Report of Project Part 14: Theory and modelling of infrared optical devices

Theory and modelling of infrared optical devices

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1. Summary

In project P14 various aspects of photonic devices were studied including their optical as well as their material properties. The focus of the Rotter group was laid on phenomena arising from the non-Hermitian physics involved in the description of scattering structures with gain and loss, such as lasers, waveguides or resonators. In particular, the counter-intuitive aspects associated with a so-called “exceptional point” were studied theoretically and realized experimentally together with the groups of P3 and P11. The theoretical work on such non-Hermitian degeneracies revealed that the associated symmetry breaking points in bounded and unbounded gain-loss structures are strongly related to each other and very robust. The lasing aspects of devices with gain could be well described with a new and efficient version of the steady-state ab-initio laser theory (SALT) which was extended to describe resonators in full 3D simulations. The scattering of electromagnetic radiation in disordered media was studied both in the context of wave transmission though waveguides with bulk disorder and surface corrugations as well as for random lasers. For the latter it was demonstrated how a suitably patterned pump profile can trick random lasers to emit into a single pre-determined direction.

The focus of the Kosina group was on numerical modeling of quantum cascade structures. At the device length scale the electronic structure is well desribed by envelope-function-based models. For dissipative carrier transport a semi-classical approach based on the Pauli master equation was adopted. These models were implemented in the Vienna Schrödinger Poisson Solver (VSP) model framework. Key issues were a careful choice of physically accurate and yet computationally efficient models, numerical stability and ease of use in order to provide a versatile design tool. In P3 a bi-functional quantum cascade device was designed for same-frequency lasing and detection. To design the active region, VSP was used in an automatized optimization loop to simultaneously tune the performance for both the laser and the detector. The bandstructure and transport models of VSP were verified for the case of an InGaAs/InAlAs quantum cascade detector. Band structure effects turned out to be important to reproduce the experimental responsivity curves. Furthermore, an optimization study of a QCL for third-harmonic generation was performed. VSP is invoked by a multi-objective particle swarm optimization algorithm to maximize the third-order susceptibility and the pump power simultaneously. A five orders of magnitude increase in the generated third-harmonic power with respect to a reference design from the literature was predicted. In the Vogl group, a fully self-consistent non-equilibrium Green’s function method has been developed to enable performance prediction and optimization of THz QCLs. A principal result is the prediction of room temperature operation for THz QCL based on III-V nanowire heterostructures

2. Scientific background / aims of research

At the start of project P14 (i.e., the beginning of the third funding period) coupled systems with gain and loss shifted to the center of attention of the photonics community. A strong driving force behind this development was the work on so-called "PT-symmetric" systems, where gain and loss are balanced symmetrically, such that these non-Hermitian devices can feature also real propagation constants. Examples include the coupling of waveguides (Guo 2009; Rüter 2010) as well as PT-symmetric lasers and absorbers (Chong 2011; Ge 2011). We predicted in 2012 (Liertzer 2012) that in variants of such systems, a so-called "exceptional point" (EP) may be induced by a suitable variation of the applied pump with the dramatic consequence that lasing was found to be inhibited in the parametric vicinity of such a non-hermitian degeneracy. The central question which we addressed in P14 was how this effect may be realized in the experiment, possibly with those coupled THz-QCLs that were fabricated already earlier in projects P3 and P11 (Fasching 2009). The problems that we faced with these photonic molecule lasers were an insufficient degree of absorption to observe an EP, a limited understanding of the coupling between the laser cavities as well as of the modes that are actually lasing in such devices. To overcome these initial hurdels, it became clear that calculations in 2D would be insufficient, making a full 3D approach compulsory and with it a complete reformulation of our laser solver (SALT). Other related topics that were on our agenda at the start of this project were the connection between PT-symmetry breaking in bounded and unbounded systems (Chong 2011), the external tunability of random lasers (Bachelard 2012) as well as various questions related to the scattering of electromagnetic waves in disordered media (Wang 2011).

Besides the nonlinear optics discussed above, this project also addresses the material aspects of the active medium. For this purpose suitable models for the electronic structure of the semiconductor nanostructure and for dissipative electron transport are required. At the mesoscopic length scales given by the devices under consideration, envelope-function-based models represent a good trade-off between physical accuracy and computational efficiency. A multiband k*p approach has been adopted both by the Kosina group and by the Vogl group and implemented in their respective simulators during the previous phases of the SFB. The Vienna Schrödinger Poisson Solver (VSP) offers a dimensionality-independent (1D, 2D, 3D) implementation using unstructured meshes for flexible geometry handling (Baumgartner 2013a). The software package Nextnano has been extended to cover doped and undoped structures, embedded quantum dots, biased and unbiased materials, finite and broken gap semiconductors, and semimetals (Birner 2007).

As far as the carrier transport in the semiconductor nanostructures is concerned, several modeling approaches are available. The most rigorious one is the Keldysh non-equilibrium Green's function technique (Datta 1997, Haug 2008). Interactions of electrons with phonons and a variety of other scattering sources can be treated perturbatively by appropriate self-energy terms. This method is well suited to study fundamental physical effects, in our case in optoelectronic devices, but its appliation is often limited to devices with not too complicated geometry, and it is often used with simplified band struture models such as constant effetive mass. Also design studies that require the sampling of a large paramater space and thus large number of simulation runs, are not feasible at present due to the computational burden. For that purpose, a semi-classical approach would be beneficial. Theoretical studies have shown that in many practical cases the steady state transport in QCLs is incoherent which allows for a semi-classical description (Jirauschek 2007). The dynamic eqution in this case is the Pauli master equation (Fischetti 1999), which is basically a set of coupled Boltzann-like equtions, one for each subband, which can be conveniently solved by the Monte Carlo method. Scattering rates are calcuated consistenly from the wave funtions within the Born approximation. The third transport model practically used for the simulation of QCLs is based on the density matrix (Iotti 2005). As compared to the NEGF, the density matrix does not contain the energy variable. This lack of spectral information influences the way how scattering mechanisms can be modeled. Often only simple relaxation terms are used (Callebaut 2005). In this project, the NEGF method and the semiclassical method have been employed.

3. Results and discussion

Starting in 2006 the steady-state ab-initio laser theory (SALT) was developed (partly by the Rotter group) to accurately provide steady-state solutions of the Maxwell-Bloch equations which are at the heart of semi-classical laser theory (Türeci 2009). Using this new and efficient technique, we were able to show, that a suitable variation of the pump applied to two coupled microcavity lasers leads to the appearance of an exceptional point (EP) in the corresponding SALT solutions. At such a non-Hermitian degeneracy both the positions and the widths of two resonances coalesce (Liertzer 2012). In the vicinity of the EP the laser was found to turn off completely or to reduce its emitted intensity, even when increasing the globally applied pump strength. To realize this effect also in the experiment, evanescently coupled micro-cavity THz QCLs (see Fig.1a) similar to the ones already fabricated (Fasching 2009) were employed in P3, P11. To find the right degree of gain and loss in these devices, we adapted the versatile and efficient finite-element package ngsolve authored by a colleague from TU-Vienna (J. Schöberl) and performed full 3D simulations of the coupled lasers which yielded very good agreement with the experimental data. Based on this correspondence, we could unambiguously demonstrate an unconventional reversal of the pump-dependence of the coupled laser in the vicinity of the EP (see Fig.1c,d), including a strongly reduced light emission for increased pump-power. This result has meanwhile been accepted for publication in Nature Communications (Brandstetter 2014) and establishes photonic molecule lasers as promising tools for exploring many further fascinating aspects of EPs, like a strong line-width enhancement (Wenzel 1996) and the coherent perfect absorption of light (Chong 2010) in their vicinity as well as non-trivial mode-switching (Gilary 2013) and the accumulation of a geometric phase (Dietz 2011) when encircling an EP parametrically. Our theoretical work (Liertzer 2012) triggered also experimental studies by other groups where the physics of EPs was studied in PT-symmetric optical setups (Peng 2014) as well as in the context of coupled electronic oscillators (Chitsazi 2014).

