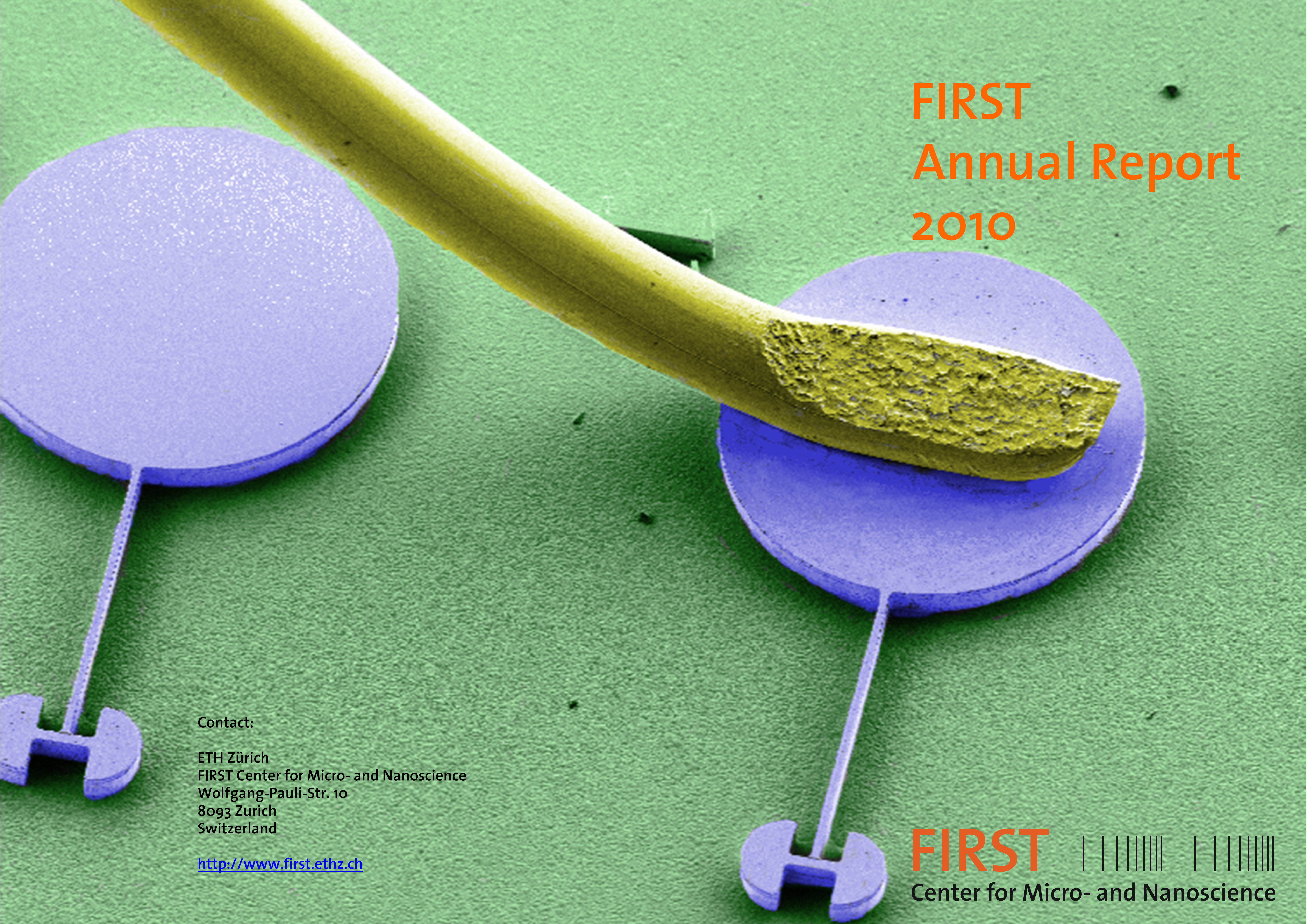


FIRST Annual Report 2010

Contact:

ETH Zürich
FIRST Center for Micro- and Nanoscience
Wolfgang-Pauli-Str. 10
8093 Zurich
Switzerland

http://www.first.ethz.ch

FIRST
Center for Micro- and Nanoscience

Cover picture:

Scanning electron micrograph picture of a sub-wavelength sized circuit based laser-oscillator, including resonator, contact wire and bonding pad. The centerpiece of the circuit based laser is the electronic resonator, consisting of two semi-circular capacitors that are connected via an inductor.

Courtesy by the group of Prof. Faist.

Table of Contents

Introduction to the 2010 annual report

FIRST – Frontiers in Research: Space and Time – is a world-class nanotechnology laboratory dedicated to the needs of the research community from ETH Zurich. By pooling together resources and know-how, it provides to the scientists access to top-notch equipment and techniques. Besides its importance as a user lab, FIRST has also a fundamental role to maintain a technical know-how and teach Ph.D students and Post-doc the latest fabrication technologies. In FIRST, users are intervening at all levels: the most experienced perform key interventions in the maintenance and in the choice of the new equipment, as well as act as mentors to the beginners.

The whole operation of FIRST is driven by the First technical team (FTT) and First operation team (FOT). They must balance the challenging requirements set by the necessity to keep a high level of safety, maintain a high level of technical expertise in a user staff with a large turn-over as well as keep a high availability of the equipment in face of the natural instrument wear and tear.

2010 has been an auspicious year for FIRST. Thanks to the support of the school board, it has acquired two important piece of equipment: a new Zeiss SEM as well as a new Plassys evaporation system. Both instruments remove a significant bottleneck in the fabrication process, enabling an increase in processing capacity required by the large and growing user base, presently at 252 users.

The FIRST management team FMT welcomes a new member, Prof. Ralf Spolenak from D-MATL, replacing Prof. Nicholas D. Spencer. The research of Prof. Spolenak is focused on nano-metallurgy. In the name of all the FMT members, I would like to thank Prof. Spencer for his engagement and work to bring FIRST forward.

The success of FIRST can be measured by the very high scientific output as witnessed by the numerous scientific publications generated, or by the number of highly qualified Ph.D students and post-docs that have learned the latest techniques in nano-technology it produces. To me, however, its best achievement is as real but more difficult to quantify: its ability to foster a true spirit of collaboration and emulation between young researchers from different disciplines.

Jerome Faist
FIRST Coordinator

FIRST – Frontiers in Research: Space and Time

In 2010, the FIRST usage has increased again. FIRST trained about 90 persons during the Introduction Days being regularly offered throughout the year. The total number of users (Figure 1) did not increase in comparison to that of the year 2009. However, the lab was used more intensely. The number of hours spent in FIRST lab to carry out technological processes with our infrastructure increased by 2000 hours (Figure 2) which corresponds to one full equivalent of a position.

