCVD-grown Ga1-xMnxN**
M. Strassburg, J. Senawiratne, Ch. Hums, N. Dietz, M.H. Kane, A. Asghar, M. Alevli, A.M. Payne, I.T. Ferguson, C.R. Summers, U. Haboeck, A. Hoffmann, D. Azamat, W. Gehlhoff
Materials Research Society Proceedings, vol. 831, ISBN 1-55899-779-2, E9.5.1-E9.5.6, 2005.

16*. Multifunctional III-nitride dilute magnetic semiconductor epilayers and nanostructures as a future platform for spintronic devices
M. H. Kane, M. Strassburg, A. Asghar, Q. Song, G. S., J. Senawirante, C. Hums, U. Haboeck, A. Hoffman, D. Azamat, W. Gelhoff, N. Dietz, Z. J. Zhang, C. Summers, I. T. Ferguson
Proceedings of SPIE, vol. 5732, pp 389-400, 2005

17. Impact of Manganese incorporation on the structural and magnetic properties of MOCVD-grown Ga1-xMnxN
M. H. Kane, A. Asghar, H. Kang, A. M. Payne, and I.T. Ferguson, C.R. Summers, C.R. Vestal, Z.J. Zhang, M. Strassburg, J. Senawiratne, and N. Dietz, D. Azamat, W. Gehlhoff, U. Haboeck, and A. Hoffmann
Mat. Res. Soc. Symp. Proc. 831, ISBN 1-55899-779-2, E9.4.1-6 (2005)

18. Optical properties of InGaN quantun dots
M. Dworzak, T. Bartel, M. Strassburg, I.L. Krestnikov, A. Hoffmann, R. Seguin, S. Rodt, A. Strittmatter, D. Bimberg
Superlattices and Microstructures 36, 763 (2005)

19*. ZnO - ein altes, neues Halbleitermaterial
C. Klingshirn, M. Grundmann, A. Hoffmann, B. K. Meyer, A. Waag
Physik Journal 5, (2006), Nr. 1 33
(Wiley-VCH Verlag GmbH &KGaA, Weinheim ISBN 1617-9439/06/0101-33)

20*. Influence of structural nonuniformity and nonradiative processes on the luminescence efficiency of InGaAsN quantum wells
L. Geelhaar, M. Galluppi, G. Jaschke, R. Averbeck, H. Riechert, T. Remmele, M. Albrecht, M. Dworzak, R. Hildebrandt, A. Hoffmann
Appl. Phys. Lett. 88, 011903 (2006)

21*. Preferential substitution of Fe on physically equivalent Ga sites in GaN
W. Gehlhoff, D. Azamat, U. Haboeck, A. Hoffmann
Physica B 376-377, 486-490 (2006)

22. Transition metals in ZnGeP2 and other II-IV-V2 compounds
W. Gehlhoff, D. Azamat, A. Hoffmann, N. Dietz, O.V. Voevodina
phys.stat. sol. (b) 243, 1687 (2006)

23. Site selectivity of Fe3+Ga and the formation of Fe3+Ga- Gai pairs in GaN
W. Gehlhoff, D. Azamat, A. Hoffmann
Physica B 376-377, 790 (2006)

24. Optical and structural microanalysis of GaN grown on SiN submonolayers
T. Riemann, T. Hempel, J. Christen, P. Veit, R. Clos, A. Dadgar, A. Krost, U. Haboeck, A. Hoffmann
J. Appl. Phys. 99, 123518 (2006)

25. Internal 5E $\rightarrow$ 5T2 transition of Fe2+ in GaN
E. Malguth, A. Hoffmann, X. Xu
Phys. Rev. B 74, 165201 (2006)

26*. Structural and electronic properties of Fe3+- and Fe2+- centers in GaN from optical and EPR experiments
E. Malguth, A. Hoffmann, W. Gehlhoff, O. Gelhausen, M.R. Phillips, X. Xu
Phys. Rev. B 74, 165202 (2006)

27. Optical properties of InGaN/GaN quantum wells on saphire and bulk GaN substrates
M. Dworzak, T. Stempel, A. Hoffmann, G. Franzen, S. Grzanka, T. Suski, R. Czernecki, M. Leszczynski, I. Grzegory
phys.stat. sol. (c) 3, 2078, (2006)

28. Optical studies of MOCVD-grown GaN-based ferromagnetic semiconductors epilayers and devices
M. H. Kane, M. Strassburg, W. E. Fenwick, A. Asghar, J. Senawiratne, D. Azamat, Z. Hu, E. Malguth, S. Graham, U. Perera, W. Gehlhoff, A. Hoffmann, N. Dietz, C.J. Summers, I.T. Ferguson
phys.stat. sol. (c) 3, 2237, (2006)

29. Properties of InN grown by High-Pressure CVD
M. Alevli, G. Durkaya, V. Woods, U. Habeck, H. Kang, J. Senawiratne, M. Strassburg, I. T. Ferguson, A. Hoffmann, and N. Dietz;
Mat. Res. Soc.Symp. Proc. 892, ISBN: 1-55899-846-2, FF6.2, pp.1-6 (2006)

30*. MOVPE growth of high-quality AlN
A. Dadgar, A. Krost, J. Christen, B. Bastek, F. Bertram, A. Krtschil, T. Hempel, J. Bläsing, U. Haboeck, A. Hoffmann
J. Cryst. Growth 297, 306 (2006)

31. Fe centers in GaN as candidates for spintronics applications
E. Malguth, A. Hoffmann, M. Phillips, W. Gehlhoff
Mat. Res. Soc. Symp. Proc. 891, Warrendale,PA, USA, ISBN: 1-55899-846-2, 219 (2006)

32. Luminescence efficiency of InGaN/GaN quantum wells on bulk GaN substrate
M. Dworzak, T. Stempel, A. Hoffmann, G. Franzen, S. Grzanka, T. Suski, R. Czernecki, M. Leszczynski, I. Grzegory
Mat. Res. Soc. Symp. Proc. 892, Warrendale,PA, USA, ISBN: 1-55899-846-2, 825 (2006)

33*. ZnO based ternary transparent conductors
A. Polity, B.K. Meyer, T. Krämer, C. Wang, U. Haboeck, A. Hoffmann
phys. stat. sol (a) 203, 2867 (2006)

34. Engineering of the radiative recombination rate in quantum dots coupled to the tilted waveguide mode
N.V. Kryzhanovskaya, P. Zimmer, N.N Ledentsov, A. Hoffmann, D. Bimberg, A.R. Kovsh, S.S. Mikhrin, V.A. Shchukin, L.Y. Karachinska, M.V. Maximov
Semiconductor Science and Technology 21, 162 (2006)

35*. Polarized emission lines from A- and B-type excitonic complexes in single InGaN/GaN quantum dots
M. Winkelnkemper, R. Seguin, S. Rodt, A. Schliewa, L. Reißmann, A. Strittmatter, A. Hoffmann, D. Bimberg ,Appl. Phys. Lett. (in print)

36. Properties of InN layers grown by high pressure chemical vapour deposition
M. Alevli, G. Durkaya, R. Kirste, A. Weesekara, W. E. Fenwick, V. T. Woods, I.T. Ferguson, A. Hoffmann, A.G. Perera and N. Dietz
Mat. Res. Soc. Symp. Proc. 955; Symposium I: Advances in III-V Nitride Semiconductor Materials and Devices, Boston, MA, USA, Nov.-Dec. 2006, I8.4, pp. 1-6, (2007).

37. Defect control through annealing of GaInNAs quantum wells and its influence on the luminescence efficiency
M. Dworzak, R. Hildebrant, A. Hoffmann, L. Geelhaar, M. Galluppi, H. Riechert, T. Remmle, M. Albrecht, Appl. Phys. Lett. (in print)

38. On the origin of the broad lifetime distribution of localized excitons in InGaN quantum dots
M. Dworzak, M. Winkelnkemper, T. Stempel Pereira, A. Hoffmann, D. Bimberg (in print)

39. Zn interstitial related donors in ammonia treated ZnO powders
J. Sann, J. Stehr, A. Hofstaetter, D. M. Hofmann, B. K. Meyer, A. Neumann, M. Plana, M. Lerch, U.Haboeck, A. Hoffmann, C. Thomsen (in print)

40. Structure-property-function relationships in nanoscaled oxide sensors:
A case study based on zinc oxide. S. Polarz, A. Roy, M. Lehmann, M. Driess, F. E. Kruis, M.R. Wagner, A. Hoffmann, (in print)

41*. Fabry-Perot effects in InGaN/GaN heterostructures on Si substrates
C. Hums, T. Finger, T. Hempel, J. Christen, A. Dadgar, A. Hoffmann, A. Krost
J. Appl. Phys. (in print)

42. Group I elements in ZnO
B.K. Meyer, N. Volbers, A. Zeuner, S. Lautenschläger, J. Sann, A. Hoffmann, U. Haboeck
Mater. Res. Soc. Symp. Proc. 891, 0891-EE 10-24.1, (2006)

9.2b.3 Invited talks

Axel Hoffmann **Transition metal ions in ZnO- a challenge for spintronic applications**
Frühjahrstagung desArbeitskreises Festkörperphysik der DPG, Berlin, Germany, March 2005

Axel Hoffmann **Acceptors in ZnO**
E-MRS Spring Meeting, Strasbourg, France, May 2005

Axel Hoffmann **Halbleiterlaser- Grundlagen und aktuelle Entwicklungen**
DPG-Lehrerfortbildung, Bad Honnef, Germany, July 2005

Axel Hoffmann **Nitrides versus ZnO properties and applications**
University of Aveiro, Aveiro, Portugal, September 2005

Axel Hoffmann **Optische Eigenschaften von ZnO und GaN**
University of Göttingen, Göttingen, Germany, November 2005

Axel Hoffmann **Optische Eigenschaften von Gruppe-III Nitriden**
Ferdinand –Braun-Institut, Berlin, Germany, Decemberr 2005

Axel Hoffmann **Optical properties of low dimensional InGaAsN heterostructures**
Workshop on low dimensional semiconductors structures 2006, Aveiro, Portugal, January 2006

Axel Hoffmann **Optical Properties of Group III-Nitride Quantum dots**
Workshop "Semiconductor Nanostructures", Berlin, September 2006