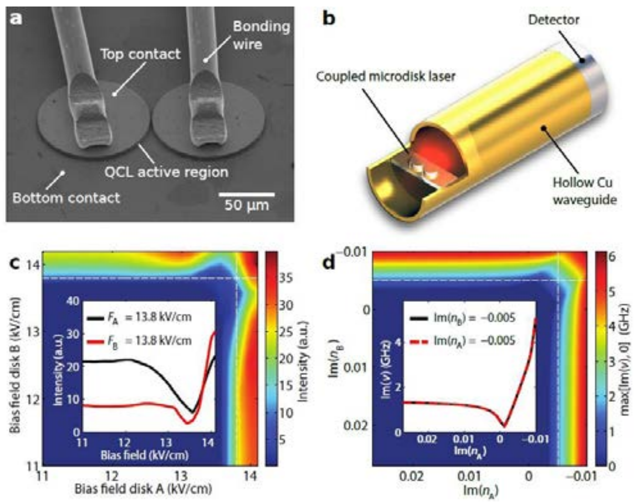

Figure 1 ***a**, Image* of the studied photonic molecule QCL. **b**, Configuration for spatially integrated measurements. **c**, Measured intensity output as a function of the electric field strength applied to the two individual disks (in the dark blue region the laser is off). The upper right corner contains the non-monotonic pump-dependence near the EP. When the field strength in one of the disks is fixed and the other disk is steered through the EP's vicinity (see white dashed lines) this results in a characteristic reversal of the laser's pump dependence (see inset for corresponding intensity curves). **d**, Numerical results from the 3D simulations in excellent agreement with experimental data.

As 2D laser models are often insufficient for describing the full spatial complexity of a real device, our aim was not only to describe the passive resonances with full 3D simulations, but also to extend our SALT solver to 3D. For this purpose we developed a direct solution method that solves the non-linear differential equations of SALT without a parametrized basis of "constant-flux states" that is presently used in all other SALT codes we are aware of. Instead, our new approach relies on a customized combination of a Newton-Raphson technique, a sparse-matrix solver, and the solution of a nonlinear eigenproblem which we implemented both on a finite-element and a finite-difference grid (Esterhazy 2013). We validated our approach in 1D and 2D against the conventional solution method and demonstrated its scalability to full-vector 3D calculations in photonic-crystal slabs. For this project we teamed up with the groups of Steven G. Johnson (MIT) and of A. Douglas Stone (Yale) with the aim of issuing, in the near future, a joint open-source SALT code that should be freely available to the community.

A topic that has attracted very much attention in PT-symmetric scattering systems is the symmetry-breaking transition occurring at an EP, where the eigenvalues change from being real to being complex conjugate pairs. In particular, the realizations of this effect in optical systems has caused much excitement in the community (Guo 2009; Rüter 2010;

Regensburger 2012; Peng 2014). As was pointed out in a theoretical paper (Chong 2011) PT-symmetry breaking does, however, not only occur in bounded scattering systems, but also in unbounded scattering domains where the corresponding PT-transition is realized in the eigenvalues of the scattering (S) matrix, which relates incoming to outgoing flux channels. In our work published in PRX (Ambichl 2013) we clarify how this PT transition in the scattering problem is related to the corresponding transitions in bounded Hamiltonian systems and demonstrate that the PT transitions in the scattering matrix are, under very general conditions, entirely insensitive to a variable coupling strength between the bounded region and the unbounded asymptotic region – a result that can be tested experimentally and visualized using the concept of Smith charts.

In a diploma thesis which we offered to a talented physics student (T. Hisch) we wanted to investigate, whether random lasers can be tuned by shaping the spatial profile of the applied optical pump beam. Similar concepts have recently emerged for the control of the frequency spectrum of the emitted random laser light (Bachelard 2012). In this project we wanted to test whether also the angular emission pattern can be tuned in this way. For this purpose, we coupled our SALT solver with a gradient-based optimization routine, which optimizes the applied pump-profile with respect to the desired target function, e.g., a directional emission profile. Our results show that in the weakly-scattering regime the emission profile can, indeed, be shaped according to any pre-determined emission pattern, including a highly directional laser output. Our results, which were published in 2013, were selected for an “editors’ suggestion” by PRL (Hisch 2013).

To better understand the scattering in random media, we performed detailed numerical calculations, both for the case of a static bulk disorder as well as for surface-disordered waveguides. In the former case we could show how in the deeply localized limit only a single transmission channel dominates the entire transmission through a disordered system. To see this effect also in the experiment we teamed up with the group of Andrey Chabanov (San Antonio, Texas) who could measure this effect with his microwave setup. In the corresponding paper in Nature Communications (Peña 2014), we could also clarify the relation between this single transmission channel and the internal localized modes in the system. For the case of surface-disordered waveguides we could demonstrate how conventionally used analytical models have to be modified such as to yield quantitative agreement with the numerical data (Doppler 2014). The key effect that was apparently overlooked in the literature is the contribution from the so-called “square gradient scattering mechanism”, which our collaborators in Puebla, Mexico were working on. As we show in another paper (Dietz 2012) the understanding of such mechanisms allows us to design waveguides with transmission band-gaps in predetermined frequency intervals - a result that was also confirmed expeirmentally.

The second main focus of this project is theory and numerical modeling of the electron dynamics in quantum cascade structures. This requires suitable models for both the electronic structure and dissipative electron transport. At the mesoscopic length scales given by the devices under consideration, envelope-function-based models for the electronic structure offer several advantages. Entire device structures with applied electric fields can be analyzed self-consistently at reasonable computatioal cost. Therefore, a multiband k*p approach has been adopted by both the Kosina group (VSP) and the Vogl group (Nextnano).

For quantitative predictions of carrier transport in open, dissipative quantum systems, two different approaches have been pursued. First, a semi-classical approach based on the Pauli master equation has been employed in several design and optimization studies of quantum cascade devices in the infrafred. Second, the Keldysh non-equilibrium Green's function technique (NEGF) has been used to predict device operation in the THz range.

The Kosina group developed a transport model for quantum cascade devices based on the Pauli master equation (Baumgartner 2012). Key issues were a careful choice of physically accurate and yet computationally efficient models, numerical stability and ease of use in order to provide a versatile design tool. Theoretical studies have shown that in many practical cases the steady state transport in QCLs is incoherent and a semi-classical description can be adopted (Jirauschek 2007). Following this approach, carrier transport is modeled via scattering between energy states. Our implementation includes acoustic and optical deformation potentials, polar optical electron-phonon scattering as well as alloy, intervalley, and interface roughness scattering. The electronic states corresponding to a single stage of the QCL are determined by solving a multi-band k*p Schrödinger equation. The Hamiltonian includes the self-consistent electrostatic potential and the band edge discontinuities of the heterostructure. The states of the whole QCL device structure are assumed to be a periodic repetition of the states of a central stage. In this way, charge conservation is ensured and periodic boundary conditions can be imposed on the PME. A reliable algorithm automatically selects the periodic wavefunctions and discards the spurios ones (Baumgartner 2012). In the next step, marix elements and transistion rates for all relevant scattering mechanisms are computed. The transport equation is solved using the Monte Carlo method. Several numerical methods to reduce the computational cost of the simulation have been developed. The transport module has been implemented in the Vienna Schrödinger Poisson Solver model framework (VSP). The following optimization studies using VSP have been performed.

Bi-functional quantum cascade device: In P03 a novel quantum cascade device has been designed for same-frequency lasing and detection (Schwarz 2012). The goal for a bi-functional device is to realize the function of a QCL and a QCD using the same epilayer. Apart from wavelength matching, such a device has to provide a good injection into the upper level when acting as a laser as well as a good extraction out of the upper level when acting as a detector. Therefore, trade-offs have to be found for the design issues of a laser and of a detector To design a bi-functional active region, VSP has been used in an automatized optimization loop to simultaneously tune the performance for both the laser and the detector. The device performance is calculated from output quantities such as energy separations, dipole matrix elements, overlap integrals, or optical gain. Due to the multidimensional optimization problem, an efficent semi-classical approach had to be adopted, whereas a full quantum transport approach would have been prohibitively time consuming.