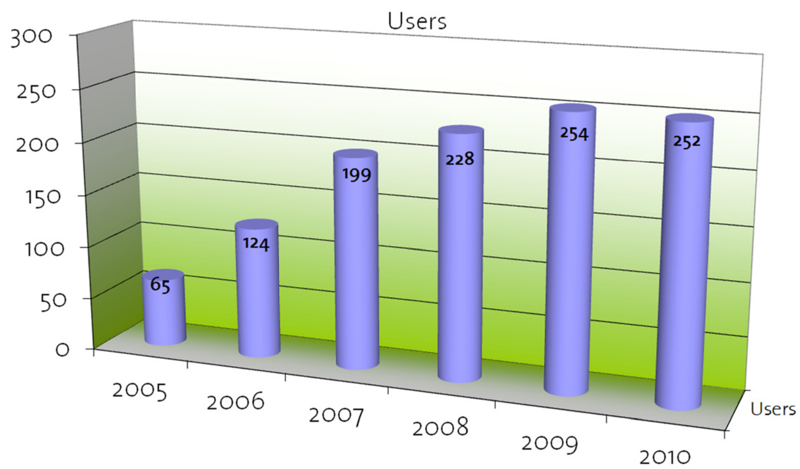


Figure 1:
Number of FIRST users for the time period from 2004 to 2010

The intense usage of FIRST has its impact for the maintenance of the infrastructure. Lab supplies such as gloves, cleanroom paper, wafer trays or glass ware have to be provided to a higher amount and more frequently. Storage is strongly limited for supplies and samples, outside and inside of FIRST lab, respectively. Because most of the new users take advantage of the excellent processing facilities, the consumption of chemicals, e.g. solvents and acids, drastically increased. The challenge is to provide continuously a high standard of service level given the changed constraints. The annual user questionnaire, equipment acquisitions and upgrades as well as constant training of users helped the FIRST staff to meet the high expectations and to provide an excellent infrastructure for research and technology. The high number of publications based on the research work in FIRST proves the success.

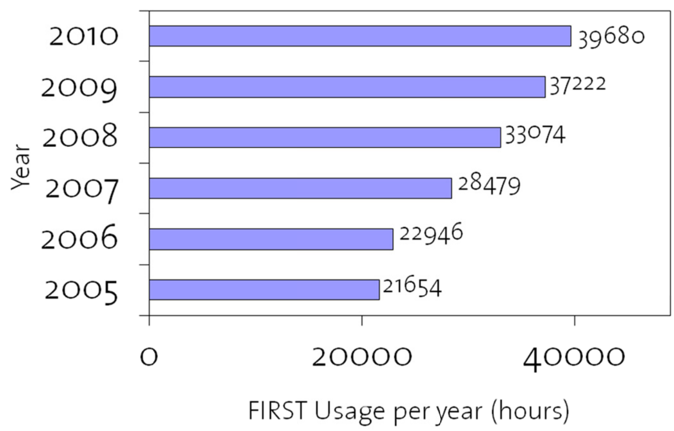


Figure 2:
Total number of hours of the use of FIRST in 2010.

Organisation of FIRST

FIRST is a centralized laboratory directly supported by the Executive Board of ETH Zurich under the lead of the Vice President of Research and Corporate Relations and chaired by the FIRST coordinator (Figure 3). Long-term scientific and technical orientation of FIRST is determined by the FIRST Management Team (FMT). FIRST is operated by the FIRST Operation Team (FOT) with the assistance of the FIRST Technical Team (FTT) and by the support of FIRST users (FMT staff).

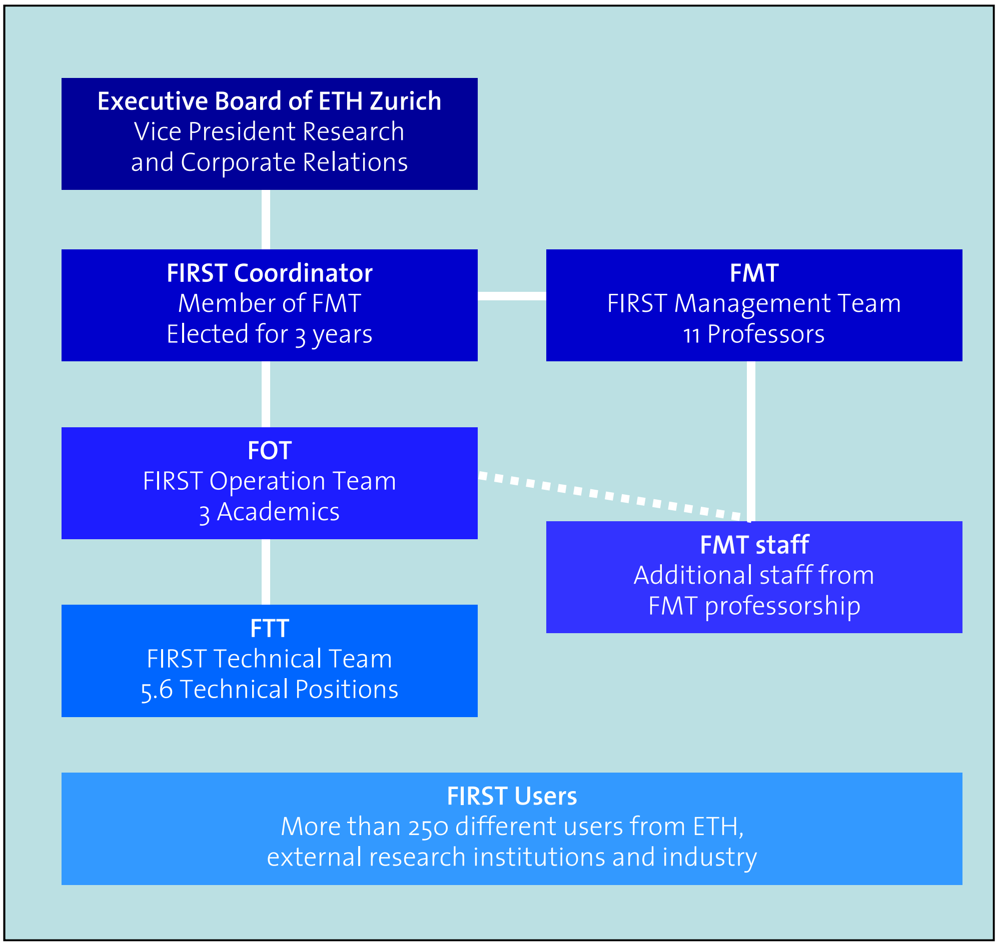


Figure 3:
Organization of FIRST

The FIRST-Management Team determines the scientific and strategic directions of FIRST. It consists of those ETH professors who have a major technological and scientific involvement and take a responsibility in FIRST by contributing actively to the operation of the FIRST technology lab. A list of FMT members is given below.