Axel Hoffmann **Nitrides versus ZnO**
Georgia TEC, Atlanta, USA, November 2006

Axel Hoffmann **Optical properties of ZnO epilayers**
MRS Fall meeting, Boston, USA, December 2006

Axel Hoffmann **Photonic properties of ZnO**
Photonic West, SPIE Conference, San Jose, January 2007

9.2b.4 PhD theses

Kaczmarczyk, Georg **Schwingungsverhalten lokaler Defekte in Breitband-Halbleitern**
16.06.2006

9.2b.5 Diploma theses

Hildebrandt, Radowan **Zeitaufgelöste Spektroskopie an InGaAsN QW Strukturen**
21.03.2006

Johnson, Benjamin E. **Optical and electrical optimisation of a voltaic thin layer membrane**
12.05.2006

McKenna, Robert **Magneto-optical properties of acceptor bound excitons in ZnO epilayers**
06/2006

Samberg, Dirk **Optische Eigenschaften von gebundenen Exzitonen in ZnO Epischichten**
03/2005

Stempel-Pereira, T. **Optische Eigenschaften von InGaN-Heterostrukturen**
06/2006

Suresh, Kondi S. **Optial properties of acceptors in ZnO**
02/2006

Vielses-Sotho, Jhonny **Magneto-optische Eigenschaften gebundener Exzitonen in ZnO Epischichten**
12/2005

Wagner, Markus R. **Optical spectroscopy of defects and impurities in ZnO**
18.08.2006

Zimmer,Patrick **Dynamik von Energie-Phasenrelaxationsprozessen In In(Ga)As/GaAs Quantenpunkten**
11.03.2005

9.2b.6 Abstracts of selected papers of department IIb

4. *Appl. Phys. Lett.* ***86****, 091909 (2005) (3 pages)*

Reconciliation of luminescence and Hall measurements on the ternary semiconductor $CuGaSe_2$

Susanne Siebentritt and Inge Beckers
Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin, Germany

Till Riemann and Jürgen Christen
Otto-von-Guericke-Universität, FNW/IEP/AFP, PF 4120, 39016 Magdeburg, Germany

Axel Hoffmann and Matthias Dworzak
Technical University Berlin, Festköperphysik, Hardenbergstrasse 36, 10623 Berlin, Germany

Previous Hall and photoluminescence investigations on $CuGaSe_2$ yielded conflicting results: defect depths determined by luminescence are lower than the ionization energy found in electrical measurements. In this contribution, we present time and spatially resolved cathodoluminescence measurements that necessitate a new interpretation of the luminescence data, leading to a consistent model for luminescence and Hall data with three acceptors with ionization energies of 60, 100, and 150 meV. Luminescence decay times are long, in the range of 100 ns, indicating strong capture. Luminescence is spatially inhomogeneous, indicating inhomogeneous distribution of defects.

6. *phys. stat. sol. (b)* ***242****, No. 3, R21– R23 (2005)*

High-energy vibrational modes in nitrogen-doped ZnO

U. Haboeck[1], A. Hoffmann[1], C. Thomsen[1], A. Zeuner[2], and B. K. Meyer[2]

[1] *Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany*

[2] *I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany*

We present results of Raman-scattering experiments on a series of nitrogen-doped ZnO epilayers grown by chemical vapour deposition. Nitrogen, a potential acceptor in ZnO, was introduced by the thermal decomposition of ammonia (NH_3). We found a structure consisting of at least four lines with frequencies of 2253, 2277, 2291, and 2304 cm^{-1}. They increase in intensity simultaneously with additional modes in the energy range of the host phonons: both scale with the nitrogen concentration in the samples. The origin of the high-energy structure is tentatively assigned to vibrations of lattice- bound nitrogen or complexes, composed of the constituents of the dopant NH_3.

16. *Proceedings of SPIE vol. 5732, Quantum Sensing and Nanophotonic Devices II, Manijeh Razeghi, Gail J. Brown, Editors, March 2005, pp. 389-400*

Multifunctional III-nitride dilute magnetic semiconductor epilayers and nanostructures as a future platform for spintronic devices

Matthew H. Kane
Georgia Institute of Technology (USA)
Martin Strassburg
Georgia Institute of Technology (USA) and Georgia State Univ. (USA)
Ali Asghar, Qing Song, and Shalini Gupta
Georgia Institute of Technology (USA)
Jayantha Senawiratne
Georgia State Univ. (USA)
Christoph Hums
Georgia State Univ. (USA) and Technische Univ. Berlin (Germany)
Ute Haboeck, Axel Hoffmann, Dmitry Azamat, and Wolfgang Gehlhoff
Technische Univ. Berlin (Germany)
Nikolaus Dietz
Georgia State Univ. (USA)
Z. John Zhang, Christopher J. Summers, and Ian T. Ferguson
Georgia Institute of Technology (USA)

This work focuses on the development of materials and growth techniques suitable for future spintronic device applications. Metal-organic chemical vapor deposition (MOCVD) was used to grow high-quality epitaxial films of varying thickness and manganese doping levels by introducing bis-cyclopentadienyl as the manganese source. High-resolution X-ray diffraction indicates that no macroscopic second phases are formed during growth, and Mn containing films are similar in crystalline quality to undoped films Atomic force microscopy revealed a 2-dimensional MOCVD step-flow growth pattern in the Mn-incorporated samples. The mean surface roughnesses of optimally grown $Ga_{1-x}Mn_xN$ films were almost identical to that from the as-grown template layers, with no change in growth mechanism or morphology. Various annealing steps were applied to some of the samples to reduce compensating defects and toinvestigate the effects of post processing on the structural, magnetic and opto-electronic properties. SQUID measurements showed an apparent ferromagnetic hysteresis behavior which persisted to room temperature. An optical absorption band around 1.5 eV was observed via transmission studies. This band is assigned to the internal Mn^{3+} transition between the ^5E and the partially filled $^5T_2$ levels of the ^5D state. The broadening of the absorption band isintroduced by the high Mn concentration. Recharging of the Mn^{3+} to Mn^{2+} was found to effectively suppress these transitions resulting in a reduction of the magnetization. The structural quality, and the presence of Mn^{2+} ions wereconfirmed by EPR spectroscopy, meanwhile no Mn-Mn interactions indicative of clustering were observed. The absence of doping-induced strain in $Ga_{1-x}Mn_xN$ was observed by Raman spectroscopy.

19. *Physik Journal 5 (2006) Nr. 1, 33*

Zinkoxid – ein alter, neuer Halbleiter

Claus Klingshirn
Institut für Angewandte Physik, Universität Karlsruhe, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe

Marius Grundmann
Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 5, 04103 Leipzig

Axel Hoffmann
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Bruno Meyer
I. Physikalisches Institut, Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Andreas Waag
Institut für Halbleitertechnik, Technische Universität Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig

Nach fünf Jahrzehnten der Forschung erlebt der in der Vergangenheit bereits totgesagte Halbleiter Zinkoxid derzeit eine stürmische Renaissance, die vor allem von der Hoffnung genährt wird, künftig blaue Leuchtdioden aus ZnO herstellen zu können. Die möglichen Anwendungen gehen aber weit darüber hinaus und umfassen zum Beispiel auch transparente Leiter für Solarzellen oder magnetische Verbindungen für die Spintronik.

20. *Appl. Phys. Lett.* ***88****, 011903 (2006)*

Influence of structural nonuniformity and nonradiative processes on the luminescence efficiency of InGaAsN quantum wells

L. Geelhaar, M. Galluppi, G. Jaschke, R. Averbeck, and H. Riechert
Infineon Technologies, Corporate Research, D-81730 Munich, Germany

T. Remmele and M. Albrecht
Institut für Kristallzüchtung, Max-Born-Strasse 2, D-12489 Berlin, Germany

M. Dworzak, R. Hildebrant, and A. Hoffmann
Berlin University of Technology, Institute of Solid State Physics, Hardenbergstr. 36, D-10623 Berlin, Germany

We compare the luminescence efficiency (i.e., room-temperature photoluminescence intensity), fluctuations in composition and thickness, degree of localization, and luminescence decay times of $In_{0.37}Ga_{0.63}As_{0.983}N_{0.017}$ quantum wells grown by molecular-beam epitaxy at different temperatures and annealed under a comprehensive variety of conditions. Luminescence efficiency is not directly coupled to structural nonuniformity or localization, and even three-dimensional growth is not detrimental by itself. In contrast, there is always a correlation between luminescence efficiency and nonradiative decay time. Therefore, the luminescence efficiency of InGaAsN quantum wells depends almost exclusively on the density of nonradiative recombination centers, while the influence of structural nonuniformity is negligible.

21. *Physica B, **376-377** (2006)*

Preferential substitution of Fe on physically equivalent Ga sites in GaN

W. Gehlhoff, D. Azamat, U. Haboeck and A. Hoffmann
Institute for Solid State Physics, Technical University Berlin, D-10623 Berlin, Germany

The EPR spectra of Fe^{3+} in high-quality thick freestanding hydride vapor phase grown GaN have been studied in the X- and Q-band. A complex resonance pattern with numerous lines of different intensities provided by three different defects is observed for these nearly stress-free iron-doped samples. The dominating part is due to isolated Fe^{3+} on Ga sites and can be well described with a spin Hamiltonian (SH) with considering the two magnetically inequivalent Ga sites with C_{3v} symmetry in the wurtzite structure of GaN. Aside from the displacement of their magnetic axis the two Ga sites are physically equivalent. However, contrary to the expectation, we observed different Fe populations of both sites that varied from a ratio 1:4 to a ratio of nearly 1:1 in different crystals. In addition and in contrast to previously published data we determined nearly isotropic *g*-values and larger values for the axial fine-structure parameters D, $a-F$ and much larger value for the cubic fine-structure parameter a.