Band structure effects in QCD: In (Baumgartner 2013b) we report a numerical study of a quantum cascade detector (QCD). The incorporated model for stimulated emission and absorption of photons is essential for the description of a QCD. A mid-infrared QCD operating at a wavelength of 4.7 µm is considered. The design of a InGaAs/InAlAs QCD reported in (Giorgetta 2009) and the measurement data therein have been used to verify the bandstructure models and the transport model of VSP. Band structure effects were found to be important in achieving quantitative agreement between simulated and measured responsivity curves. A four-band k*p model is required to give sufficienlty accurate basis states. The resulting subband nonparabolicity has a signifcant effect on the predicted responsivity curve because it alters the in-plane carrier motion.

Third harmonic generation in QCL: A systematic optimization study of a QCL with integrated nonlinearity for third-harmonic generation has been performed (Mojibpour 2014). The active region needs to be designed for fundamental pump radiation emission and simultaneous third order nonlinear emission. VSP is invoked by a multi-objective particle swarm optimization algorithm to maximize the third-order susceptibility and the pump power simultaneously. The structure described in (Mosely 2004) is used as a reference structure. Our study predicts an optimized structure with a five orders of magnitude increase in the generated third-harmonic power as compared to the reference design. The design utilizes extraction and injection schemes, each based on double resonant phonon transitions.

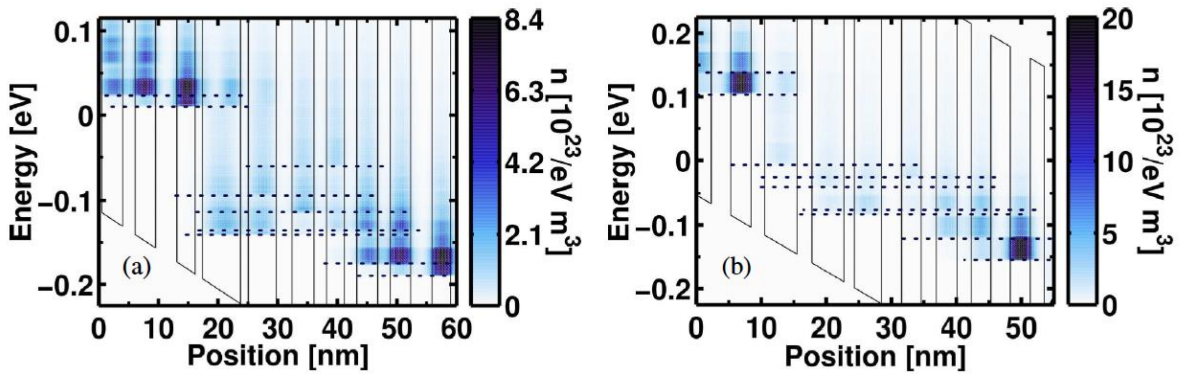

Figure 2 Energy and position-resolved electron density in a QCL optimized for third harmonics generation at 300K. Reference design (left panel), optimized design (right panel).

Instability study for a ring cavity QCL: The fast gain recovery of QCL results in two kinds of instabilities in the multimode regime. In ring cavity lasers only the Risken-Nummedal-Graham-Haken (RNGH)-like instability can occur (Gordon 2008). We have performed an optimization study of ring cavity QCL employing the particle swarm optimization method (Moradinasab 2013). The large number of simulations needed were performed using VSP. The optimizer iteratively improves the reference structure by modifying the well and barrier widths, and the applied electric field so as to achieve the maximum gain and laser operation below the instability threshold. The nonlinear dynamics of the optimized structure is then studied by a numerical solution of the Maxwell-Bloch equations. Side modes in the optical spectrum appear with increasing pumping strength or increasing saturable absorption coefficient.

Terahertz QCL: In the Vogl group a fully self-consistent non-equilibrium Green's function method has been developed to enable performance prediction and optimization of THz QCLs. Electronic transport is theoretically investigated in nanowire superlattices (SL) of varying diameters, from the quantum dot SL regime to the quantum well SL regime (Grange 2014). Scattering processes due to electron-phonon couplings, phonon anharmonicity, charged impurities, surface and interface roughness, and alloy disorder are included on a microscopic basis. Elastic scattering mechanisms are treated in a partially coherent way beyond the self-consistent Born approximation. The nature of transport along the superlattice is shown to depend dramatically on the lateral dimensionality. In the nanowire regime, the electron velocity-field characteristics are predicted to deviate strongly from the standard Esaki-Tsu form. A principal result is the prediction of room temperature operation for THz QCL based on III-V nanowire heterostructures (Grange 2013). In addition, an increase of the coherent propagation lengths in the nanowire regime is predicted, that could allow designs with larger tunneling barriers and much lower current threshold.

4. Cooperation within and outside of the SFB

The most active cooperations of the Rotter group within the SFB were carried out with the Unterrainer and with the Strasser groups (P11,P3) with whom the project on Exceptional Points was realized in a strongly collaborative fashion (Brandstetter 2014). To this project also J. Schöberl from TU-Vienna as well as H. Türeci from Princeton University contributed with their expertise on finite-element calculations and laser physics, respectively. The Yale group around A. D. Stone contributed to the project on PT-symmetry (Ambichl 2014). This group as well as the one of S. G. Johnson from MIT and the group of J. M. Melenk from TU-Vienna were involved in the work on the SALT approach (Esterhazy 2014). The microwave studies on random media were experimentally realized in the group of A. A. Chabanov from the University of San Antonio, Texas (Peña 2014). The work on shaping the emission profile of random lasers (Hisch 2013) was carried out in cooperation with F. Mintert from Freiburg University (now at Imperial College, London) and with D. Pogany from TU-Vienna, who contributed with their expertise on optimization procedures and implementation issues. Another project that was initiated within the SFB, but which has not yet reached the publication stage, is related to lasing in colloidal core/shell nanocrystal films which was observed in the group of W. Heiss (P5). Here the collaboration between the Heiss and the Rotter group is focused on a classification of the random lasing signatures with the aim to characterize and to adequately describe this phenomenon in these new systems.

Inside the SFB the Kosina group closely cooperated with P3 on quantum cascade detector modeling and providing the tool for designing the bi-funtional device (Scharz 2013).

The group also has a cooperation with Ansgar Jüngel, Professor at the Institute of Analysis and Scientific Computing at TU Vienna, on numerical methods for open quantum systems (Mennemann 2013) and participated in the Vienna Graduate School on Computational Material Science. H. Kosina cooperates with Dragica Vasileska from Arizona State University on quantum transport and thermal transport in nanostructures. In the winter term 2012 she was a visiting Professor in the group.

The development of the quantum transport code in the group of P. Vogl has benefited from theoretical support by A. Wacker from the group "Nonequlibrium Quantum Transport in Nanosystems" at Lund University, and from comparative studies of full quantum and semiclassical approaches carried out in cooperation with C. Jirauschek, head of the research group "Modeling of Quantum Cascade Devices" at TU Munich.

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For a complete list of publications of this project part please refer to 3.2.1 (List of publications)!

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Rüter, Christian E., Konstantinos G. Makris, Ramy El-Ganainy, Demetrios N. Christodoulides, Mordechai Segev, and Detlef Kip. 2010. “Observation of Parity–time Symmetry in Optics.” *Nature Physics* 6 (3): 192–95. doi:10.1038/nphys1515.

Schwarz, B., Reininger, P., Detz, H., T. Zederbauer, A. M. Andrews, S. Kalchmair, W. Schrenk, O. Baumgartner, H. Kosina, G. Strasser. 2012. "A bi-functional quantum cascade device for same-frequency lasing and detection"; Applied Physics Letters, 101 (2012), 1911091 - 1911094, doi: 10.1063/1.4767128.

Srajer, Johannes, Andreas Schwaighofer, Georg Ramer, Stefan Rotter, Bilal Guenay, Albert Kriegner, Wolfgang Knoll, Bernhard Lendl, and Christoph Nowak. 2013. “Double-Layered Nanoparticle Stacks for Surface Enhanced Infrared Absorption Spectroscopy.” *Nanoscale* 6 (1): 127–31. doi:10.1039/C3NR04726A.

Türeci, Hakan E, A Douglas Stone, Li Ge, Stefan Rotter, and Robert J Tandy. 2009. “Ab Initio Self-Consistent Laser Theory and Random Lasers.” *Nonlinearity* 22 (1): C1–C18. doi:10.1088/0951-7715/22/1/C01.