Each FMT professor has to contribute manpower to the FIRST lab to support its operation. This personnel support is referred to as the FMT staff. The FMT professors and their group members are considered to be primary users of the FIRST lab.

The FIRST coordinator represents the FMT to the ETH management. He reports to the Vice President Research and Corporate Relations and represents the FMT and the FOT. The FIRST coordinator is elected for a 3-years period by the members of the FMT and appointed by the ETH Board. The FIRST coordinator is a member of the FMT.

The FMT in 2010:

Prof. Dr. C. Bolognesi
Terahertz Electronics Group
http://www.ifh.ee.ethz.ch/

Prof. Dr. J. Dual
Mechanics and Experimental Dynamics
http://www.ifm.ethz.ch

Prof. Dr. K. Ensslin
FIRST coordinator 2004–2007
Nanophysics;
http://www.nanophys.ethz.ch

Prof. Dr. J. Faist
FIRST coordinator 2010–2012
Quantum Optoelectronics Group
http://www.phys.ethz.ch/~mesoqc

Prof. Dr. C. Hierold
FIRST coordinator 2007–2009
Micro- and Nanosystems
http://www.micro.mavt.ethz.ch

Prof. Dr. A. Imamoglu
Quantum Photonics
http://www.iqe.ethz.ch/quantumphotonics

Prof. Dr. H. Jäckel
FIRST coordinator 2002–2003
High-Speed Electronics and Photonics
http://www.ife.ee.ethz.ch

Prof. Dr. U. Keller
Ultrafast Laser Physics
http://www.iqe.ethz.ch/ultrafast

Prof. Dr. B. Nelson
Institute of Robotics and Intelligent Systems
http://www.iris.ethz.ch

Prof. Dr. N. D. Spencer (until February 2010)
Laboratory for Surface Science and Technology
http://www.surface.mat.ethz.ch

Prof. Dr. R. Spolenak (since February 2010)
Nanometallurgy
http://www.met.mat.ethz.ch

Prof. Dr. A. Wallraff
Quantum Device Lab
http://www.solid.phys.ethz.ch/wallraff/

FIRST Operation

The daily business of FIRST is managed by a team of three scientists (FIRST Operation Team, FOT) with the support of technicians (FIRST Technical Team, FTT). The main tasks and responsibilities of the FOT are: evaluation and support of technical and scientific work in FIRST, facility management of FIRST, supervising of additional staff supplied by FMT members, and the administration of FIRST.

Prof. Dr. Jérôme Faist

FIRST Coordinator

2010 - 2012

Dr. Otte Homan

FIRST Operation Team

Thin film technology
Processing &lithography
Safety & health

Dr. Emilio Gini

FIRST Operation Team

MOVPE, characterization
Infrastructure
Finances

Dr. Silke Schön

FIRST Operation Team

MBE, characterization
User interface & projects
Public relations

The FIRST Technical Team consists of 5.6 full positions shared by 6 technicians, 1 team assistant and 1 person for IT support. Mrs. Claudine Wehrli finished her work as team assistant in FIRST and we welcomed Tracy Napitupulu in our team.

Dominique Aeschbacher (50%)
FIRST Technical Team

Computer administration

Christian Fausch (50%)

FIRST Technical Team

Electronics,
semiconductor
characterization

Sandro Bellini

FIRST Technical Team

Wet chemistry
E-beam lithography

Maria Leibinger (50%)

FIRST Technical Team

Photolithography
E-beam lithography
CV profiling

Petra Burkard (50%)

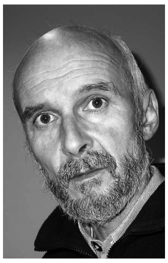
FIRST Technical Team

Thin film technology
Plasma technology

Hansjakob Rusterholz

FIRST Technical Team

MBE support
Wire bonding
Web / Graphics



Martin Ebnöther

FIRST Technical Team

MOVPE support
Laboratory supplies

Tracy Napitupulu (50%)

FIRST Technical Team

Team assistant
User administration

Scientific equipment: additions and upgrades in 2010

Additional FESEM


Figure 4:
Additional FESEM in FIRST.

FIRST-Lab's field emission scanning electron microscope is very popular with the users, more than active 85 users had the 'driver's license' for our Zeiss Ultra-55 SEM early in 2009. To facilitate faster and longer access to an increasing community of users, FIRST-Lab decided to purchase a second SEM, when the necessary laboratory space for it became free. After a thorough evaluation, a similar system was purchased, a ZEISS Ultra-55-Plus (Figure 4). The Plus addition includes a so-called 'Charge Compensation' module, in which nitrogen gas is injected over the sample surface, allowing the compensation of surface charging, especially in non-conducting samples such as electron-beam and optical-resist structures, insulation layers, quartz and glass micro- and nanostructures, etc. Further properties include a complete detection system with SE2, InLens SE and InLens energy selective BSE detectors, as well as a 5-axis 130-mm motorized stage. The system was installed in September and enjoys active use by 60 users.

New electron beam evaporator for metals

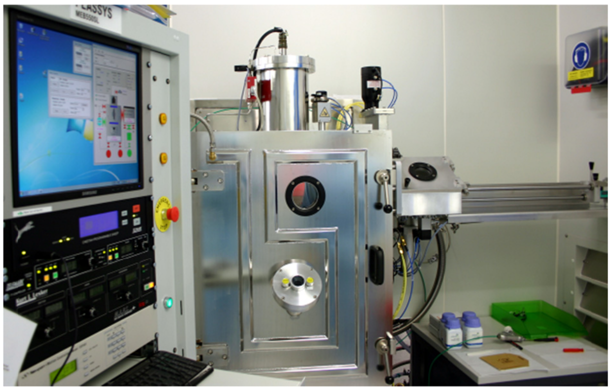


Figure 5:
New electron beam evaporator for metals.