26. *Phys. Rev. B **74**, 165202 (2006)*

Structural and electronic properties of Fe^{3+} and Fe^{2+} centers in GaN from optical and EPR experiments

E. Malguth, A. Hoffmann, and W. Gehlhoff
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany
O. Gelhausen and M. R. Phillips
Microstructural Analysis Unit, University of Technology, Sydney, Broadway, NSW 2007 Australia
X. Xu
Cree, Inc., 4600 Silicon Drive, Durham, North Carolina 27703, USA

This work provides a consistent picture of the structural, optical, and electronic properties of Fe-doped GaN. A set of high-quality GaN crystals doped with Fe at concentrations ranging from 5×10^{17} cm^{-3} to 2×10^{20} cm^{-3} is systematically investigated by means of electron paramagnetic resonance and various optical techniques. Fe^{3+} is shown to be a stable charge state at concentrations from 1×10^{18} cm^{-3}. The fine structure of its midgap states is successfully established, including an effective-mass-like state consisting of a hole bound to Fe^{2+} with a binding energy of 50±10 meV. A major excitation mechanism of the $Fe^{3+}(^4T_1\rightarrow{}^6A_1)$ luminescence is identified to be the capture of free holes by Fe^{2+} centers. The holes are generated in a two-step process via the intrinsic defects involved in the yellow luminescence. The $Fe^{3+/2+}$ charge-transfer level is found 2.863±0.005 eV above the valence band, suggesting that the internal reference rule does not hold for the prediction of band offsets of heterojunctions between GaN and other III-V materials. The $Fe^{2+}(^5E\rightarrow{}^5T_2)$ transition is observed around 390 meV at any studied Fe concentration by means of Fourier transform infrared spectroscopy. Charge-transfer processes and the effective-mass-like state involving both Fe^{2+} states are observed. At Fe concentrations from 1×10^{19} cm^{-3}, additional lines occur in electron paramagnetic resonance and photoluminescence spectra which are attributed to defect complexes involving Fe^{3+}. With increasing Fe concentration, the Fermi level is shown to move from near the conduction band to the $Fe^{3+/2+}$ charge-transfer level, where it stays pinned for concentrations from 1×10^{19} cm^{-3}. Contrary to cubic II-VI and III-V materials, both electronic states are effected by only a weak Jahn-Teller interaction.

30. *J. Cryst. Growth 297, Issue 2, (2006)*

MOVPE growth of high-quality AlN

A. Dadgar[a, c], A. Krost[a, c], J. Christen[a], B. Bastek[a], F. Bertram[a], A. Krtschil[a], T. Hempel[a], J. Bläsing[a], U. Haboeck[b] and A. Hoffmann[b]

[a]*Fakultät für Naturwissenschaften, Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany*
[b]*Institute of Solid State Physics, Technical University Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*
[c]*AZZURRO Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg, Germany*

AlN layers were grown on Si and sapphire substrates in a horizontal and a vertical metalorganic chemical vapour phase epitaxy system.AlN grown in the horizontal reactor is smooth and shows intense band-edge cathodoluminescence but Ga can be found in the layers even after several microns of AlN growth. After cleaning the reactor and using a new Ga-free quartz and graphite system the layer quality is drastically reduced and we observe a rough morphology. In the vertical system pure AlN layers with smooth surfaces can be grown even on a Ga-contaminated susceptor and no Ga is found in the layers. In cathodoluminescence (CL) measurements an enhancement of oxygen or silicon-related luminescence peaks is found for the growth on sapphire or silicon substrates, respectively. A comparison of CL and Raman measurements reveals a strong tensile stress for AlN on Si that corresponds to ~1 GPa and relaxes at cracks where a wavelength shift of 4 nm is observed. AlN grown on sapphire is found to be under compressive stress at room temperature.

33. *phys. stat. sol. (a)* ***203****, No. 11, 2867– 2872 (2006)*

ZnO based ternary transparent conductors

Angelika Polity[1], Bruno K. Meyer[1], Thorsten Krämer[1], Changzhong Wang[1],Ute Haboeck[2], and Axel Hoffmann[2]

[1] *I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen,Germany*

[2] *Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*

$ZnO_{1-x}S_x$ films in the whole composition range were deposited by radio-frequency reactive sputtering on different substrates. Raman measurements verified that the LO phonon of ZnO shifts towards lower frequencies as a function of the S content in the alloyed films. The composition dependence of the band gap energy in the ternary system was determined by optical transmission and the optical bowing parameter was found to be about 3 eV. We compare this behavior to ZnOSe films which can, however, only be synthesized in a narrow composition range close to the binary constituents ZnO and ZnSe.

35. *Applied Physics Letters (in print)*

Polarized emission lines from A- and B-type excitonic complexes in single InGaN/GaN quantum dots

M. Winkelnkemper
Institut für Festkörperphysik, Technische Universität Berlin,
D-10623 Berlin, Germany and
Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany

R. Seguin, S. Rodt, A. Schliwa, L. Reißmann, A. Strittmatter, A. Hoffmann, and D. Bimberg*
Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany and
(Dated: November 9, 2006)

Cathodoluminescence measurements on single InGaN/GaN quantum dots (QDs) are reported. The measurement reveal complex emission spectra with up to five emission lines per QD. The lines are polarized along orthogonal directions. Realistic eight-band k p calculations show that the polarization of the lines can be explained by recombinations involving hole states which are either formed by the A valence band or the B valence band.

41. *Journal of Applied Physics 101 (2007)*

Fabry-Perot effects in InGaN/GaN heterostructures on Si-substrate

C. Hums, T. Finger, T. Hempel, J. Christen, and Armin Dadgar[a)]
Fakultät für Naturwissenschaften, Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39016 Magdeburg, Germany

A. Hoffmann
Institut für Festkörperphysik, Technische Universität Berlin,Hardenbergstraße 36, D-10623 Berlin, Germany

A. Krost
Fakultät für Naturwissenschaften, Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39016 Magdeburg

(Received 14 November 2006; accepted 4 December 2006)

A strong intensity modulation is found in spatially and angular resolved photoluminescence spectra of InGaN/GaN heterostructures and quantum wells epitaxially grown on Si(111) substrates. This Fabry-Perot effect results from the high refractive index contrasts at the GaN/Si and dthe Air/InGaN interfaces. It can be used for a wavelength stabilization of the sample upon temperature change and, e.g., in the case of light emitting diodes, to additionally reduce the blueshift at increasing injection currents. A simple geometric approach has been chosen to calculate the influence of layer thickness, absorption and refractive indices, as well as detection angle. The cavity can be described quantitatively by a simple three layer Fabry-Perot model. An analytical expression is derived for the external luminescence line shape. Microphotoluminescence measurements at samples with the silicon substrate locally removed corroborate the model. © *2007 American Institute of Physics.* [DOI: 10.1063/1.2434010]

9.3 Department III

Prof. Dr. rer. nat. Mario Dähne
Prof. em. Dr.-Ing. Hans-Eckhart Gumlich

9.3.0 Staff

Secretary
Angela Berner (part time)

Technical staff
Gerhard Pruskil

PhD candidates and teaching assistants
Dr. Holger Eisele
Dipl.-Phys. Kai Hodeck
Dipl.-Phys. Rainer Timm

PhD candidates (status of 31.12.2006 - thesis completed = c)
Dipl.-Phys. Jan Grabowski
Dipl.-Phys. Lena Ivanova
Dipl.-Phys. Andrea Lenz
Dipl.-Phys. Martina Wanke

Diploma students (status of 31.12.2006 – thesis completed = c)
Omar Al-Khatib (c)
Maximillian Assig (c)
Christian Griesche (c)
Silvia Hagedorn
Lena Ivanova (c)
Bujar Jerliu (c)
Karolin Löser
Dominik Martin (c)
Matthias Müller (c)
Grit Petschick (c)
Norman Tschirner (c)
Vivien Voßebürger (c)

9.3.1 Summary of activities

The main research subject of the group of M. Dähne is the investigation of the structural, electronical and optical properties of semiconductor interfaces and nanostructures. In the experiments, special emphasis lies on the use of local probes, such as scanning-tunneling microscopy (STM) and spectroscopy (STS), cross-sectional scanning-tunneling microscopy (XSTM) and spectroscopy (XSTS), and scanning-nearfield optical microscopy (SNOM). Complementary information is obtained from photoelectron spectroscopy (PES) with synchrotron radiation at the Berlin storage ring BESSY. All experiments except SNOM are performed in ultra-high vacuum (UHV).

There are mainly four experimental setups:

1. An STM chamber with a preparation chamber containing LEED, sputter gun and effusion cells.
2. A chamber designed especially for XSTM experiments.
3. A SNOM setup, which works at temperatures down to 4 K.
4. A III-V MBE chamber combined with an STM system.

For PES experiments, chambers from Prof. Kaindl at the Freie Universität Berlin are used.

Recent results are listed in the following:

1. Atomic structure of quantum dots. Here the atomic structure, chemical composition and local electronic properties of semiconductor nanostructures, in particular quantum dots, are studied using XSTM. For this purpose, a cross-sectional (110) surface prepared in-situ by cleavage is studied by the STM tip. In experiments at InAs, InGaAs, InGaAsN, GaAs and GaSb quantum dots, prepared by different collaborators in science and industry, the particular growth behavior was studied, with special emphasis on the shape, size, local stoichiometry and stacking behavior of the dots and on the electronic structure. Recently, also the local electronic structure was studied using scanning tunneling spectroscopy.

2. Optical properties of single quantum dots. The photoluminescence of individual InGaAs quantum dots, prepared in department I, was studied at temperatures between 4 K and 300 K using SNOM. Using a new home-built instrument, the temperature dependence of the spectral linewidth and the development of trions and biexcitons were studied.

3. Lanthanide silicide nanowires on Si(001) and Si(557). The self-organized formation of lanthanide silicide nanowires on Si(001) and Si(557) and their anisotropic electronic properties were studied in detail using STM and ARPES. While the relatively narrow nanowires on Si(001) show clear one-dimensional metallicity, nanowires on Si(557) are much broader and hence characterized by a two-dimensional band structure.

4. Initial stages of InAs quantum dot growth. In an MBE-STM chamber, which was recently provided by Prof. Jacobi from the Fritz Haber Institute and allows studying quantum dot growth on an atomic scale, first results were obtained on the structure of GaAs buffer layers. Both the c4x4 and the 4x2 reconstructions could be observed. Experiments on the atomic structure of InAs dots and the wetting layer are under way.