Wang, Jing, and Azriel Z. Genack. 2011. “Transport through Modes in Random Media.” *Nature* 471 (7338): 345–48. doi:10.1038/nature09824.

Wenzel, H., U. Bandelow, H. J. Wunsche, and J. Rehberg. 1996. “Mechanisms of Fast Self Pulsations in Two-Section DFB Lasers.” *Quantum Electronics, IEEE Journal of* 32 (1): 6 9–78 doi: 10.1109/3.481922.

5. CV of Stefan Rotter – Project Part 14

Personal data

Date and place of birth:	Aug. 12th 1975, Vienna, Austria
Nationality:	Austrian
Present employment	Vienna University of Technology (TU Vienna)
	Wiedner Hauptstraße 8-10/136, A-1040 Vienna, Austria
Phone:	+43 1 58801 13618
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Career history

1999	Diploma Degree in Technical Physics (with distinction), TU-Vienna (university studies partially at Ecole Polytechnique Fédérale de Lausanne, CH)
1999-2000	Alternative service (instead of compulsory military duty) at the Anne Frank Foundation, Amsterdam, the Netherlands
2004	PhD Degree in Physics (with distinction), TU-Vienna
2000-2006, 2008-2010	Research and Teaching Assistant
	Institute for Theoretical Physics, TU Vienna
2006-2008	Postdoctoral Associate and Fellow of the Max Kade and of the W.M. Keck Foundation, Department of Applied Physics, Yale University, USA
2011-2013	Professor for Theoretical Physics (tenure track position), TU Vienna
since 2013	Tenured full professor for Theoretical Physics, TU Vienna

Publications

Around 45 refereed publications in scientific journals (1 Science, 1 Nature Communication (+1 accepted), 9 PRLs, 1 PRX, 2 NJP, 1 APL, 1 EPL, 1 cover article in Nonlinearity, 1 book chapter) and several more unrefereed conference proceedings as well as invited popular science papers (Nature Physics, SPIE Newsroom)

Research Interests

Laser theory, nonlinear optics, complex wave scattering, quantum chaos, cavity quantum electrodynamics, coherent electron transport, topological insulators, graphene

Academic Honours and Awards (five most relevant)

• Max Kade Fellowship, Austrian Academy of Sciences (2005)

• W.M. Keck Fellowship, Yale University (2007)

• Science Prize (Wissenschaftspreis), Province of Lower Austria (2008)

• High potential funding, Vienna Science Fund (WWTF, 2009)

• Invited one week lecture series on quantum scattering, Heidelberg Graduate School (2010)

Invited conference talks (five most recent)

• 9th International Workshop on Disordered Systems, San Antonio, Texas (2014)

• Summer school "Waves and disorder", Cargèse, Corsica, France (2014)

• 9th Int. Conference on chaos and nonlinear dynamics, Maribor, Slovenia (2014)

• Workshop on Coherent Phenomena in Disordered Optical Systems, ICTP, Trieste (2014)

• 44th Winter Colloquium on the Physics of Quantum Electronics, Snowbird, Utah (2014)

Funded research projects (five most relevant)

• “Generating particle-like scattering states in absorptive wave transport” I1142-N27, bi-national project funded as project PI (in Austria) with 115k€ by the Austrian Science Fund (FWF), 2013-2016 (French partner: U. Kuhl, Nice);

• “Nonlinear phenomena in complex photonic structures” F49-P10, funded as project PI with 300k€ by the Austrian Science Fund (FWF) within the special research project SFB NextLite “Next Generation Light Synthesis and Interaction” (Project 10), 2013-2017;

• “Nonlinear lasing phenomena in complex media” NOLACAOME 303228, funded as project host with 260k€ by the European Union (International Marie Curie Outgoing Fellowship with Princeton University as outgoing institution), 2012-2015;

• “Light coupling to light: Non-linear interactions in semiconductor micro-lasers” LICOTOLI MA09-030, funded as PI with 495k€ by the Vienna Science and Technology Fund (WWTF), 2010-2015;

• “Interplay between the mesoscopic Stoner and Kondo effects”, postdoctoral scholarships (90kUS$) by the Max Kade and W. M. Keck Foundations, 2006-2008;

International cooperations (last five years)

Prof. Yoram Alhassid (Yale University), Prof. Andrey Chabanov (University of Texas at San Antonio), Prof. Yidong Chong (Nanyang Technological University), Dr. Li Ge (College of Staten Island, CUNY), Dr. Peter Geltenbort (ILL, Grenoble), Prof. Sylvain Gigan (Institut Langevin, ESPCI, Paris), Prof. Felix Izrailev (Universidad Autonoma de Puebla), Prof. Steven G. Johnson (MIT), Prof. Roland Ketzmerick (TU Dresden), Prof. Ulrich Kuhl (Universite de Nice Sophia Antipolis), Prof. Massimo Macucci (Universita di Pisa), Prof. Nikolay M. Makarov (Puebla, Mexico), Dr. Florian Mintert (Freiburg Institute for Advances Studies), Prof. Patrick Sebbah (Institut Langevin, ESPCI, Paris), Prof. Christoph Stampfer (RWTH Aachen), Prof. A. Douglas Stone (Yale University), Prof. Hans-Jürgen Stöckmann (Philipps Universität Marburg), Prof. Hakan Türeci (Princeton University), Prof. Ludger Wirtz (University of Luxembourg)

Refereeing and community service

Referee services were provided for the following journals: Science, Nature, Nature Physics, Nature Communications, Review of Modern Physics, Physical Review Letters, Physical Review A & B, Physics Letters B, Physica E, European Physics Journal, New Journal of Physics, Semiconductor Science and Technology, Waves in Random and Complex Media, Journal of Physics, Chaos, and Journal of Computational Physics.

Member of PhD Committees and PhD reviewer at ENS Cachan, University of Erlangen-Nuremberg, Institut Langevin Paris, Comenius University Bratislava and TU-Vienna.

Referee for proposals of the French Science Fund (ANR).

Popular Science

1 invited News & Views article in Nature Physics, 1 invited SPIE Newsroom article, several presentations about “Physics and Music” on Austrian public radio (Ö1) and invited talks at science festivals and seminars (Spiel.Raum.Physik, Vienna Science Salon, Metalab etc.)

Work highlighted in the following media

Science Perspective, Nature News, Physics Today Newspick, Physical Review Focus, Physics Viewpoint, PRL Editor’s Suggestion, Physics World, Yahoo News, Optics.org, Science Daily, Photonics, Physical Review Kaleidoscope, La Recherche, Science Daily, Laser Focus World, PhysOrg, COSMonline, Scinexx, Photonics Spectra, Imaging & Microscopy, Pro-Physik, Der Standard, Die Presse, ORF, Wiener Zeitung, ETH-Life, New Haven Register, Chilli, as well as in press releases of Yale, ETH–Zürich, ILL and TU-Vienna. Cover image of the journal Nonlinearity in the year 2009.