FIRST decided to replace the workhorse evaporation system for metals, a Leybold Univex500 (6 7cc pockets, 10kV, 6kW, nearly 60 active users) by a new system with a larger source capacity, improved pump speed, more flexible ion beam surface cleaning abilities and an efficient and fool proof load lock and transfer system. 7 systems from 6 suppliers were evaluated and a MEB550SL system from Plassys-Bestek SA (France) was purchased (Figure 5). It was delivered in November and was in operation two weeks later. The new system has now 8 15cc pockets, a 10 kV and 10 kW electron beam source, a larger throwing distance for improved film thickness homogeneity and better lift-off metallization results. A small load lock and a large pump system enable rapid transfer times. Default metals are Ti, Cr, Ni, Ge, Pt, and Au, and two pockets are shared by Cu, Ta, Pd, and possibly some other metals in the near future. The ion beam source offers careful sputter cleaning of the substrates in high vacuum (base pressure typically 3E-8 mbar) immediately before metal deposition. Over 70 users have been (re)trained to use the new system. On average an evaporation run now takes approximately 30 minutes, whereas it was close to one hour in the past.

Raith150 electron beam lithography upgrade

Our older Raith150 system (Figure 6, in operation since 2000) received a control hardware replacement. The EM control PC, the interface software, as well as the electron beam lithography software were all upgraded to the latest version, ensuring spare parts and software patch availability for another 10 years of operation. The upgrade was done in July. It is currently used by 24 active users who spent 3100 hours of login time on the system.

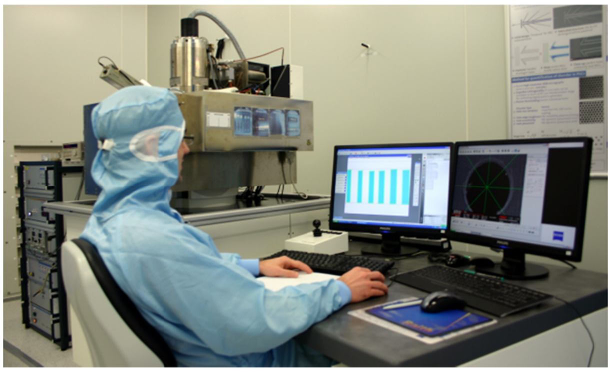


Figure 6:
Raith 150 electron beam upgrade

ABM deep UV mask aligner 4" upgrade

FIRST operates 3 contact printing mask aligners, one of them a so-called deep UV aligner from ABM Inc. It uses 220 and 258nm wavelength light for pattern exposures, and it can be used for g- and i-line photo resists as well. An interesting application of deep UV exposures is that it can be used with resists such as PMMA as well, materials which are normally used for electron beam lithography. Several users have now developed processes using PMMA and deep UV light, and wished to use these processes on 4" Silicon substrates. FIRST-Lab has purchased a chuck for the ABM aligner (Figure 7), now allowing the deep UV exposure of chips (down to 2x2mm), as well as 2", 3" and 4" substrates and parts thereof.

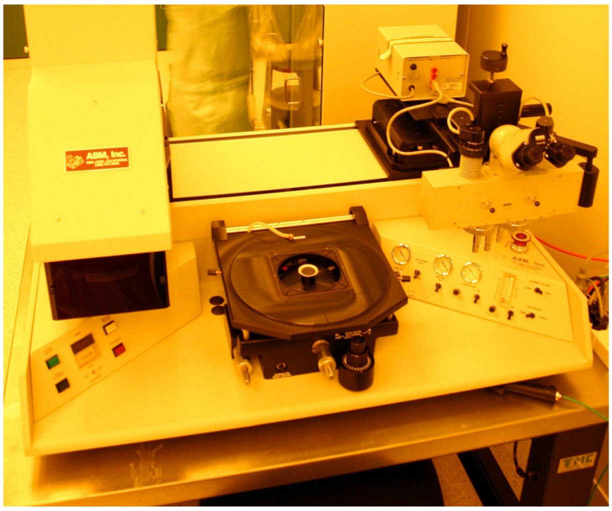


Figure 7:
ABM deep UV mask aligner .

Preparation chamber for MBE systems

The analysis chamber attached to the two GEN III Veeco MBE systems was rebuilt to a preparation chamber. The XPS option with analyzer and X-ray source was hardly used.

Therefore, FIRST sold it. In replacement, a water-cooled cell baking unit was designed and built to improve the crucible and cell baking for MBE maintenance. The preparation chamber is now used for hydrogen cleaning of sample surface for regrowth and for cell baking.

Oxford Plasma systems PLC update

The plasma deposition and etching tools (Figure 8) from Oxford Instruments Plasma Technology received a control electronics and software update. The existing PLCs PC and software on our RIE76 (1994) and RIE80 (2002) reactive ion etching systems as well as on the PECVD (2002) deposition system were replaced by the latest models on offer from OIPT. They ensure that spare parts and software patches will be available for another 10 years. Our ICP system (2002) will receive a similar upgrade in 2011.

Figure 8:
Oxford Plasma systems PLC update.

PVD sputter system: 4^{th} magnetron sputtering source

Many users enjoy our PVD sputter deposition tool (Figure 9), currently 32 individuals. The nature of the system requires that the sputter targets (approximately 25 different metals and 10 compound materials such as SiO_2 or TiN) are frequently exchanged. Each target exchange requires the chamber to be opened, and hence slows down the throughput while drastically increasing the waiting times for the users. Upon request from users FIRST-Lab decided to purchase an additional RF/DC magnetron source, increasing the number of installed sources from 3 to 4. By optimizing the materials sequence schedule, now several users, each with different combinations of materials, can use the system between subsequent chamber openings, thus improving the cycle time for each target.

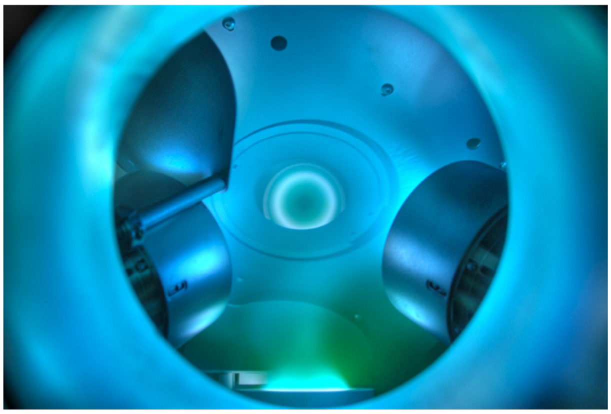


Figure 9:
PVD sputter system: 4^{th} magnetron sputtering source added.