9.3.2 Publications

The abstracts of papers marked by* are reprinted in section 9.3.5

1.* **Formation and atomic structure of GaSb nanostructures in GaAs studied by cross-sectional scanning tunneling microscopy**
R. Timm, J. Grabowski, H. Eisele, A. Lenz, S.K. Becker, L. Müller-Kirsch, K. Pötschke, U.W. Pohl, D. Bimberg, and M. Dähne
Physica E ***26****, 231 (2005)*

2.* **Effects of strain and confinement on the emission wavelength of InAs quantum dots due to a $GaAs_{1-x}N_x$ capping layer**
O. Schumann, S. Birner, M. Baudach, L. Geelhaar, H. Eisele, L. Ivanova, R. Timm, A. Lenz, S.K. Becker, M. Povolotskyi, M. Dähne, G. Abstreiter, and H. Riechert
Physical Review B ***71****, 245316 (2005)*

3.* **Structure and electronic properties of dysprosium silicide nanowires on vicinal Si(001)**
C. Preinesberger, G. Pruskil, S.K. Becker, M. Dähne, D.V. Vyalikh, S.L. Molodtsov, C. Laubschat, and F. Schiller
Applied Physics Letters ***87****, 083107 (2005)*

4. **Limits of InGaAs/GaAs quantum dot growth studied by cross-sectional scanning tunneling microscopy**
A. Lenz, H. Eisele, R. Timm, S.K. Becker, R.L. Sellin, U.W. Pohl, D. Bimberg, and M. Dähne
Proceedings of EW-MOVPE XI, ed. by E. Kapon and A. Rudra (Lausanne 2005), p. 31

5. **Formation and atomic structure of GaSb quantum dots in GaAs studied by cross-sectional scanning tunneling microscopy**
R. Timm, A. Lenz, J. Grabowski, H. Eisele, K. Pötschke, U.W. Pohl, D. Bimberg, and M. Dähne
Proceedings of EW-MOVPE XI, ed. by E. Kapon and A. Rudra (Lausanne 2005), p. 39

6.* **Atomic structure of thin dysprosium-silicide layers on Si(111)**
I. Engelhardt, C. Preinesberger, S.K. Becker, H. Eisele, and M. Dähne
Surface Science ***600****, 755 (2006)*

7.* **Structure of InAs/GaAs quantum dots grown with Sb surfactant**
R. Timm, H. Eisele, A. Lenz, T.-Y. Kim, F. Streicher, K. Pötschke, U.W. Pohl, D. Bimberg, and M. Dähne
Physica E ***32****, 25 (2006)*

8.* **A cross-sectional scanning tunneling microscopy study of GaSb/GaAs nanostructures**
R. Timm, A. Lenz, J. Grabowski, H. Eisele, and M. Dähne
Proceedings of MSM 14, ed. by A.G. Cullis and J.L. Hutchison (Springer Proceedings in Physics, Vol. 107, 2006), p. 479

9.* **Onset of GaSb/GaAs quantum dot formation**
R. Timm, A. Lenz, H. Eisele, L. Ivanova, K. Pötschke, U.W. Pohl, D. Bimberg, G. Balakrishnan, D.L. Huffaker, and M. Dähne
p*hysica status solidi (c)* ***3****, 3971 (2006)*

10.* **Structural investigation of hierarchically self-assembled GaAs/AlGaAs quantum dots**
A. Lenz, R. Timm, H. Eisele, L. Ivanova, D. Martin, V. Voßebürger, A. Rastelli, O.G. Schmidt, and M. Dähne
Physica Status Solidi (b) ***243****, 3976 (2006)*

9.3.3 Invited talks

Maximilian Assig	**Aufbau und Inbetriebnahme eines aperturlosen optischen Rasternahfeldmikroskops** Max-Planck-Institut für Festkörperforschung, Stuttgart, December 2005
Mario Dähne	**Rastertunnelmikroskopie – eine Reise durch die Nanowelt** Freie Universität Berlin, April 2005
Mario Dähne	**Querschnitts-Rastertunnelmikroskopie an Quantenpunkten** Mario Dähne Hahn-Meitner-Institut, Berlin, June 2005
Mario Dähne	**Querschnittsrastertunnelmikroskopie an Quantenpunkten** Universität Göttingen, June 2006
Holger Eisele	**Cross Sectional Scanning Tunneling Microscopy of GaAsN** Infineon AG, München, June 2005
Holger Eisele	**Growth Related Cross Sectional STM Study of InAs/GaAs Quantum Dots** Carnegie-Mellon-University, Pittsburgh, USA, July 2005
Holger Eisele	**Growth Related Cross Sectional STM Study of InAs/GaAs Quantum Dots** University of Texas at Austin, USA, July 2005
Holger Eisele	**Looking at the Structure of InAs/GaAs Quantum Dots** University of New Mexico, USA, Albuquerque, July 2005
Holger Eisele	**Growth-Correlated Structure of InAs/GaAs quantum dots** University of Sheffield, United Kingdom, September 2005
Holger Eisele	**Growth-correlated structure of InAs/GaAs quantum dots** Max-Planck-Institut für Festkörperforschung, Stuttgart, October 2005

Holger Eisele	**Growth-correlated structure of InAs/GaAs quantum dots Workshop on Structural Analysis of Self-Assembled Nanostructures,** Eindhoven, November 2005
Holger Eisele	**Mikroskopie jenseits des Lichts** Lehrerfortbildungsseminar der Humboldt-Universität Berlin; Rheinsberg, May 2006
Holger Eisele	**X-ray, TEM, and STM Analysis of Nanostructures** International Symposium on Semiconductor Nanostructures, Berlin, September 2006
Holger Eisele	**Structural Analysis of Semiconductor Nanostructures by Cross-Sectional Scanning Tunneling Microscopy** Humboldt-Universität Berlin, December 2006
H.-E. Gumlich	**Der freie Wille** Baltic Sea Workshop, Heltersberg, September 2005
H.-E. Gumlich	**Einstein und Gott** Technische Universität Cottbus, November 2005
H.-E. Gumlich	**Echo des Urknalls** Baltic Sea Workshop, Beckerwitz, August 2006
Omar Al-Khatib	**Optical Nearfield Spectroscopy of Individual InAs/GaAs Quantum Dots at Low Temperatures)** Humboldt-Universität Berlin, November 2006
Andrea Lenz	**First results of InAs and GaAs quantum dots studied with cross-sectional STM** Max-Planck-Institut für Festkörperforschung, Stuttgart, September 2005
Dominik Martin	**Nitrogen induced properties in GaInNAs observed by cross-sectional scanning tunneling microscopy (XSTM)** Humboldt-Universität Berlin, November 2006
Rainer Timm	**Formation, Atomic Structure, and Electronic Properties of GaSb/GaAs and InAs:Sb/GaAs Quantum Dots Studied by Cross-Sectional STM** University of Sheffield, United Kingdom, September 2005
Martina Wanke	**Self-assembled dysprosium-silicide nanowires on Si(001)** Technische Universität Berlin, Mai 2006
Vivien Voßebürger	**Abbildung einzelner Stickstoffatome in der GaAs(110)-Oberfläche mittels Querschnittsrastertunnelmikroskopie** Universität Marburg, September 2006

Vivien Voßebürger	**Imaging of single N-atoms in the GaAs(110)-surface by cross-sectional scanning tunneling microscopy** Universität Konstanz, September 2006

9.3.4 Diploma theses

Ivanova, Lena	**Rastertunnelspektroskopie an Halbleiter-Nanostrukturen** January 2005
Müller, Matthias	**Wachstumsinduzierte Modifikationen der atomaren Struktur von InAs-Quantenpunkten** March 2005
Tschirner, Norman	**Struktur von selbstorganisierten Seltenerdsilizid-Nanodrähten** April 2005
Griesche, Christian	**Rasternahfeld-Lumineszenzspektroskopie an Quantenpunkten mit lokaler Dichtefluktuation** September 2005
Assig, Maximilian	**Aufbau und Inbetriebnahme eines aperturlosen optischen Rasternahfeldmikroskops** January 2006
Al-Khatib, Omar	**Lumineszenzuntersuchungen an einzelnen Quantenpunkten bei unterschiedlichen Temperaturen** March 2006
Jerliu, Bujar	**Wachstum von Mangansiliziden auf der Si(001)-Oberfläche** August 2006
Voßebürger, Vivien	**Charakterisierung einzelner Stickstoffatome in der GaAs(110)-Oberfläche** September 2006
Martin, Dominik	**Charakterisierung stickstoffinduzierter Eigenschaften in GaInNAs** September 2006

9.3.5 Abstracts of selected papers of department III

1. *Physica E* ***26****, 231 (2005)*

Formation and atomic structure of GaSb nanostructures in GaAs studied by cross-sectional scanning tunneling microscopy

R. Timm, J. Grabowski, H. Eisele, A. Lenz, S.K. Becker, L. Müller-Kirsch, K. Pötschke, U.W. Pohl, D. Bimberg, and M. Dähne
Technische Universität Berlin, Institut für Festkörperphysik, D-10623 Berlin, Germany

GaSb nanostructures in GaAs, grown by metalorganic chemical vapor deposition, were studied with cross-sectional scanning tunneling microscopy. Three different samples were examined, containing a thin quantum well, a quantum well near the critical thickness for dot formation, and finally self-organized quantum dots with base lengths of 5–8 nm and heights of about 2 nm. The dots are intermixed with a GaSb content between 60% and 100%. Also small 3D and 2D islands were observed, possibly representing quantum dots in an early growth stage and quantum dot precursors. All GaSb layers exhibit gaps, which are indications of an island-like growth mode during epitaxy.