List of refereed publications (last five years, only those not listed in 3.2 are shown)

S. Putz, D. O. Krimer, R. Amsüss, A. Valookaran, T. Nöbauer, J. Schmiedmayer, S. Rotter, and J. Majer (2014), Protecting a spin ensemble against decoherence in the strong-coupling regime of cavity QED, Nature Physics (under review), arXiv:1404.4169

J. Doppler, J. A. Méndez-Bermúdez, J. Feist, O. Dietz, D. O. Krimer, N. M. Makarov, F. M. Izrailev, and S. Rotter (2014), Reflection resonances in surface-disordered waveguides: strong higher-order effects of the disorder, New J. Phys. 16, 053026, DOI: 10.1088/1367-2630/16/5/053026

Jenke T., G. Cronenberg, J. Burgdörfer, L. A. Chizhova, P. Geltenbort, A. N. Ivanov, T. Lauer, T. Lins, S. Rotter, H. Saul, U. Schmidt, H. Abele (2014), Gravity resonance spectroscopy constrains dark energy and dark matter scenarios, Phys. Rev. Lett. 112, 151105, DOI: 10.1103/PhysRevLett.112.151105 (selected for Physics Viewpoint, Nature News, PRL Editors' Suggestion)

Girschik A., F. Libisch, and S. Rotter (2012), Topological insulator in the presence of spatially correlated disorder, Phys. Rev. B 88, 014201, DOI: 10.1103/PhysRevB.88.014201

Chizhova L.A., S. Rotter, T. Jenke, G. Cronenberg, P. Geltenbort, H. Abele, and J. Burgdörfer (2012), Transport of ultracold neutrons through a mirror system with surface roughness as a velocity filter, Phys. Rev. E 89, 032907, DOI: 10.1103/PhysRevE.89.032907

Dietz O., H.-J. Stöckmann, U. Kuhl, F. M. Izrailev, N. M. Makarov, J. Doppler, F. Libisch, S. Rotter (2012), Surface Scattering and Band Gaps in Rough Nanowires and Waveguides, Phys. Rev. B Rapid Comm. 86, 201106(R), DOI:10.1103/PhysRevB.86.201106

Libisch F., S. Rotter and J. Burgdörfer (2012), Transport through graphene nanoribbons: suppression of transverse quantization by symmetry breaking, New J. Phys. 14, 123006, DOI:10.1088/1367-2630/14/12/123006

Libisch L., S. Rotter, and J. Burgdörfer (2011), Disorder scattering in graphene nanoribbons, Phys. Status Solidi B 11, 2598, DOI: 10.1002/pssb.201100157

Ge L., Y.D. Chong, S. Rotter, H.E. Türeci, and A.D. Stone (2011), Unconventional modes in lasers with spatially varying gain and loss, Phys. Rev. A 84, 023820, DOI: 10.1103/PhysRevA.84.023820

Amsüss R., C. Koller, T. Nöbauer, S. Putz, S. Rotter, K. Sandner, S. Schneider, M. Schramböck, G. Steinhauser, H. Ritsch, J. Schmiedmayer and J. Majer (2011), Cavity QED with magnetically coupled collective spin states, Phys. Rev. Lett. 107, 060502, DOI: 10.1103/PhysRevLett.107.060502

Rotter S., P. Ambichl and F. Libisch (2011), Generating particle-like scattering states in wave transport, Phys. Rev. Lett. 106, 120602, DOI: 10.1103/PhysRevLett.106.120602 (highlighted in Physics Focus)

Bärnthaler A., S. Rotter, F. Libisch, J. Burgdörfer, S. Gehler, U. Kuhl and H.-J. Stöckmann (2010), Probing decoherence through Fano resonances, Phys. Rev. Lett. 105, 056801, DOI: 10.1103/PhysRevLett.105.056801

Libisch F., S. Rotter, J. Güttinger, C. Stampfer and J. Burgdörfer (2010), Transition to Landau levels in graphene quantum dots, Phys. Rev. B 81, 245411, DOI: 10.1103/PhysRevB.81.245411

Brezinova I., L. Wirtz, S. Rotter, C. Stampfer and J. Burgdörfer (2010), Transport through open quantum dots: Making semiclassics quantitative, Phys. Rev. B 81, 125308, DOI: 10.1103/PhysRev B.81.125308

Totaro M., M. Marconcini, S. Rotter, D. Logoteta and M. Macucci (2009), Using gate voltages to tune the noise properties of a mesoscopic cavity, AIP Conf. Proc. 1129, 409, DOI: 10.1063/1.3140486

Feist J., A. Bäcker, R. Ketzmerick, J. Burgdörfer and S. Rotter (2009), Nanowires with surface disorder: Giant localization lengths and dynamical tunneling in the presence of directed chaos, Phys. Rev. B 80, 245322, DOI: 10.1103/PhysRevB.80.245322

Rotter S. and Y. Alhassid (2009), The strong-coupling limit of a Kondo spin coupled to a mesoscopic quantum dot: Effective Hamiltonian in the presence of exchange correlations, Phys. Rev. B 80, 184404, DOI: 10.1103/PhysRevB.80.184404

Türeci H.E., A.D. Stone, L. Ge, S. Rotter and R.J. Tandy (2009), Ab initio self–consistent laser theory and random lasers, Nonlinearity 22, 1, DOI: 10.1088/0951-7715/22/1/C01

10 most important publications (out of those not listed in 3.2)

S. Putz, D. O. Krimer, R. Amsüss, A. Valookaran, T. Nöbauer, J. Schmiedmayer, S. Rotter, and J. Majer (2014), Protecting a spin ensemble against decoherence in the strong-coupling regime of cavity QED, Nature Physics (under review), arXiv:1404.4169

Jenke T., G. Cronenberg, J. Burgdörfer, L. A. Chizhova, P. Geltenbort, A. N. Ivanov, T. Lauer, T. Lins, S. Rotter, H. Saul, U. Schmidt, H. Abele (2014), Gravity resonance spectroscopy constrains dark energy and dark matter scenarios, Phys. Rev. Lett. 112, 151105, DOI: 10.1103/PhysRevLett.112.151105 (selected for Physics Viewpoint, Nature News, PRL Editors' Suggestion)

Rotter S., P. Ambichl and F. Libisch (2011), Generating particle-like scattering states in wave transport, Phys. Rev. Lett. 106, 120602, DOI: 10.1103/PhysRevLett.106.120602 (highlighted in Physics Focus)

Amsüss R., C. Koller, T. Nöbauer, S. Putz, S. Rotter, K. Sandner, S. Schneider, M. Schramböck, G. Steinhauser, H. Ritsch, J. Schmiedmayer and J. Majer (2011), Cavity QED with magnetically coupled collective spin states, Phys. Rev. Lett. 107, 060502, DOI: 10.1103/PhysRevLett.107.060502

Burgdörfer J., S. Rotter, Quantum mechanics (2009), Chapter 1 (invited) in the Encyclopedia of Applied High Energy and Particle Physics, R. Stock (ed.), Wiley (selected as sample chapter for the promotion of the encyclopedia, see Link)

Feist J., A. Bäcker, R. Ketzmerick, S. Rotter, B. Huckestein, and J. Burgdörfer (2006), Nanowires with surface disorder: Giant localization length and quantum-to-classical crossover", Phys. Rev. Lett. 97, 116804, DOI: 10.1103/PhysRevLett.97.116804

Türeci H.E., L. Ge, S. Rotter and A.D. Stone (2008), Strong interactions in multimode random lasers, Science 320, 643, DOI: 10.1126/science.1155311 (selected for Science Perspectives)

Rotter S., H.E. Türeci, Y. Alhassid and A.D. Stone (2008), Interacting quantum dot coupled to a Kondo spin: A Universal Hamiltonian study, Phys. Rev. Lett. 100, 166601, DOI: 10.1103/PhysRev.Lett.100.166601

Aigner F., S. Rotter, and J. Burgdörfer (2005), Shot noise in the chaotic-to-regular crossover regime, Phys. Rev. Lett. 94, 216801, DOI: 10.1103/PhysRevLett.94.216801

Rotter S., J.-Z. Tang, L. Wirtz, J. Trost, and J. Burgdörfer (2000), Modular recursive Green's function method for ballistic quantum transport, Phys. Rev. B 62, 1950 DOI: 10.1103/PhysRevB.62.1950

5.1 CV of Hans Kosina – Project Part 14

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Personal data

Date and place of birth:	28.12.1961, Haidershofen, Austria
Nationality:	Austrian
Personal Homepage:	http://www.iue.tuwien.ac.at/
University education	
1987	Diploma degree in Electrical Engineering, TU Wien
1992	Doctoral degree in technical sciences, TU Wien
1997	Habilitation in Microelectronics, TU-Wien
Career History	
1987 - 1988	Project assistant, Inst.f. flexible Automation, TU Wien
1988 - 1998	Assistant professor, Inst. f. Microelectronics, TU Wien
since 1998	Associate professeor, Inst. f. Microelectronics, TU Wien

Publications

36 contributions to books, 145 publications in scientific journals, 268 contributions to conference proceedings

Research Interests

Technology CAD, semiconductor device modelling, electronic transport in nanostructures, Monte Carlo methods for classical and quantum transport, modeling of carbon nanotube and graphene-based devices, nanostructured thermoelectric energy converters, optoelectronic devices, quantum cascade lasers, and nanowire devices.