ALD upgrade

During 2010, the ALD received a new Picohot source. This source system can be used by standard industry source containers and can be heated up to 200°C. In the past we had only one heated source. For the deposition of Hafnium and Titanium, both precursors (TEMAH and TIP) were used in the same heated source and shared the same crucible and plumbing. This posed problems of safety, contamination and reduced reproducibility. The new Picohot source solved these problems and enables the tool to run new source chemicals which might be required in the future.

In addition, FIRST purchased an extra dry pump for the ALD. Due to hard depositions in the pump, a yearly service is necessary, causing long downtimes for the ALD. This will be avoided in the future by the spare pump, identical to the existing.

Replacement and renovation on wet benches

In October, the 132-KHz ultrasonic baths (Figure 10) were exchanged in the lithography- and wet chemistry rooms. After eight years of permanent use, the piezoelectric elements deteriorated and went out of order. Following user's requests, FIRST evaluated larger-sized baths to allow cleaning of wafers up to four inch in diameter.

In addition, special baths for the cleaning of the spin coating chucks were installed in the lithography room (Figure 11). The idea was to have a washing station where spinner chucks and spinner rings can be cleaned very easily.

In the second part of the wet bench renovation, we replaced the protective covers sheets. They mainly suffered from solvent spilling and became blind so that the wet bench control units were difficult to operate. The replacement covers are made of safety glass (Figure 12) and less sensitive to solvents and acids.

Figure 10:
Ultrasonic bath

Figure 11:
Special baths for chuck cleaning

Figure 12:
Protective glass cover.

(Surface) Particle Counter and Minifogger

Figure 13:
New Particle counter.

For the monitoring of the laboratory air quality, FIRST-Lab uses a multi-channel airborne particle counter, which measures the particulate load in the air on a 24/7 basis. The air in each cabin is sampled every 14 minutes, and particles >0.3µm are counted. For our other laboratory quality monitoring tasks, we use a simple handheld counter. However, it is limited in battery and memory capacity, and only has a 1/10th flow rate. FIRST-Lab bought a new large particle counter in 2010 (Figure 13), allowing efficient mobile APC measurements in the laboratory. The purchased system however has a special property – it has been designed to measure surface particle concentrations as well. With this function, it allows us to monitor the cleanliness of surfaces as well. This is especially important for our user training task, teaching users how to keep the surfaces of equipment, storage space, workspace, etc. clean, and demonstrating to them what they can typically expect in terms of clean (or dirty) surfaces. The new particle counter allows FIRST to assist other groups at ETH to determine the air flow in the cleanrooms, e.g. in the new undergraduate studens't cleanroom lab in the Physics department.

Additionally to the particle counter, a miniature fogger was purchased as well. It is small, light, fast , easy to use, and allows us to improve the clean room behavioral training of our users in terms of local air flow, turbulences and human movements in the laboratory.

FIRST equipment: general overview

Molecular beam epitaxy (2 Veeco/Applied EPI Gen-III MBE systems, VG V80H system)

- Epitaxial growth of phosphides, arsenides, antimonides and dilute nitrides on up to 4-inch substrates with Si-, C- or Be-doping for active and passive semiconductor devices, e.g. quantum cascade lasers, surface emitting lasers, optical switches, saturable absorbers, and for quantum dot growth and nanocoil fabrication.
- Three growth chambers with diffuse reflectance spectroscopy (BandiT), pyrometers, reflectometry (Laytec EpiR) and reflection high-energy electron diffraction (RHEED) for in-situ growth monitoring (Figure 14).
- Preparation chamber with an atomic hydrogen source for surface oxide reduction processes.

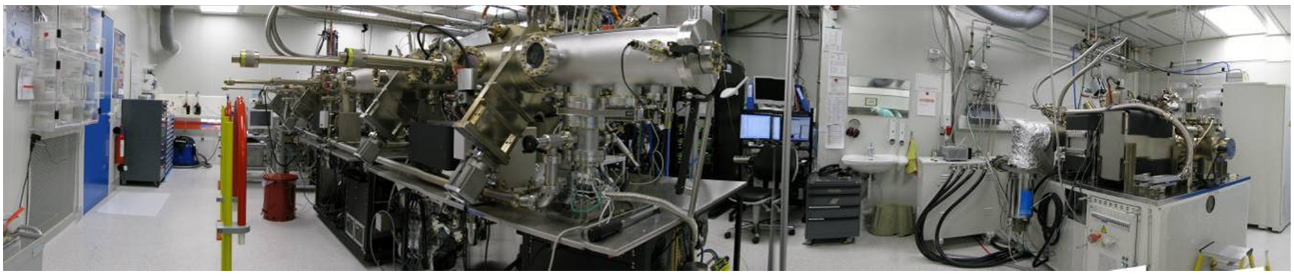


Figure 14:
MBE systems in FIRST: 2 Veeco GEN III systems and a VG V80H system.

Metal-organic vapor phase epitaxy (AIX 200/4)

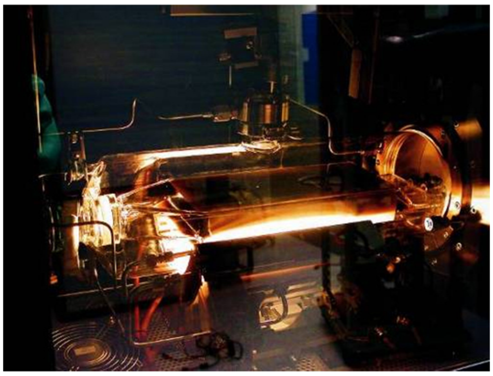


Figure 15:
MOVPE reactor.

- Growth of phosphides, arsenides and antimonides on InP and GaAs substrates with zinc carbon for p-type, silicon or sulfur for n-type doping and iron for semi-insulating material (Figure 15).
- Growth of nanowhiskers.
- EpiRAS in-situ growth monitoring.

Thin film deposition and annealing

- Plasmalab 80+D plasma deposition (PECVD) of SiN_x and SiO_x films (Oxford Instruments).
- Three electron beam evaporation systems for metals, superconductors and dielectric materials (Leybold, Plassys). In 2010 a new Plassys MEB550SL system (8 pocket 10kV 10kW electron beam system with ion beam cleaning) was purchased and is now in operation.
- DC/RF magnetron sputter deposition system for metals and dielectric films (PVD Products).
- Rapid thermal annealing system with N2 and N_2/H_2 gas supply (JIPELEC).