2. *Physical Review B* ***71****, 245316 (2005)*

Effects of strain and confinement on the emission wavelength of InAs quantum dots due to a $GaAs_{1-x}N_x$ capping layer

O. Schumann,[1,2] S. Birner,[2] M. Baudach,[3] L. Geelhaar,[1] H. Eisele,[3] L. Ivanova,[3] R. Timm,[3] A. Lenz,[3] S. K. Becker,[3] M. Povolotskyi,[4] M. Dähne,[3] G. Abstreiter,[2] and H. Riechert[1]
[1]*Infineon Technologies AG, Corporate Research Photonics, D-81730 Munich, Germany*
[2]*Walter Schottky Institute, Technical University of Munich, Am Coulombwall 3, D-85748 Garching, Germany*
[3]*Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany*
[4]*Department of Electronic Engineering, University of Rome "Tor Vergata, via del Politecnico, 1, 00133 Rome, Italy*

A GaAsN capping layer grown on InAs quantum dots (QDs) induces a strong redshift of the emission wavelength and extends it beyond 1.3 mm. We investigated this effect systematically by changing the nitrogen content in the GaAsN layer, varying the thickness of this layer, and embedding a GaAs spacer layer between the GaAsN layer and the QDs. The samples were grown on GaAs(001) substrates by plasma-assisted solid source molecular beam epitaxy (MBE). Additionally, we simulated the band structure and the electron and hole energy levels based on 6x6 **k·p** calculations, including strain and piezoelectric effects. We found that the wavelength extension is caused by the decrease of the confining energy barrier for the electron wave function in the QDs due to the lower conduction band energy of the GaAsN layer with respect to GaAs. The strain inside the QDs is almost unaffected by the overgrowth with the tensilely strained GaAsN layer. The insertion of a GaAsN layer below the QDs yields only a very small change in wavelength compared to the effect produced by a GaAsN capping layer. This difference is attributed to a reduced QD volume due to the growth on GaAsN that is suggested in cross-sectional scanning tunneling microscopy (XSTM) measurements. The blueshift due to this structural change of the QDs compensates for the redshift that is induced by the decreased confinement.

3. *Applied Physics Letters* ***87****, 083107 (2005)*

Structure and electronic properties of dysprosium-silicide nanowires on vicinal Si(001)

C. Preinesberger, G. Pruskil, S. K. Becker, and M. Dähne
Technische Universität Berlin, Institut für Festkörperphysik, D-10623 Berlin, Germany
D. V. Vyalikh, S. L. Molodtsov, and C. Laubschat
Technische Universität Dresden, Institut für Festkörperphysik, D-01062 Dresden, Germany
F. Schiller
Technische Universität Dresden, Institut für Festkörperphysik, D-01062 Dresden, Germany and Donostia International Physics Center, Paseo Manuel Lardizabal 4, E-20018 San Sebastián, Spain

Dysprosium-silicide nanowires with widths of 15–100 Å and lengths exceeding several 1000 Å can be formed on Si(001) by self-assembly. Because of the anisotropy of the Si(001) surface, these nanowires grow in two orthogonal directions. In this study we demonstrate that growth on vicinal substrates results in a perfect unidirectional alignment of the wires. This allows an investigation by angle-resolved photoelectron spectroscopy showing anisotropic metallicity of the nanowires.

6. *Surface Science* ***600****, 755 (2006)*

Atomic structure of thin dysprosium-silicide layers on Si(111)

I. Engelhardt, C. Preinesberger, S. K. Becker, H. Eisele, and M. Dähne
Technische Universität Berlin, Institut für Festkörperphysik, D-10623 Berlin, Germany

We report on scanning tunneling microscopy results of thin dysprosium-silicide layers formed on Si(111). In the submonolayer regime, both a $2\sqrt{3} \times 2\sqrt{3}\,R30°$ and a 5×2 superstructure were found. Based on images taken at different tunneling conditions, a structure model could be developed for the $2\sqrt{3} \times 2\sqrt{3}\,R30°$ superstructure. For one monolayer, a 1×1 superstructure based on hexagonal $DySi_2$ was observed, while several monolayers thick films are characterized by a $\sqrt{3} \times \sqrt{3}\,R30°$ superstructure from Dy_3Si_5.

7. *Physica E* ***32****, 25 (2006)*

Structure of InAs/GaAs quantum dots grown with Sb surfactant

R. Timm, H. Eisele, A. Lenz, T.-Y. Kim, F. Streicher, K. Pötschke,U.W. Pohl, D. Bimberg, and M. Dähne
Institut für Festkörperphysik, PN 4-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

InAs quantum dots in GaAs, grown under the presence of Sb by metalorganic chemical vapor deposition, were studied with cross sectional scanning tunneling microscopy. Large flat quantum dots with a truncated pyramidal shape, base lengths between 15 and 30 nm, heights of 1–3 nm, and a rather pure InAs stoichiometry were found for the case of an Sb supply during the InAs deposition. If Sb is already supplied during GaAs stabilization prior to InAs deposition, the dots become even larger and tend to get intermixed with Ga, but remain coherently strained with a reversed cone-like In distribution. Regarding the quantum dot growth Sb acts as surfactant, whereas an incorporation of individual Sb atoms was observed in the wetting layer.

8. *Proceedings of MSM 14, ed. by A.G. Cullis and J.L. Hutchison (Springer Proceedings in Physics, Vol. 107, 2006), p. 479*

A cross-sectional scanning tunneling microscopy study of GaSb/GaAs nanostructures

R. Timm, A. Lenz, J. Grabowski, H. Eisele, and M. Dähne
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin

We present cross-sectional scanning tunneling microscopy results of GaSb quantum wells and dots in GaAs. A fascinating potential of this technique for the investigation of overgrown nanostructures is demonstrated by revealing structural details of GaSb dots and wells with atomic resolution, by introducing a method to obtain the local stoichiometry, and by discussing different contributions to the image contrast in combination with the type-II band alignment.

9. physica status solidi (c) **3**, 3971 (2006)

Onset of GaSb/GaAs quantum dot formation

R. Timm,1 A. Lenz,1 H. Eisele,1 L. Ivanova,1 K. Pötschke,1 U. W. Pohl,1 D. Bimberg,1 G. Balakrishnan,2 D. L. Huffaker,1,2 and M. Dähne1

1 Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

2 Center for High Technology Materials, University of NewMexico, Albuquerque, NM 87106, USA

We present cross-sectional scanning tunneling microscopy results on GaSb nanostructures in GaAs, analyzing their shape, size and chemical composition. By comparing different quantum wells and quantum dot layers, grown both by metalorganic chemical vapor deposition and by molecular beam epitaxy, the onset of quantum dot evolution is studied. Quantum dots are found already after a deposition of 1 monolayer GaSb. Intermixing of the deposited GaSb with GaAs due to anion exchange as well as different effects of Sb segregation during overgrowth are demonstrated.

10. *physica status solidi (b)* ***243****, 3976 (2006)*

Structural investigation of hierarchically self-assembled GaAs/AlGaAs quantum dots

A. Lenz,[1] R. Timm,[1] H. Eisele,[1] L. Ivanova,[1] D. Martin,[1] V. Voßebürger,[1] A. Rastelli,[2] O. G. Schmidt,[2] and M. Dähne[1]

[1] Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

[2] Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

Recent investigations of self-organized unstrained inverted GaAs/AlGaAs quantum dots, prepared by a combination of Stranski–Krastanov growth mode and an in situ etching technique, show GaAs quantum dots with large confinement energy and high size homogeneity. Here we present first cross-sectional scanning tunneling microscopy data of these quantum dots, characterized by a lateral extension of about 35 nm, heights of about 5–6 nm, and a reversed truncated pyramidal shape. We further observe a decomposition of the AlGaAs host layers and a roughening of the AlGaAs/GaAs interfaces.

9.4 Department IV

Prof. Dr. rer. nat. Michael Kneissl
Prof. Dr. rer. nat. Wolfgang Richter (retired since 01.04.2005

9.4.0 Staff

Secretary
Angela Berner (part time)
Claudia Hinrichs (part time)

Technical staff
Engelbert Eder
Christof Maerker

Senior scientists
Dr. Markus Pristovsek
Dr. Patrick Vogt

Post Docs
Dr. Sandhya Chandola
Dr. Simona Silaghi
Minghong Yang, PhD

PhD candidates and teaching assistants (status of 31.12.2006 – thesis completed = c)
Dipl.-Phys. Martin Leyer
Dipl.-Phys. Jan-Robert van Look
Dipl.-Phys. Christian Meißner
Dipl.-Phys. Florian Poser (c) (until 31.05.2005)
Dipl.-Phys. Bert Rähmer (until 15.03.2006)

PhD candidates (status of 31.12.2006 – thesis completed = c)

Dipl.-Phys. Christoph Cobet (c) (until 31.10.2005)

Laurea di Dottore in Chimica Massimo Drago (c) (until 31.12.2006)

Dipl.-Phys. Massimo Drago (c) (until 31.12.2006)

Laurea in Scienza e Tecnologia dei Materiali Roberto Jakomin

Dipl.-Phys. Christian Kaspari (until 02.12.2006)

Dipl.-Phys. Raimund Kremzow

Dipl.-Phys. Regina Passmann (until 30.06.2005)

Dipl.-Phys. Stefan Weeke (until 31.12.2006)

Dipl.-Phys. Katrin Wilmers (until 15.01.2005)

Diploma students (status of 31.12.2006 – thesis completed = c)

Tobias Arlt

Thomas Bruhn

Robert Ehlert (c)

Christian Friedrich

Tim Kolbe

Raimund Kremzow (c)

Miron Kropp (c)

Viola Küller

Martin Leyer (c)

Philipp Myrach (c)

Andreas Oestereich (c)

Alexander Philippou (c)

Simon Ploch

Munise Rakel (c)

Marc Rothe

Lars-Peter Scheller

Jessica Schlegel

Joachim Stellmach

Christoph Werner (c)

9.4.1 Summary of activities

2005 was a year of transition for the department IV of the IFKP. Wolfgang Richter retired in March from his position as a fulltime professor at the IFKP of the TU Berlin and took up a new full professorship at the physics department of the Universitá Roma “Tor Vergata”, where he works on nano-optics. However, he continues to serve his scientific responsibilities at the department IV such as leading his ongoing projects at TU Berlin, advising PhD students and collaborating in new projects.
Since August 2005 the group is headed by Michael Kneissl, who joined the Institute for Solid State Physics from Xerox Corporation’s Palo Alto Research Center (PARC). He also holds a joint appointment at the Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH) in Berlin where he is heading the GaN Optoelectronics group. The newly formed "Experimental Nanophysics and Photonics" research group is exploring a wide range of topics including the epitaxial growth of wide-bandgap semiconductor materials, the study of optical and electronic properties of semiconductor surfaces and heterostructures, and the development of novel optoelectronic devices. Our research is aimed at controlling the formation of structures on a nanometer scale and to tailor the electronic properties of these new materials in order to create novel devices.
Prof. Kneissl brings profound knowledge in epitaxial growth of nitride-based semiconductors and wide-bandgap optoelectronic devices. Major milestones of his engagement at PARC include the demonstration of blue-violet GaN-based laser diodes in 1997, first current-injection distributed feedback InGaN laser diodes in 1998, room-temperature cw operation of blue-violet ridge-waveguide laser diodes in 1999, and the first Q-switched two-section InGaN laser diodes in 2001. More recently his research has focused on the development of semiconductor ultraviolet optical sources. Some of the accomplishments are the first demonstration of ultraviolet laser diodes with AlGaN and InAlGaN MQW active regions and the first current-injection laser diodes grown on bulk AlN substrates.
Since May 2006 Prof. Norbert Esser, Head of the Institut for Analytical Sciences (ISAS) in Berlin is associated to our group holding an S-professorship at the TU Berlin. Part of the cooperation is the joint work in the field of surface analysis with the focus on group-III nitrides and functionalization of III-V(001) surfaces by organic molecules.