Associate Editor of the following journals

Journal of Computational Electronics;
IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems.

Refereeing for the following journals

Journal of Computational Electronics, IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, IEEE Transactions on Electron Devices, IEEE Transactions on Nanotechnology, Solid State Electronics, Journal of Applied Physics, Journal of Mathematical Physics, and others.

Publications in journals and books (last 5 years)

1. H. Karamitaheri, N. Neophytou, H. Kosina: "*Anomalous diameter dependence of thermal transport in ultra-narrow Si nanowires*";Journal of Applied Physics, **115** (2014), 024302_1 - 024302_7, doi:10.1063/1.4858375.
2. O Baumgartner, Z. Stanojevic, K. Schnass, M. Karner, H. Kosina: "*VSP-a quantum-electronic simulation framework*"; Journal of Computational Electronics, **12** (2013), 701 – 721, doi: 10.1007/s10825-013-0535-y.
3. H. Karamitaheri, N. Neophytou, M. Karami Taheri, R. Faez, H. Kosina: *"Calculation of Confined Phonon Spectrum in Narrow Silicon Nanowires Using the Valence Force Field Method";* Journal of Electronic Materials, **42** (2013), 2091 - 2097
4. H. Karamitaheri, N. Neophytou, H. Kosina: *"Ballistic Phonon Transport in Ultra-Thin Silicon Layers: Effects of Confinement and Orientation";* Journal of Applied Physics, 113 (2013), 204305-1 - 204305-9, doi:10.1063/1.4808100.
5. H. Karamitaheri, M. Pourfath, R. Faez, H. Kosina: *"Atomistic Study of the Lattice Thermal Conductivity of Rough Graphene Nanoribbons";* IEEE Transactions on Electron Devices, 60 (2013), 2142 – 2147, doi: 10.1109/TED.2013.2262049.
6. J.-F. Mennemann, A. Jüngel, H. Kosina: *"Transient Schrödinger-Poisson simulations of a high-frequency resonant tunneling diode oscillator";* Journal of Computational Physics, 239 (2013), 187 – 205, doi: 10.1016/j.jcp.2012.12.009.
7. N. Neophytou, H. Kosina: *"Optimizing Thermoelectric Power Factor by Means of a Potential Barrier";* Journal of Applied Physics, 114 (2013), 044315_1 - 044315-6, doi:10.1063/1.4816792.
8. N. Neophytou, X. Zianni, H. Kosina, S. Frabboni, B. Lorenzi, D. Narducci: *"Simultaneous Increase in Electrical Conductivity and Seebeck Coefficient in Highly Boron-Doped* Nanocrystalline Si"; Nanotechnology, 24 (2013), 205402, doi: 10.1088/0957-4484/24/20/205402.
9. H. Karamitaheri, N. Neophytou, M. Pourfath, R. Faez, H. Kosina: "*Engineering Enhanced Thermoelectric Properties in Zigzag Graphene Nanoribbons*"; Journal of Applied Physics, **111** (2012), 5; 054501-1 - 054501-9, doi: 10.1063/1.3688034.
10. H. Karamitaheri, N. Neophytou, M. Pourfath, H. Kosina: "*Study of Thermal Properties of Graphene-Based Structures using the Force Constant Method*"; Journal of Computational Electronics (invited), **11** (2012), 1; 14 – 21, doi: 10.1007/s10825-011-0380-9.
11. M. Moradinasab, H. Nematian, M. Pourfath, M. Fathipour, H. Kosina: "*Analytical Models of Approximations for Wave Functions and Energy Dispersion in Zigzag Graphene Nanoribbons*"; Journal of Applied Physics, **111** (2012), 7; 074318-1 - 074318-9, doi:10.1063/1.3702429.
12. H. Nematian, M. Moradinasab, M. Pourfath, M. Fathipour, H. Kosina: "*Optical Properties of Armchair Graphene Nanoribbons Embedded in Hexagonal Boron Nitride Lattices*"; Journal of Applied Physics, **111** (2012), 093512-1 - 093512-6, doi: 10.1063/1.4710988.
13. N. Neophytou, H. Kosina: "*Bias-Induced Hole Mobility Increase in Narrow [111] and [110] Si Nanowire Transistors*"; IEEE Electron Device Letters, **33** (2012), 5; 652 – 654, doi: 10.1109/LED.2012.2188879.

14. N. Neophytou, H. Kosina: "*Confinement-Induced Carrier Mobility Increase in Nanowires by Quantization of Warped Bands*"; Solid-State Electronics, **70** (2012), 81 – 91, doi: 10.1016/j.sse.2011.11.018.

15. N. Neophytou, H. Kosina: "*Large Thermoelectric Power Factor in P-Type Si (110)/[110] Ultra-Thin-Layers Compared to Differently Oriented Channels*"; Journal of Applied Physics, **112** (2012), 2; 024305-1 - 024305-6, doi:10.1063/1.4737122.

16. N. Neophytou, H. Kosina: "*Numerical Study of the Thermoelectric Power Factor in Ultra-Thin Si Nanowires*"; Journal of Computational Electronics (invited), **11** (2012), 1; 29 – 44, doi:10.1007/s10825-012-0383-1.

17. N. Neophytou, H. Kosina: "*On the Interplay between Electrical Conductivity and Seebeck Coefficient in Ultra-Narrow Silicon Nanowires*"; Journal of Electronic Materials, **41** (2012), 6; 1305 – 1311, doi: 10.1007/s11664-011-1891-7.

18. Z. Stanojevic, V. Sverdlov, O. Baumgartner, H. Kosina: "*Subband Engineering in N-Type Silicon Nanowires using Strain and Confinement*"; Solid-State Electronics, **70** (2012), 73 – 80, doi: 10.1016/j.sse.2011.11.022.

19. A. Yazdanpanah Goharrizi, M. Pourfath, M. Fathipour, H. Kosina, S. Selberherr: "*A Numerical Study of Line-Edge Roughness Scattering in Graphene Nanoribbons*"; IEEE Transactions on Electron Devices, **59** (2012), 2; 433 – 440, doi: 10.1109/TED.2011.2173690.

20. J. Cervenka, H. Kosina, S. Selberherr, J. Zhang, N. Hrauda, J. Stangl, G. Bauer, G. Vastola, A. Marzegalli, F. Montalenti, L. Miglio: "*Strained MOSFETs on Ordered SiGe Dots*"; Solid-State Electronics, **65-66** (2011), 81 – 87, doi: 10.1016/j.sse.2011.06.041.

21. H. Karamitaheri, M. Pourfath, R. Faez, H. Kosina: "*Geometrical Effects on the Thermoelectric Properties of Ballistic Graphene Antidot Lattices*"; Journal of Applied Physics, **110** (2011), 5; 054506-1 - 054506-6, doi: 10.1063/1.3629990.

22. H. Karamitaheri, M. Pourfath, M. Pazoki, R. Faez, H. Kosina: "*Graphene-Based Antidots for Thermoelectric Applications*"; Journal of the Electrochemical Society, **158** (2011), 12; K213 - K216, doi: 10.1149/2.025112jes.

23. N. Neophytou, G. Klimeck, H. Kosina: "*Subband Engineering for P-Type Silicon Ultra-Thin Layers for Increased Carrier Velocities*"; Journal of Applied Physics, **109** (2011), 053721-1 - 053721-6, doi: 10.1063/1.3556435.

24. N. Neophytou, H. Kosina: "*Atomistic Simulations of Low-Field Mobility in Si Nanowires: Influence of Confinement and Orientation*"; Physical Review B, **84** (2011), 085313-1 - 085313-15, doi: 10.1103/PhysRevB.84.085313.

25. N. Neophytou, H. Kosina: "*Effects of Confinement and Orientation on the Thermoelectric Power Factor of Silicon Nanowires*"; Physical Review B, **83** (2011), 245305-1 - 245305-16, doi: 10.1103/PhysRevB.83.245305.

26. N. Neophytou, H. Kosina: "*Hole Mobility Increase in Ultra-Narrow Si Channels under Strong (110) Surface Confinement*"; Applied Physics Letters, **99** (2011), 092110-1 - 092110-3, doi: 10.1063/1.4879242.