Materials characterization

- Two 4-crystal, high resolution, X-ray diffraction systems (Seifert 3003 PTS-HR, Figure 16, and Philips X'pert).
- Rapid photoluminescence mapping system (Accent RPM 2000).
- Two digital scanning electron microscopes (Zeiss).
- C-V doping profiler (Dage).
- Hall-effect measurement system Accent HL5500.
- Spectroscopic ellipsometer (Sentech SE850).
- Stylus force step profiler (Alphastep 500).
- Atomic force microscope (MFP-3D, Asylum Research).
- Optical microscopes (Nikon Eclipse L200 and L200D).

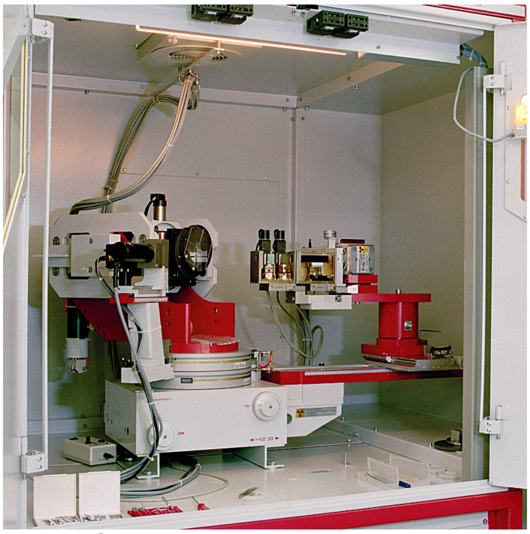


Figure 16:
Seifert X-ray diffraction system.

Optical lithography

- Karl Süss MJB3 manual contact printing mask aligner, also suited for IR back-side alignment. It uses 365 nm and 405 nm UV-light. Optical resolution is approximately 0.4 µm.

- Karl Süss MA6 semi-automatic contact printing mask aligner with split field optics. Currently configured for 2/3/4-inch substrates and 3/4/5-inch masks. It uses 365 nm and 405 nm wide-band UV-light. Optical resolution is approximately 0.4 μm.
- ABM Inc. deep UV contact printing mask aligner, configured for either 220/258 or 365/405 wavelength exposures. Chucks and mask holders for small (5x5mm^2) chips and wafers (2", 3", 4") are available. The optical resolution in PMMA and other deep UV sensitive resists is below 300 nm.
- New photoresist spinners, furnaces and hot plates (see above), wet processing area.

Electron beam lithography

Two electron beam lithography systems (Raith150 and Raith150TWO), dedicated control software environment. Thermal Schottky field emitter source with 2 nm beam resolution, and with variable beam energy between 0.2 keV and 30 keV, with beam currents between 15 pA and 3.8 nA. Maximum sample size is 4 inch on the Raith150 and 6 inch on the Raith150TWO. Write field stitching and overlay accuracy are better than 40 nm for 200 μm write field size. The Raith150TWO system also offers wafer height measurement and control, as well as a fixed-beam moving-stage exposure option for very long structures. It has a new 20 MHz pattern generator, equipped with very efficient data object fracturing algorithms. The current state-of-our-art is sub-10nm quantum structures.

Atomic force microscope lithography

Atomic force tip oxidation of Ti, GaAs and graphene films, using a scanning force microscope in atmospheric conditions. Write fields are approx. 10 μm x 10 μm, and sub-micron to nm line width has been demonstrated.

Wet and dry etching

- 20m^2 wet benches with ultrasonic baths, spin-dryer, heater/ chiller, solvents, acids, base liquid handling.
- 2x RIE systems (Oxford PlasmaLab 80) with fluorine based chemistry for dielectrics and metals (Figure 17).
- ICP system (Oxford PlasmaLab 180): Chlorine based chemistry, 13.56 MHz RIE and

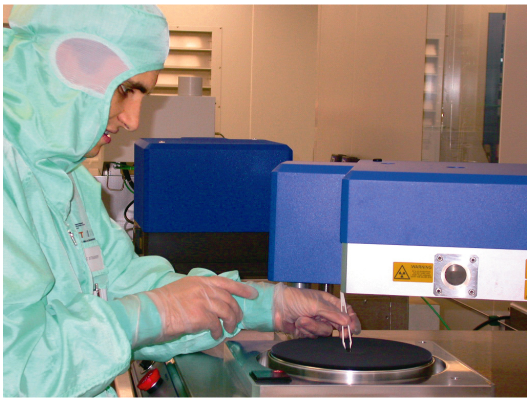


Figure 17:
Reactive ion etching (RIE).

synchronous ICP power sources, load lock.

- Technics Plasma 100E down-stream microwave oxygen asher.
- UVOCS ultra violet ozone cleaning system.

LPCVD nanotube and nanowire deposition

Figure 18:
Low-pressure chemical vapor deposition (LPCVD).

Carbon nanotube and silicon nanowire research is boosted by our LPCVD system from ATV Technology (Figure 18). It allows catalytic growth of single- and multiwalled carbon nanotubes (CNTs) from methane gas, as well as silicon nanowires (SiNWs) from silane gas on structured substrates (e.g. MEMS and NEMS devices) at low process pressures. If desired, low frequency plasmas can be generated by dipole antennas inside the reactor. Novel built-in micro-heaters allow localized CNT deposition on individually heated areas on substrates.

Atomic layer deposition

MEMS and NEMS processes, as well as basic chemistry research, profit from the atomic layer deposition system from Picosun (Figure 19). It is configured for the controlled and defect free deposition of Al_2O_3 and ZnO_2 from metal-organic precursors and pure water, one atomic layer at a time. In 2010, a second heated source for solid and low pressure liquid precursors and a special receptor for powder coating applications were purchased, installed and tested, allowing HfO_2, TiO_2 and powder coatings.

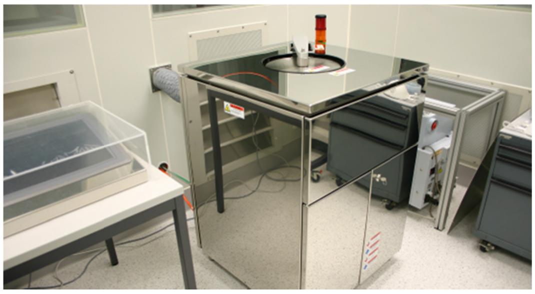


Figure 19:
Atomic layer deposition (ALD).