The research focus of the group is aimed towards the development of new materials and nanostructures, including epitaxial growth of InGaN quantum dots for laser diodes emitting in the green spectral range and beyond, MOVPE of (In)AlGaN quantum wells and quantum dots for emitters in the near and deep UV, and epitaxy of InN and InGaN semiconductors for application in multi-junction solar cells or high electrons mobility transistors. These activities are complemented by the groups extensive experience in MOVPE growth and in-situ characterization of nitride materials (e.g. spectroscopic ellipsometry) in particular the growth of high indium containing nitride materials including InN that has been a research topic for the past several years. The application of optical analytical techniques is strongly favored and allows for the optimization of established processes as well as the development of new processes. This enabled the study of surfaces and interfaces under UHV conditions as well as in gas phase environments (MOVPE, passivation, post-growth analysis). Special attention was therefore paid to the technical development of the optical methods. This was especially Reflectance Anisotropy Spectroscopy in a fast multichannel version, Spectroscopic Ellipsometry extending into the UV for the needs of the nitrides and Raman Scattering. To complement the optical information, mostly obtained in-situ, and to ease the theoretical interpretation, standard surface science analytical techniques (LEED, AES, STM, ARUPS and SXPS at BESSY) were utilized whenever possible, and last but not least STM was also used intensively in UHV but recently also under MOVPE conditions

Further topics of the group are innovative device technologies, in particular new concepts of GaN-based light emitters. Our research activities include the development of light emitting diodes in the near and deep ultraviolet spectral range, e.g. for applications in water purification, GaN-based vertical cavity surface emitting diodes (VCSEL), highly coherent short wavelength sources (e.g. InGaN MQW DFB laser diodes), and nitride based optical microcavities for single photon emitters. In co-operation with the FBH, nitride laser development activities have already started in September 2005 and meanwhile first optically pumped edge-emitting laser structures at 405nm and blue-violet LEDs have been demonstrated with state of the art performance characteristics.

The work of the Sonderforschungsbereich 296 on III-V semiconductor growth continued and yielded exiting results in three areas. In the area of nitrides we have deeply investigated the sapphire nitridation to further optimize the InN growth. The crystalline quality of the resulting layers is now comparable or better than the best results of other groups using MOVPE. Also the understanding of the different stages of the nitridation process (crucial also for the growth of other nitrides) could be deepened with the help of spectroscopic ellipsometry as a real time in-situ monitoring tool. In-situ spectroscopic ellipsometry also helped to improve the InN growth and determine the optical properties of the high quality InN material for the first time prior to any contamination and for temperature between 300 and 900K. Ex-situ ellipsometry and soft X-ray photoemission at BESSY were used to determine and understand different oxidation effect of InN in air and the deoxidation process. These results will serve as a profound basis for the new growth activities for nitride device structures.
Other novel results in the framework of the Sfb269 were achieved in the area of in-situ monitoring of classical III-V semiconductor growth. Using in-situ multi-channel RAS (Reflectance Anisotropy Spectroscopy) measurement we discovered doping related signal oscillations which could be used to determine doping level and thickness directly during growth. We also succeeded in the first time ever in-situ STM (Scanning Tunneling Microscopy) measurements during MOVPE growth. This new in-situ technique allows for time resolved atomic scale measurements in a MOVPE reactor during the formation of nanostructures. Time resolved Oswald ripening of Quantum dots was measured directly very recently for the first time. These activities were honoured by several invitations to international conferences and articles.

Another area of activities is the investigation of semiconductor surfaces and their interfaces with thin layers formed by organic molecules. Organic molecules are capable to functionalize semiconductor surfaces thus enabling the combination of the selective and electronic properties of the organic molecules with the technological applications of semiconductor devices. This combination is considered to play a key role for future developments in the field of sensors and biotechnology. Our work, concerning this issue, is focussed on the interface formation between small organic (ring) molecules and III-V(001) surfaces. Changes of structural aspects on an atomic scale and the related changes of the electronic surface properties upon deposition of organic molecules are crucial for the technological application. We could demonstrate that RAS is a suitable experimental tool to characterise the interface formation of the III-V semiconductor with the organic molecules. This result is important as it shows the potential of RAS to be used as an in-situ technique to investigate the complex bonding mechanism between the organic molecules and semiconductor surfaces.

9.4.2 Publications

The abstracts of papers marked by* are reprinted in section 9.4.6

1.* **Laser gain properties of AlGaN quantum wells**
W.W. Chow & M. Kneissl, ,
J. Appl. Phys. 98, 114502 (2005).

2. **Spiral-shaped microcdisk laser**
M. Kneissl, G.D. Chern, M. Teepe, D.W. Treat, Z. Yang, R.K. Chang, N.M. Johnson,
SPIE Proc. **5738**, 225 (2005).

3. **Gain and photoluminescence spectroscopy in violet and ultra-violet InAlGaN laser structures**
Schmidt, O. Wolst, M. Kneissl, P. Kiesel, Z.H. Yang, M. Teepe, N.M. Johnson,
phys. stat. sol. (c) 2, No. 7, 2891 (2005).

4. **Spiral-shaped microcavity laser: a new class of semiconductor laser**
M. Kneissl, M. Teepe, N. Miyashita, N.M. Johnson, G.D. Chern, R.K. Chang and Noble M. Johnson
AIP Conference Proceedings 772, 1517 (2005).

5. **Determination of the Piezoelectric Field in InGaN Quantum Wells**
I.H. Brown, I.A. Pope, P.M. Smowton , P Blood, and J.D. Thomson, W.W. Chow, D.P. Bour, M. Kneissl,
Appl. Phys. Lett. **86**, 131108 (2005).

6. **Free and bound excitons in bulk AlN**
E. Silveira; Freitas Jr., J. A.; Slack, G.; Schowalter, L.; Kneissl, M. A.; Treat, D. W.; Johnson, N. M.,
J. Cryst. Growth **281**, 188 (2005).

7. **Optical Anisotropy and Magneto Optical Properties of Ni on Preoxidized Cu(110)**
T. Herrmann, K. Lüdge, W. Richter, K. G. Georgarakis, P. Poulopoulos, R. Nünthel, J. Lindner, M. Wahl, N. Esser,
AIP Conference Proc., Vol. 772, 1517 (2005).

8. **Electronic structure and reflectance anisotropy spectrum of InAs(110)**
X. López-Lozano, O. Pulci, C. Noguez, K. Fleischer, R. Del Sole, W. Richter
Phys. Rev. B. **71**, 125337 (2005)

9. **Effects of the low temperature buffer and annealing on the properties on InN layers grown by MOVPE**
P. Ruterana, M. Morales, F. Gourbilleau, P. Singh, M. Drago, T. Schmidtling, U. W. Pohl, W. Richter
Phys. Stat. Sol. (a) **202**(5) 781-784 (2005)

10.* **In situ sprectroscopic ellipsometry study of GaN nucleation layer growth and annealing on sapphire in metal-organic vapor-phase epitaxy**
T. Schmidtling, U. W. Pohl, W. Richter, S. Peters
J. Appl. Phys. **98**, 033522 (2005)

11. Development of InN metalorganic vapor phase epitaxy
M. Drago, C. Werner, M. Pristovsek, U. W. Pohl, W. Richter
Cryst. Res. Technol. 40, No. 10-11, 993-996 (2005)

12. Highly sensitive strain detection in silicon by reflectance anisotropy sprectroscopy
D. Papadimitriou, W. Richter
Phys. Rev. B **72**, 075212 (2005)

13. Optical response of Ag-induced reconstructions on vicianl Si(111)
S. Chandola, J. Jacob, K. Fleischer, P. Vogt, W. Richter, J. F. McGilp
phys. stat. sol. (b) **242**(15) 3017 (2005)

14. A fast reflectance anisotropy spectrometer for in situ growth monitoring
C. Kaspari, M. Pristovsek, W. Richter
phys. stat. sol. (b) **242**(13) 2561-2569 (2005)

15.* MOVPE growth and surface reconstructions of GaAsN(001) surfaces
R. Ehlert, F. Poser, N. Esser, P. Vogt, W. Richter
phys. stat. sol. (b) **242**(13) 2575-2580 (2005)

16. Surface Structure of CuGaSe2 (001)
T. Deniozou, N. Esser, S. Siebentritt, P. Vogt, R. Hunger,
Thin Solid Films 480-481, 382 (2005)

17. VUV-ellipsometrie on GaN: Probing conduction band properties by core level excitations
N. Esser, M. Rakel, C. Cobet, W.G. Schmidt, W. Braun, M. Cardona
phys. stat. sol. (b), 242 (2005) 2601

18. Detailed analysis of the dielectric function for wurtzite InN and In-rich InAIN alloys
R. Goldhahn, P. Schley, A.T. Winzer, G. Gobsch, V. Cimalla, O. Ambacher, M. Rakel, C. Cobet, N. Esser
phys. stat. sol (a), 203 (2005) 42

19. Stability of tris(8-hydroxyquinoline)-aluminum(III) films investigated by vacuum ultraviolet spectroscopic ellipsometry.
C. Himcinschi, O. Gordan, G. Salvan, F. Muller, D.R.T. Zahn, C. Cobet, N. Esser, W. Braun,
Appl. Phys. Lett. 86 (2005) 111907

20. Analysis of organic films and interfacial layers by infrared spectroscopic ellipsometry
K. Hinrichs, M. Gensch, N. Esser
Appl. Spectroscopy 59 (2005) 272A

21. Ellipsometry from infrared to vacuum ultraviolet: Structural properties of thin anisotropic guanine films on silicon.
K. Hinrichs, S. Silaghi, C. Cobet, N. Esser, D.R.T. Zahn
phys. stat. sol. (b), 242 (2005), 2681

22. Growth of strained GaAsSb layers on GaAs (001) by MOVPE.
M. Pristovsek, M. Zorn, U. Zeimer, M. Weyers
Journ. Crys. Growth 276 (2005) 347

23. Dielectric functions of DNA base films from near-infrared to ultra-violet
S. Simona, M. Friedrich, C. Cobet, N. Esser, W. Braun, D.R.T. Zahn,
phys. stat. sol. (b) 242 (2005) 3047

24. Strong changes in the dielectric functions of cytosine upon molecular modification
Yu Suzuki, O.D. Gordan, S. Silaghi, D.R.T. Zahn, A. Schubert, W. Thiel, C. Cobet, N. Esser, W. Braun,
Appl. Phys. Lett. 87 (2005) 214101

25. Spectroscopic ellipsometry and reflectance anisotropy spectroscopy of biomolecular layers on silicon surfaces
D.R.T. Zahn, S. Silaghi, C. Cobet, M. Friedrich, N. Esser
Phys. Stat. Sol. (b), 242 (2005) 2671

26. Shock-induced band gap shift in GaN: anisotropy of the deformation potentials
Peng, H. Y.; McCluskey, M. D.; Gupta, Y. M.; Kneissl, M. A.; Johnson, N. M.,
Phys. Rev. B **73**, 134408 (2006).