27. N. Neophytou, H. Kosina: "*Thermoelectric Properties of Ultra Scaled Silicon Nanowires Using the sp3d5s*-SO Atomistic Tight-Binding Model and Boltzmann Transport*";

Journal of Electronic Materials, **40** (2011), 5; 753 – 758, doi: 10.1007/s11664-011-1542-z.

28. A. Yazdanpanah Goharrizi, M. Pourfath, M. Fathipour, H. Kosina, S. Selberherr: "*An Analytical Model for Line-Edge Roughness Limited Mobility of Graphene Nanoribbons*"; IEEE Transactions on Electron Devices, **58** (2011), 11; 3725 – 3735, doi: 10.1109/TED.2011.2163719.
29. O. Baumgartner, M. Karner, V. Sverdlov, H. Kosina: "*Electron Subband Structure in Strained Silicon UTB Films from the Hensel-Hasegawa-Nakayama Model - Part 2 Efficient Self-Consistent Numerical Solution of the k.p Schrödinger Equation*"; Solid-State Electronics, **54** (2010), 143 – 148, doi: 10.1016/j.sse.2009.12.010.
30. A. Lugstein, M. Steinmair, A. Steiger-Thirsfeld, H. Kosina, E. Bertagnolli: "*Anomalous Piezoresistance Effect in Ultrastrained Silicon Nanowires*"; Nano Letters, **10** (2010), 3204 – 3208, doi: 10.1021/nl102179c.
31. G. Milovanovic, H. Kosina: "*A Semiclassical Transport Model for Quantum Cascade Lasers based on the Pauli Master Equation*"; Journal of Computational Electronics, **9** (2010), 3-4; 211 – 217, doi: 10.1007/s10825-010-0325-8.
32. M. Nedjalkov, H. Kosina, P. Schwaha: "*Device Modeling in the Wigner Picture*"; Journal of Computational Electronics, **9** (2010), 3-4; 218 – 223, doi: 10.1007/s10825-010-0316-9.
33. N. Neophytou, S. Kim, G. Klimeck, H. Kosina: "*On the Bandstructure Velocity and Ballistic Current of Ultra-Narrow Silicon Nanowire Transistors as a Function of Cross Section Size, Orientation, and Bias*"; Journal of Applied Physics, **107** (2010), 113701-1 - 113701-9, doi: 10.1063/1.3372764.
34. N. Neophytou, H. Kosina: "*Large Enhancement in Hole Velocity and Mobility in p-type [110] and [111] Silicon Nanowires by Cross Section Scaling: An Atomistic Analysis*"; Nano Letters, **10** (2010), 4913 – 4919, doi: 10.1021/nl102875k.
35. N. Neophytou, M. Wagner, H. Kosina, S. Selberherr: "*Analysis of Thermoelectric Properties of Scaled Silicon Nanowires Using an Atomistic Tight-Binding Model*"; Journal of Electronic Materials, **39** (2010), 9; 1902 – 1908, doi: 10.1007/s11664-009-1035-5.
36. H. Kosina, S. Selberherr: "*The Field of Computational Electronics from a European Perspective (Guest Editorial)*"; Journal of Computational Electronics, **8** (2009), 3-4; 173, doi: 10.1007/s10825-009-0302-2.
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38. O. Baumgartner, Z. Stanojevic, H. Kosina: "*Monte Carlo Simulation of Electron Transport in Quantum Cascade Lasers";* in "*Monte Carlo Methods and Applications*", K. K. Sabelfeld, I. Dimov (ed); De Gruyter, 2012, ISBN: 978-3-11-029347-0, 59 - 67.
39. H. Karamitaheri, M. Pourfath, R. Faez, H. Kosina: "*An Investigation of the Geometrical Effects on the Thermal Conductivity of Graphene Antidot Lattices*"; in: "*Dielectrics in Nanosystems -and- Graphene, Ge/III-V, Nanowires and Emerging Materials for Post-CMOS Applications 3*", Z. Karim, D. Misra, P.

Srinivasan, Y. Obeng, S. De Gendt (ed.); ECS Transactions, 2011, ISBN: 978-1-56677-864-0, 185 - 192.

40. M. Nedjalkov, D. Querlioz, P. Dollfus, H. Kosina: "*Wigner Function Approach*"; in: "*Nano-Electronic Devices: Semiclassical and Quantum Transport Modeling*", D. Vasileska, S.M. Goodnick (ed.); Springer, 2011, (invited), ISBN: 978-1-4419-8839-3, 289 - 358.

41. M. Pourfath, H. Kosina: "*Numerical Study of Quantum Transport in Carbon Nanotube-Based Transistors*"; in: "*Encyclopedia of Nanoscience and Nanotechnology*", H. Nalwa (ed.); American Scientific Publishers, 2011, ISBN: 1-58883-168-x, 541 - 581.

42. M. Vasicek, V. Sverdlov, J. Cervenka, T. Grasser, H. Kosina, S. Selberherr: "*Transport in Nanostructures: A Comparative Analysis Using Monte Carlo Simulation, the Spherical Harmonic Method, and Higher Moments Models*"; in: "*Lecture Notes in Computer Science, Vol. 5910*", I. Lirkov, S. Margenov, J. Wasniewski (ed.); Springer, 2010, ISSN: 0302-9743, 443 - 450.

10 most important publications

1. O. Baumgartner, Z. Stanojevic, K. Schnass, M. Karner, H. Kosina: "*VSP-a quantum-electronic simulation framework*"; Journal of Computational Electronics, 12 (2013), 701 – 721, doi: 10.1007/s10825-013-0535-y

2. H. Karamitaheri, N. Neophytou, H. Kosina: "*Ballistic Phonon Transport in Ultra-Thin Silicon Layers: Effects of Confinement and Orientation*";Journal of Applied Physics, 113 (2013), 204305-1 - 204305-9, doi:10.1063/1.4808100.

3. J.-F. Mennemann, A. Jüngel, H. Kosina: *"Transient Schrödinger-Poisson simulations of a high-frequency resonant tunneling diode oscillator";*Journal of Computational Physics, 239 (2013), 187 – 205, doi: 10.1016/j.jcp.2012.12.009

4. N. Neophytou, X. Zianni, H. Kosina, S. Frabboni, B. Lorenzi, D. Narducci: *"Simultaneous Increase in Electrical Conductivity and Seebeck Coefficient in Highly Boron-Doped Nanocrystalline Si";*Nanotechnology, 24 (2013), 205402, doi: 10.1088/0957-4484/24/20/205402

5. N. Neophytou, H. Kosina: "*Large Thermoelectric Power Factor in P-Type Si (110)/[110] Ultra-Thin-Layers Compared to Differently Oriented Channels*"; Journal of Applied Physics, 112 (2012), 2; 024305-1 - 024305-6, doi:10.1063/1.4737122.

6. Z. Stanojevic, V. Sverdlov, O. Baumgartner, H. Kosina: "*Subband Engineering in N-Type Silicon Nanowires using Strain and Confinement*"; Solid-State Electronics, 70 (2012), 73 - 80, doi: 10.1063/1.3556435.

7. H. Karamitaheri, M. Pourfath, R. Faez, H. Kosina: "*Geometrical Effects on the Thermoelectric Properties of Ballistic Graphene Antidot Lattices*"; Journal of Applied Physics, 110 (2011), 5; 054506-1 - 054506-6, doi: 10.1063/1.3629990.

8. N. Neophytou, H. Kosina: "*Effects of Confinement and Orientation on the Thermoelectric Power Factor of Silicon Nanowires*"; Physical Review B, 83 (2011), 245305-1 - 245305-16, doi: 10.1103/PhysRevB.83.245305.

9. M. Pourfath, H. Kosina: *"Numerical Study of Quantum Transport in Carbon Nanotube-Based Transistors";*in "*Encyclopedia of Nanoscience and Nanotechnology*", H. Nalwa (ed); American Scientific Publishers, 2011, ISBN: 1-58883-168-x, 541 - 581.