Back-end-of-line processing

- Lapper PM5 (Logitech)
- Electroplating facility
- Two wire bonders (Westbond) for Au and Al
- Wafer bonder (AML), Wafer saw (DISCO)

FIRST infrastructure and safety

FIRST's total area of 860 m^2 contains 10 cleanroom cabins with an area of 400 m^2. The air in the cabins is controlled and monitored with respect to particle concentration, temperature and humidity and is exchanged up to once per minute. Various loops with different water qualities are installed. Over 20 different media are distributed throughout FIRST: water of different qualities, neutral and reactive gases and large amounts of liquid nitrogen. Several kilometers of cables distribute electrical power or collect data from controllers and sensors. An automatic surveillance system with over 800 data points monitors the status of the facility including the very important safety infrastructure. Expressed in numbers:

- fresh air input: 45'000 m^3/hour
- maximum cooling power: 650 kW
- installed electrical power: 350 kW
- liquid nitrogen consumption: 500'000 liters/year
- 28 toxic gas sensors

As long as the infrastructure works well, hardly anyone will notice its complexity. The FIRST operation team is in close contact with the users in order to optimize the cleanroom conditions in respect to air quality and economy of resources.

After 9 years of almost uninterrupted performance our electro-de-ionization system for the preparation of ultrapure water has been replaced.

Additional cooling water facilities had to be installed for the new systems purchased in 2010.

In the frame of a call for tenders for the management and maintenance of the technical infrastructure a new supplier has been chosen. We hope that in the future we will get the same quality of these services for less money.

For the supply of cleanroom overalls and their regular washing cycle we switched to a system based on leasing.

In 2010, FIRST lab also improved conveying of alarms to users and staff. The existing alarm horns were replaced and two additional horns were mounted. They are of a new type which is more clearly audible inside the laboratory, and is more easily recognized as an alarm sound. We also installed a voice-modem and connected it to our 'Cat. I' and Cat. II' alarm triggers. During normal office hours, this modem transmits the alarms in FIRST lab to staff office telephones (or pagers). During off-hours, staff will now receive alarm information at home, and have the opportunity to respond quickly if needed.

Education and use of the lab

General seminars

FIRST lab welcomed about 90 people to its 10 introduction days carried out regularly throughout the year. The introduction day provides a beginner's training for the work in the FIRST cleanroom. It covers information to access procedure, to equipment trainings, to infrastructure and safety. It also contains a cleanliness seminar to prepare our new user in the best way for a successful work in the FIRST lab. Since June 2010, FIRST has offered a chemistry seminar within the FIRST introduction day to provide basic technical knowledge to all those users with no chemistry background but a need for sample processing with acids and solvents.

2010 also sported the annual firefighting course, in close collaboration with the Health, Safety and Environment staff of ETH Zürich. During 6 courses specifically organized for FIRST users, close to 70 new users and 20 long term users of FIRST were trained in what is necessary to sustain a fire and what one can do to prevent this, and – in case of a true emergency – how to combat the various types of fires.

Figure 20:
Firefighting training for FIRST users.

Mentoring

The mentor system in FIRST is well established. It aims to support new users to achieve cleanroom practice and to transfer technology know-how. The mentors are experienced users from nearly all groups working in FIRST. The mentors are appointed and trained by the FOT. At the end of 2010, FIRST works with 40 mentors to help the new users with their first steps in our cleanroom.

Special seminars and technological experience exchange

Clean room hygiene management: On May 21st, 2010 FIRST contributed in the teaching course 'Specialized cleaning methodologies and hygiene management' of the Zurich University of Applied Sciences, Life Sciences and Facility Management, in collaboration with Lecturer Thomas Hofmann (ZHAW Wädenswil) and Prof. Gerhard Winter of the Albstadt-Sigmaringen University of Applied Sciences (Life Sciences Dept., Germany.). A group of thirteen 6th Semester BSc. students of the Facility Managements, Special Cleaning Methodologies and Hygienemanagement course visited FIRST. Between two detailed lectures on clean room technologies, GMP standards and special cleaning requirements for research clean room facilities, they visited FIRST-Lab to see how such methodologies are applied in practice. The course will be rerun in 2011.

Electron beam evaporation techniques: Following the arrival of the new electron beam evaporation system for metals, all potential users of this system were called to a seminar. The main goal was to distribute, share and improve the available knowledge between users on the deposition of ohmic and Schottky type contacts to III-V semiconductors, leading to generally better devices, more possibilities for sharing resources and knowledge, and - in the end - to use the new equipment more efficiently. Nearly 25 users came and represented a large share of the groups in FIRST. Several interesting discussions on available materials, layer packet optimization and measured details on contacts were initiated. There are good expectations that in the future, through collective efforts, we can operate the new system in a very efficient way.

User questionnaire

We conducted a User Survey among the active users of FIRST early in 2010. The general feedback was very positive; many of the criticized point of the previous survey (2008) had improved. Several team members were explicitly mentioned by the users and thanked for their support of FIRST.

New critical issues were the repeated downtimes with the evaporation systems (a new system has been purchased and installed in 2010) and with the ALD system (a spare pump and another source have been purchased to prevent long downtimes in the future). Users complained about the heavy use of the FESEM, which lead to the purchase of a second FESEM.

In general, the users do not mind the visitors (we have more than 300 in 2010). They do desire more frequent user seminars about technology topics, and they also appreciate the mentoring system, from both sides (mentors and new students). The general improvement in laboratory

cleanliness, due to both the improved user training and the change to a different cleaning company and staff was well received.
Many suggestions for improvements were submitted, usually related to an individual system. Of course, the FIRST Team is committed to improve such situations wherever possible.

Visits and Public Relations

The FIRST lab cleanroom is very attractive to all kind of visitors. FIRST staff and users support professional visits to demonstrate the highly sophisticated technology platform where many young scientists carry out the research work. In 2010, FIRST lab welcomed more than 370 visitors, mainly scientific guests and collaborators, potential hires and industrial partners.