27.* Ultraviolet InAlGaN Light Emitting Diodes Grown on Hydride Vapor Phase Epitaxy AlGaN/Sapphire Template
Michael Kneissl, Zhihong Yang, Mark Teepe, Cliff Knollenberg, Noble M. Johnson, Alexander Usikov and Vladimir Dmitriev,
Jpn. J. of Appl. Phys. **45**, 3905 (2006).

28. Vertical injection thin-film AlGaN/AlGaN multiple-quantum-well deep ultraviolet light-emitting diodes
L. Zhou, J. E. Epler, M. R. Krames, W. Goetz, M. Gherasimova, Z. Ren, J. Han, M. Kneissl, and N. M. Johnson,
Appl. Phys. Lett. **89**, 241113 (2006).

29. The Quest for Uni-Directionality with WGMs in μ-Lasers: Coupled Oscillators and Amplifiers
Richard K. Chang, Gustavo E. Fernandes, and Michael Kneissl,
to be published in the Proceedings of the 8th International Conference on Transparent Optical Networks, (2006).

30.* MOVPE growth of InN with ammonia on sapphire
M. Drago, P. Vogt, W. Richter
phys. stat. sol. (a) **203**(1) 116-126 (2006)

31. Effect of light on the reflectance anisotropy and chain-oxygen related Raman signal in untwinned, underdoped crystals of YBa2Cu3O7-δ
S. Bahrs, A. Bruchhausen, A.R. Goñi, G. Nieva, A. Fainstein, K. Fleischer, W. Richter, C. Thomsen
Journ. Phys. and Chem. of Solids **68** 340-343 (2006)

32. Investigation of InN layers grown by MOCVD using analytical and high resolution TEM: The structure, band gap, role of the buffer layers
P. Ruterana, M. Abouzaid, F. Gloux, W. Maciej, J. L. Doualan, M. Drago, T. Schmidtling, U. W. Pohl, W. Richter
phys. stat. sol. (a) 203(1) 156-161 (2006)

33.* In-situ Scanning Tunneling Microscopy during Metal-organic Vapour Phase Epitaxy
B. Rähmer, M. Pristovsek, M. Breusing, R. Kremzow, W. Richter
Appl. Phys. Lett. **89**(6) 063108 (2006)

34. InN growth on sapphire using different nitridation procedure
M. Drago, C. Werner, M. Pristovsek, U.W. Pohl, W. Richter
phys. stat. sol. (a) **203**(7) 1622-1625 (2006)

35. STM images quantum dot epitaxy inside an MOCVD reactor
Markus Pristovsek
Compound Semiconductors 12(11) 14-16 (2006)

36. Large photocurrent generation in multiwall carbon nanotubes
P. Castrucci, F. Tombolini, M. Scarselli, E. Speiser, S. Del Gobbo, W. Richter, M. De. Crescenzi, M. Diociaiuti, E. Gatto, M. Venanzi
Appl. Phys. Lett. 89, (2006)

37. Free-electron response in reflectance anisotropy spectra
K. Fleischer, S. Chandola, Th. Herrmann, N. Esser, W. Richter, J. F. McGilp
Phys. Rev. B 74, 195432 (2006)

38. Investigation of InN layers grown by MOCVD using analytical and high resolution TEM: The structure, bandgap role of the buffer layers
P. Ruterana, M. Abouzaid, F. Gloux, W. Maciej, J. L. Doualan, M. Drago, T. Schmidtling, U. W. Pohl and W. Richter
physica status solidi (a), 203, 158 (2006)

39. Homoepitaxial growth rate measurement using in-situ Reflectance Anisotropy Spectroscopy
Ch. Kaspari, M. Pristovsek, W. Richter
J. Crystal Growth (in print)

40. In-situ Scanning Tunnelling Microscopy during Metal-Organic Vapour Phase Epitaxy
M. Pristovsek, B. Rähmer, M. Breusing, R. Kremzow, W. Richter
J. Crystal Growth (in print)

41. Segregation and desorption of antimony in InP in MOVPE
S. Weeke, M. Leyer, M. Pristovsek, F. Brunner, W. Richter
J. Crystal Growth (in print)

42.* Optical anisotropy of cyclopentene terminated GaAs(001) surfaces
R. Passmann, M. Kropp, T. Bruhn, B.O. Fimland, F.L. Bloom, A.C. Gossard, W. Richter, N. Esser, P. Vogt
Journal: Appl. Phys. A, invited paper, (in print)

9.4.3 Invited talks

Massimo Drago	**MOVPE growth of InN and surface analysis** E-MRS Warschau, Polen, September 2005
Massimo Drago	**In-situ spectroscopic ellipsometry as a tool for monitoring and optimization of growth for nitrides semiconductors** 4th Workshop Ellipsometry, Bundesanstalt für Materialforschung, Stuttgart, February 2006
Massimo Drago	**Metal-organic vapour phase epitaxy of InN and GaN and in-situ growth monitoring with spectroscopic ellipsometry** Colloquium at the Ferdinand-Braun-Institut für Höchstfrquenztechnik, Berlin, June 2006
Norbert Esser	**Optical Analysis of Ultra thin films with monolayer precision** X. Holzhau Meeting, Doubice, Tschechien, April 2005
Norbert Esser	**Spectroscopic Ellipsometry for Interface Characterization: From clean surfaces to ultrathin organic/anorganic layers** Collquium, Int. Univ. Bremen, May 2005
Norbert Esser	**Surface Structure analysed by optical Spectroscopy: Molecules, Atomic Nanowires** Humboldt-Universität zu Berlin, Institut für Physik, Berlin, July 2005
Norbert Esser	**Surface Analysis by Optical Spectroscopy: Advances and Prospects** Joint Meeting of the German and Polish Vacuum Society, "Vacuum based Science and Technolgy", Krakow, Polen, October 2005
Norbert Esser	**Analysis of epitaxial III-Nitride layers and interfaces with VUV-ellipsometry** Ferdinand-Braun-Institut, Berlin, November 2006
Norbert Esser	**Optische Analytik von Grenzflächen: Struktur von ultradünnen organischen und anorganischen Schichten** Humboldt-Universitär zu Berlin, Institut für Chemie, Berlin, November 2006
Norbert Esser	**Molecular and Atomic Structures and Interfaces: Analysis with Ellipsometry** Universität Würzburg, Institut für Physik, June 2006
Norbert Esser	**Spectroscopic Ellipsometry for Analysis of Organic/Anorganic Interfaces** Universiteit Hasselt, Instituut voor Materiaalon, Derzoek/Belgien, September 2006

Michael Kneissl **From ultraviolet light emitting diodes to microcavity disk lasers – New frontiers in InAlGaN optoelectronics**
Spring Meeting of the German Physical Society (DPG), Dresden, March 2006

Michael Kneissl **Near- and Deep-UV InAlGaN MQW Lasers**
SPIE Photonics West Conference 2006, San Jose, USA, January 2006

Michael Kneissl **Leuchtdioden und Laser im nahen und tiefen UV – Anwendungen und Herausforderungen**
VDI Fachtagung Optische Technologien, Düsseldorf, November 2006

Michael Kneissl **Ultraviolette LEDs and Lasers – Applications and Challanges**
Colloquium at the Fraunhofer Inst. für angewandte Festkörperphysik together with the Unversity of Freiburg, Freiburg, June 2006

Michael Kneissl **From ultraviolet LEDs to microdisk lasers – New frontiers in InAlGaN optoelectronics**
Colloquium at Inst. für Festkörperphysik of the University of Bremen, Bremen, January 2006

Michael Kneissl **New Frontiers in GaN Optoelectronics – Applications and Challenges**
Symposium "Semiconductor Nanostructures : Where do we stand – were do we go", TU Berlin, September 2006

Michael Kneissl **Ultraviolet LEDs & Lasers grown on sapphire and bulk AlN substrates**
6th International Conference on Nitride Semiconductors (ICNS-6) , Bremen, August 2005

Michael Kneissl **UV LEDs and Lasers - Applications and Challenges**
Workshop on UV/VUV-spectroscopy for thin film and interface analysis, Berlin, November 2005

Michael Kneissl **New Frontiers in InAlGaN Optoelectronics**
Seminar at Osram Opto Semiconductor, Regensburg , November 2005

Markus Pristovsek **In-situ STM in MOVPE**
11th European Workshop on MOVPE 2005, Lausanne, Schweiz, May 2005

Markus Pristovsek **In-situ STM in MOVPE: Promises, Problems, Pictures**
13th international Conference on MOVPE 2006, Miyazaki, Japan, May 2006

Wolfgang Richter **Analysis of Rugate Filters by Spectroscopic Ellipsometry**
4th Workshop Ellipsometry, Bundesanstalt für Materialforschung, Stuttgart, February 2006

Wolfgang Richter — **Raman Scattering with high Spatial Resolution**
International Summershool in Epioptics, Erice Sicily, Italy, July 2006