10. H. Kosina, M. Nedjalkov: "*Wigner Function-Based Device Modeling*"; in: "*Handbook of Theoretical and Computational Nanotechnology*", issued by: Forschungszentrum Karlsruhe; American Scientific Publishers, Los Angeles, 2006, ISBN: 1-58883-042-x, 731 – 763.

5.2. Curriculum vitae of Peter Vogl

Present employment

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Personal Data

Birth:	3/19/1949; Graz, Austria
Marital Status:	Married, one daughter (born 1977) and one son (born 1979)
Citizenship:	Austrian
Scientific Societies:	German Physical Society, Austrian Physical Society, American Physical Society, Corresponding Member of the International Center for Theoretical Physics in Trieste (Italy)
Honors:	Fulbright travel grant for research in the US, 1977
	Max-Kade grant for research in the US, 1986
	Fellowship of Japan Society for the Promotion of Science, Japan, 1996
Education:	Habilitation in theoretical physics, March 1980, University of Graz
	PhD in Physics, Nov. 1974 University of Graz, Graz, Austria
	Study of theoretical physics and mathematics at the University of Graz, 1968-1974
	Gymnasium Bruck/Mur, Austria, 1959-1967

Field of specialization

Theoretical Solid State Physics

Professional Experience

2000-2003: Vice Dean of faculty of physics, Technische Universität München

1998-1999: Dean of faculty of physics, Technische Universität München

Since 1990: Chairman and member of several committees at Technische Universität München (faculty of physics board, full professor search committees, examiners' board, board for curriculum reform, board for international affairs, codirector of TUM institute for teacher's education)

Conference organizations:

Coorganizer MSS-6 in Garmisch-Partenkirchen, 1993,

Program Chairman HCIS-10 Berlin, 1997,

Coorganizer IEEE-NANO2004 in München, 2004

Several workshops

Scientific services

Referee for Physical Review, Physical Review Letters, Journal of Applied Physics, Applied Physics Letters, Solid State Communications, J. Physics and others.

Scientific activities

Emphasis on electronic structure and charge carrier transport in semiconductors, ferroelectrics, magnetic materials and conducting polymers.

Citation Classics: Theory of deep impurities 1980 (#12), Tight binding model of semiconductors 1983 (#26)

Employment

3/93-present: Full Professor (Ordinarius f. Theoretische Physik)

Walter Schottky Institut and Physik Department der Techn. Univ. München, T 33,

D-85748 Garching, Germany.

2/90-2/93: Associate Professor (außerord. Universitätsprofessor, C3)

Physik Department der Techn. Univ. München, T 30, D-85748 Garching, Germany.

3/80-2/90: Assistant Professor (Assistenzprofessor)

Institute for Theoretical Physics,University of Graz, A-8010, Austria.

4/86-5/87. Visiting scientist (collaborator)

Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM 87545, USA.

10/81-7/83.Visiting staff member.

Max-Planck-Institute for Solid State Research, D-7000 Stuttgart 80, Germany.

1/75-2/80.Assistant Professor (Universitätsassistent)

Institute for Theoretical Physics,University of Graz, A-8010 Austria.

12/77-1/79.Research Associate.

University of Illinois,Dept. of Physics,Urbana,IL 60801,USA.

2/71-1/75.Teaching Assistant.

Institute for Theoretical Physics,University of Graz, A-8010 Austria.

Research Fundings as principal investigator

"Modeling and simulation of Semiconductor Nanostructures", Award # N000140110242, Office of Naval Research, USA, 2001-2004, 189 US K$

"Modeling of electronic properties and spin-selective carrier dynamics of nanometer devices", Center of Excellence SFB 348, Deutsche Forschungsgemeinschaft, 2001-2003, 240 K€

"Theory of spin relaxation and spin dependent tunneling processes in low-dimensional semiconductor structures", Center of Excellence SFB 631, Deutsche Forschungsgemeinschaft, 2003-2007, 300 K€

"Two-dimensional quantum mechanical simulation for sub-25nm SIO transistors", Infineon Technologies AG, since 1998, 40-100 K€/year

List of pubications (last five years)

1. T. Andlauer, T. Zibold, P. Vogl, "Self-consistent electronic structure method for broken-gap superlattices", Proc. SPIE 7222, 722211 (2009), doi: 10.1117/12.814677.

2. T. Kubis, P. Vogl, "Predictive Quantum Theory of Current and Optical Gain in Quantum Cascade Lasers", Laser Physics 19, 762 (2009), doi: 10.1134/S1054660X0904032X.

3. T. Kubis, P. Vogl, "Predictive quantum theory of current and optical emission in quantum cascade lasers", Proc. SPIE 7230, 723019 (2009), doi: 10.1117/12.808483.

4. C. Schindler, P. Vogl, "Prediction of giant intrinsic spin-Hall effect in strained p-GaAs quantum wells", Journal of Physics: Conference Series 193, 012103 (2009).

5. H. Yasuda, T. Kubis, P. Vogl, N. Sekine, I. Hosako, K. Hirakawa, "Nonequilibrium Green's function calculation for four-level scheme terahertz quantum cascade lasers", Appl. Phys. Lett. 94, 151109 (2009), doi: 10.1088/1742-6596/193/1/012103.

6. T. Kubis, P. Vogl, "How periodic are terahertz quantum cascade lasers?", Journal of Physics: Conference Series 193, 012063 (2009), doi:10.1088/1742-6596/193/1/012063.

7. M. Kugler, T. Andlauer, T. Korn, A. Wagner, S. Fehringer, R. Schulz, M. Kubová, C. Gerl, D. Schuh, W. Wegscheider, P. Vogl, C. Schüller, "Gate control of low-temperature spin dynamics in two-dimensional hole systems", Physical Review B 80, 035325 (2009), doi: 10.1103/PhysRevB.80.035325.

8. T. Andlauer, P. Vogl, "Full-band envelope function approach for type-II broken-gap superlattices", Physical Review B 80, 035304 (2009), doi: 10.1103/PhysRevB.80.035304.

9. T. Andlauer, P. Vogl, "Electrically controllable g tensors in quantum dot molecules", Physical Review B 79, 045307 (2009) [selected as Physical Review Editors' Suggestion; selected by David P. DiVincenzo for Virtual Journal of Quantum Information Vol. 9, Issue 1 (Jan 2009); selected by David Awschalom for Virtual Journal of Nanoscale Science & Technology Vol. 19, Issue 4 (Jan 26, 2009); selected for a Viewpoint in Physics 2, 16 (2009)], doi: 10.1103/PhysRevB.79.045307.

10. S. Birner, C. Schindler, P. Greck, M. Sabathil, P. Vogl, "Ballistic quantum transport using the contact block reduction (CBR) method", Journal of Computational Electronics 8 (3), 267-286 (2009), doi: 10.1007/s10825-009-0293-z.

11. P. Greck, C. Schindler, T. Kubis, P. Vogl, "The nonequilibrium Green's functions method and descendants: ways to avoid and to go", doi: 10.1109/IWCE.2010.5677996.

12. P. Vogl, T. Kubis, "The non-equilibrium Green's function method: an introduction", Journal of Computational Electronics 9, 237-242 (2010), doi: 10.1007/s10825-010-0313-z.

13. C. Deutsch, A. Benz, H. Detz, P. Klang, M. Nobile, A. M. Andrews, W. Schrenk, T. Kubis, P. Vogl, G. Strasser, K. Unterrainer, "Terahertz Quantum Cascade Lasers based on Type II InGaAs/GaAsSb/InP", Applied Physics Letters 97, 261110 (2010), doi: 10.1063/1.3532106.

14. R. Roloff, T. Eissfeller, P. Vogl, W. Pötz, "Electric g tensor control and spin echo of a hole-spin qubit in a quantum dot molecule", New Journal of Physics 12, 093012 (2010), doi: 10.1088/1367-2630/12/9/093012.

15. T. Kubis, P. Vogl, "Assessment of approximations in nonequilibrium Green's function theory", Phys. Rev. B 83, 195304 (2011), doi: 10.1103/PhysRevB.83.195304.

16. T. Eissfeller, P. Vogl , "Real-space multiband envelope-function approach without spurious solutions", Phys. Rev. B 84, 195122 (2011), doi: 10.1103/PhysRevB.84.195122.