Wolfgang Richter — **Metal Organic Vapour Phase Epitaxie**
University of Parma, May 2006

Wolfgang Richter — **Monitoring of Epitaxial Surface Processes by Reflectance Anisotropy Spectroscopy**
University of Parma, May 2006

Patrick Vogt — **Interface formation between small organic molecules and III-V (001) surfaces**
International Summershool in Epioptics, Erice Sicily, Italien, July 2006

Patrick Vogt — **Interface Formation between small organic molecuels and III-V (001) surfaces**
Workshop "Organics Meeting", University of Rome "Tor Vergata", Italy, December 2006

9.4.4 PhD theses

Christoph Cobet — **Linear optical properties of III-nitride semiconductors between 3 and 30 eV**
07.10.05

Massimo Drago — **MOVPE growth of InN analyzed by in-situ spectroscopic ellipsometry**
23.10.06

Michael Fischer — **Untersuchungen zur Einsatzfähigkeit der N_2- und H_2O-CARS-Thermometrie und H_2O-CARS-Konzentrationsmessung bei der Analyse von H_2-Staustrahltriebwerken**
27.10.05

Karsten Fleischer — **Optical anisotropy and vibrational properties of Sn, In and Cs nanowires**
29.06.05

Florian Poser — **Stickstoffeinbau in Galliumarsenid Eigenschaften und Charakterisierung des Wachstums in der Metallorganischen Gasphasenepitaxie**
07.10.05

Torsten Schmidtling — **MOVPE growth and characterization of group-III nitrides using in situ spectroscopic ellipsometry**
12.12.05

Thomas Trepk — **The Dielectric Function of III-V Semiconductors at High Temperatures**
12.05.05

9.4.5 Diploma theses

Robert Ehlert — **Austauschreaktionen von As und N auf III-V-Halbleiter-Oberflächen**
30.05.05

Raimund Kremzow — **In-Situ SPM Untersuchungen in der MOVPE**
02.02.06

Miron Kropp — **Analyse der Grenzflächenstruktur molekülterminierter Oberflächen von III-V-Halbleitern**
05.09.06

Martin Leyer — **Der Einfluss von Antimon auf das epitaktische Wachstum von III-V-Halbleitern**
22.02.06

Philipp Myrach — **RAS im UV/VUV-Spektralbereich zur Untersuchung molekülterminierter Oberflächen**
17.06.06

Andreas Oestereich — **Oxidation und Deoxidation von III-V-Halbleitern**
05.09.06

Alexander Philippou — **Einbau von Mangan in III-V-Halbleiter**
12.01.05

Munise Rakel — **Spektroskopische Ellipsometrie an Rumpfniveau-Anregungen**
19.08.05

Christoph Werner — **Epitaktisches MOVPE-Wachstum von In(Ga)N und Untersuchung des Oxidationsverhaltens**
17.02.05

9.4.6 Abstracts of selected papers of department IV

1. *J. Appl. Phys.* ***98****, 114502 (2005)*

Laser gain properties of AlGaN quantum wells

W. W. Chow
Semiconductor Material and Device Sciences Department, Sandia National Laboratories, Albuquerque, New Mexico 87185-0601
M. Kneissl
Electronic Materials and Devices Laboratory, Palo Alto Research Center, 3333 Coyote Hill Road, Palo Alto, California 94304

Laser gain is investigated for AlGaN wurtzite quantum-well structures emitting in the wavelength range from 270 to 340 nm. The calculations show that gain properties vary notably with aluminum concentration in the quantum well. The TE gain dominates over the entire spectral range, although an enhancement of TM gain is observed for AlGaN quantum wells with the high aluminium mole fraction. The calculations also predict an increase in threshold current density for the shorter-wavelength lasers.

10. *J. Appl. Phys.* ***98****, 033522 (2005)*

In situ sprectroscopic ellipsometry study of GaN nucleation layer growth and annealing on sapphire in metal-organic vapor-phase epitaxy

T. Schmidtling, U. W. Pohl, W. Richter, S. Peters
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

Deposition and annealing of GaN nucleation layers (NLs) on sapphire during metal-organic vapor-phase epitaxy were studied using in situ spectroscopic ellipsometry. Growth was found to start with a remarkable delay after precursor switching through the formation of an initial roughness and a subsequent coalescence, which leads to the formation of a dense nucleation layer. The initial growth rate strongly depends on growth environment pretreatment and decreases if the susceptor is coated with GaN from preceding growth runs. The evaluation of the optical properties of as-grown NLs shows that the growth rate strongly affects the crystalline quality of the NL. At decreased growth rate the band gap E0 appears more pronounced with values indicating a predominantly cubic structure. During annealing above 800°C a structural change is observed: the thickness of the dense part of the NL increases on expense of the rough part, maintaining an almost constant total layer thickness. Simultaneously the formation of the hexagonal phase in the NL occurs. The process is accomplished at about 950°C and is followed by a desorption of the NL at a rate of 1.4 nm/s in ammonia and nitrogen ambient at 1060°C. The observations are confirmed by ex situ atomic force microscopy and scanning electron microscopy measurements.

15. *phys. stat. sol. (b)* ***242****(13) 2575-2580 (2005)*

MOVPE growth and surface reconstructions of GaAsN(001) surfaces

R. Ehlert[1], F. Poser[1], N. Esser[2], P. Vogt[1], W. Richter[1,3]
[1] *Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*
[2] *ISAS - Institute for Analytical Sciences - Department Berlin, Albert-Einstein- Str. 9, 12489 Berlin, Germany*
[3] *Universita degli Studi Roma "Tor Vergata", Via della Ricerca Scientifica 1, 00133 Roma, Italy*

In this study we present comparative in-situ Reflectance Anisotropy Spectroscopy (RAS) studies of GaAs1-xNx under MOVPE conditions and in UHV for samples with a nitrogen content of up to 5%. The samples were grown by MOVPE and after growth capped with an amorphous As-layer, transferred to UHV and decapped by annealing. Three different surface reconstructions (c(4 × 4), (2 × 4), (4 × 2)) were obtained after decapping and prolonged annealing at different temperatures. These reconstructions, though similar to those found on the GaAs(001) surface show clear nitrogen-related features in the RAS line shape.

27. *Jpn. J. Appl. Phys.* ***45****, 3905 (2006)* ***8***

Ultraviolet InAlGaN Light Emitting Diodes Grown on Hydride Vapor Phase Epitaxy AlGaN/Sapphire Templates

Michael Kneissl, Zhihong Yang, Mark Teepe, Cliff Knollenberg,
Noble M. Johnson, Alexander Usikov[1] and Vladimir Dmtriev[1]
Palo Alto Research Center Inc., 3333 Coyote Hill Road, Palo Alto, CA 94304, U.S.A.
[1]*TDI Inc., 12214 Plum Orchard Drive, Silver Spring, MD 20904, U.S.A.*

We demonstrate high-efficiency UV InAlGaN multiple-quantum-well light-emitting diodes (LED) deposited by metal–organic chemical vapor deposition (MOCVD) on hydride vapor phase epitaxy (HVPE) grown AlGaN/sapphire templates. The combination of HVPE and MOCVD allows the separate optimization of the growth of high-quality AlGaN/sapphire templates and sophisticated LED heterostructures. High-performance UV LEDs emitting in the range between 373 and 289 nm have been realized. LED devices emitting near 330 nm exhibit cw light output power of more than 11mW and an external quantum efficiency (EQE) of 1.5%. Under pulsed bias testing, peak light output is more than 55mW with an EQE of 2.3%.

30. *phys. stat. sol. (a), **203**(1) 116-126 (2006)*

MOVPE growth of InN with ammonia on sapphire

M. Drago, P. Vogt, W. Richter
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

MOVPE growth of InN on sapphire substrate is reviewed focusing on the critical growth parameters. Based on our in situ spectroscopic ellipsometry results obtained during growth and the results found in the literature we suggest a strategy for successful growth of high quality InN layers. This includes nitridation of the substrate, growth parameters and suppression of layer peeling off. We find that the optimal temperature for the nitridation of the sapphire is around 1050°C and the optimal growth temperature is always very close to the highest possible temperature which is determined by the thermal decomposition of the InN layer. The smallest accessible V/III ratio, before Indium droplets formation occurs, lies between 5000 and 10000 depending on the growth parameters. With the procedure we suggest here the growth temperature can be increased up to 580°C with changes of the respective V/III ratio limits resulting in an improvement of the InN quality.

33. *Appl. Phys. Lett. **89**, 063108 (2006)*

In-situ Scanning Tunneling Microscopy during Metal-organic Vapour Phase Epitaxy

B. Rähmer, M. Pristovsek, M. Breusing, R. Kremzow, W. Richter
Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

The authors report the first ever in situ scanning tunnelling microscopy measurements in metal-organic vapor phase epitaxy (MOVPE) using an active cooling shield for operation up to 650 °C. Apart from fundamental considerations and constraints, some MOVPE specific problems are discussed. The authors present images representing the current status and discuss the effect of tip interaction with the MOVPE process.

42. *Appl. Phys. A (in print)*

Optical anisotropy of cyclopentene terminated GaAs(001) surfaces

R. Passmann[1,2], M. Kropp[1], T. Bruhn[1], B.O. Fimland[3], F. L. Bloom[4], A. C. Gossard[4], W. Richter[1,5], N. Esser, P. Vogt[1]

[1] *Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*
[2] *ISAS - Institute for Analytical Sciences - Department Berlin, Albert-Einstein- Str. 9, 12489 Berlin, Germany*
[3] *Department of Electronics and Telecommunication, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway*
[4] *Materials Department, University of California, Santa Barbara, Santa Barbara, California 93106-5050*
[5] *Universita degli Studi Roma "Tor Vergata", Via della Ricerca Scientifica 1, 00133 Roma, Italy*

Up to now most of the experimental work regarding the adsorptionof organic molecules has been concerned with silicon. Here we study the interface formation on a III-V-semiconductor, GaAs(001). We show that reflectance anisotropy spectroscopy (RAS) is a sensitive technique to investigate the interface formation between organic molecules and semiconductor surfaces. With RAS it is possible to determine the surface reconstruction and also the structural changes at the interface during the deposition of organic molecules. These changes and the underlying adsorption process are discussed here for the adsorption of cyclopentene on the GaAs(001)c(4x4), (2x4) and (4x2).

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