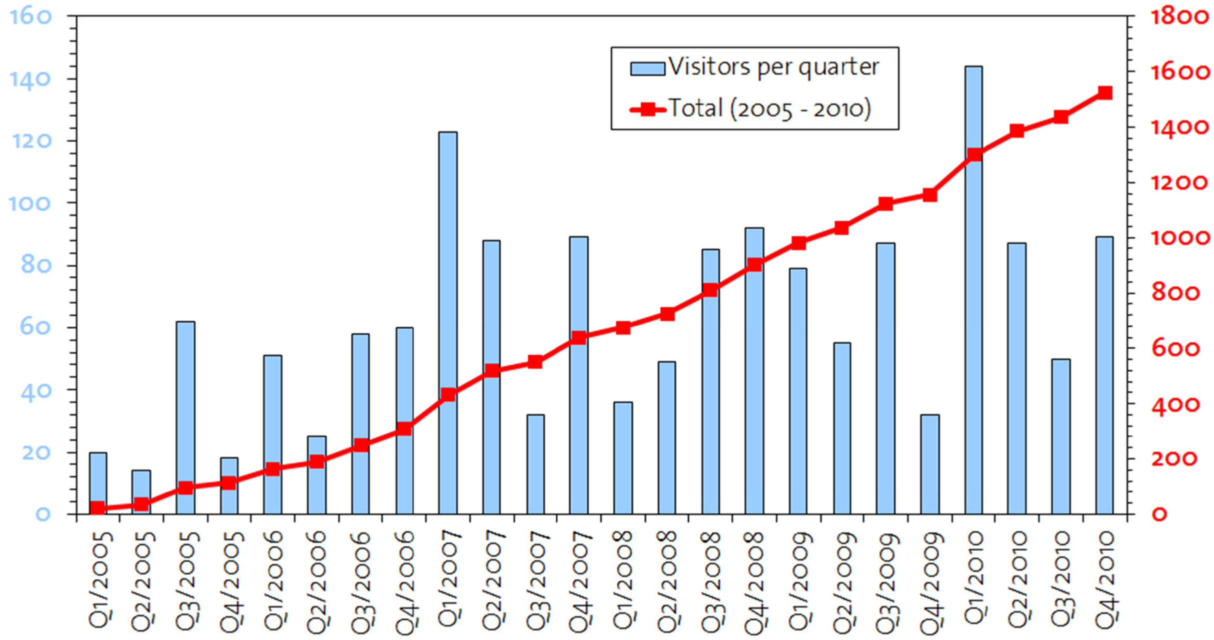


Figure 21:
Number of visitors in FIRST over the past six years displayed by number per quarter (blue bars, left axis) and summed (red line, right axis).

Research in FIRST

FIRST welcomed 40 different groups with approximately 45 projects to use our unique technical infrastructure for their research. In the following, a list of all projects with the coordinates for the groups is provided.

ETH Projects (FMT)

Prof. C. Bolognesi, Terahertz Electronics Group, D-ITET:
http://www.ifh.ee.ethz.ch/

- Terahertz InP/GaAsSb Double Heterojunction Bipolar Transistors (BOL1)
- InP/GaInAs Low-Noise Pseudomorphic High Electron Mobility Transistors (BOL2)
- AlGaN/(Ga,In)N Heterostructure Field-Effect Transistors (BOL3)

Prof. J. Dual, Institute for Mechanical Systems, D-MAVT:
http://www.ifm.ethz.ch
- Mechanics of Micro- and Nanostructures (DUA4)

Prof. K. Ensslin, Nanophysics, D-PHYS:
http://www.nanophys.ethz.ch
- Nanophysics (ENS5)

Prof. J. Faist, Quantum Optoelectronics Group, D-PHYS:
http://www.qoe.ethz.ch/
- Intersubband quantum optoelectronics (FAI5)

Prof. C. Hierold, Micro and Nanosystems, D-MAVT:
http://www.micro.mavt.ethz.ch
- CNTs, NEMS and MEMS (HIE6)

Prof. A. Imamoglu, Quantum Photonics Group, D-PHYS:
http://www.iqe.ethz.ch/quantumphotonics
- Nanostructures (IMA4)

Prof. H. Jäckel, Electronics Laboratory, D-ITET:
http://www.ife.ee.ethz.ch
- Photonic bandgap engineering for dense optical integration / Photonic crystals for active optical devices (JAE2)
- InP-based all-optical sub-ps switches for Tb/s optical communication (JAE4)

Prof. U. Keller, Ultrafast Laser Physics Lab D-PHYS:
http://www.ulp.ethz.ch
- Sesam, VECSEL and MIXSEL (KEL4)

Prof. B. Nelson, Institute of Robotics and Intelligent Systems, D-MAVT:
http://www.iris.ethz.ch
- CNT NEMS + Nanocoils (NEL3)

Prof. N. Spencer, Laboratory for Surface Science and Technology, D-MATL:
http://www.surface.mat.ethz.ch
- Microfabricated surfaces as platform to study adult and stem cells in designed microenvironments (SPE1)
- Large-area nanopore-patterned membranes for waveguide and biosensing integrated with on-chip microfluids (SPE3)

Prof. R. Spolenak, Nanometallurgy, D-MATL:
http://www.met.mat.ethz.ch
- Combinatorial thin metal film deposition (SPO2)

Prof. A. Wallraff, Quantum Device Lab, D-PHYS:
http://www.solid.phys.ethz.ch/wallraff/
- Superconducting Qubits (WAL4)

ETH Projects (non-FMT)

Prof. B. Batlogg, Physics of New Materials, D-PHYS:
http://www.pnm.ethz.ch
- Novel organic semiconductors for thin – film transistor applications (BAT1)

Prof. P. Dittrich, Laboratory of Organic Chemistry, D-CHAB:
http://www.dittrich.ethz.ch
- Fabrication of microfluidic master structures *(DIT1)*

Dr. M. Döbeli, Ion Beam Physics, D-PHYS:
http://www.ams.ethz.ch/
- Silicon Nitride membranes for ion beam physics (DOE1)

Prof. L. Gauckler, Nonmetallic Inorganic Materials, D-MATL:
http://www.nonmet.mat.ethz.ch
- OneBat – micro solid oxide fuel cell (GAU1)

Prof. P. Günter, Nonlinear Optics Lab, D-PHYS:
http://www.nlo.ethz.ch
- Structuring of thin ferroelectric films for electro-optically active photonic devices (GUN2)

Prof. D. Hilvert, Laboratory of Organic Chemistry, D-CHAB:
http://www.protein.ethz.ch
- Microfabrication of PDMS microfluidic chips (HIL1)

Prof. J. F. Löffler, Laboratory of Metal Physics and Technology, D-MATL:
http://www.metphys.mat.ethz.ch/
- Composite doped meta-materials (LOE1)

Prof. H. G. Park, Institute of Energy Technology, D-MAVT:
http://www.iet.ethz.ch/
- Microfabrication of Carbon Nanotube Nanofluidic Platforms (PAR1)

Prof. D. Poulikakos, Laboratory of Thermodynamics in Emerging Technologies, D-MAVT:
http://www.ltnt.ethz.ch/
- Measurement of Thermophysical, Electromechanical and Transport Properties of Individual Carbon Nanotubes (POU1)

Prof. V. Sandoghdar, Nano-Optics, D-CHAB:
http://www.nano-optics.ethz.ch
- Nanooptics (SAN2)

Prof. B. Schönfeld, Laboratory of Metal Physics and Technology, D-MATL:
http://www.metphys.mat.ethz.ch/
- Near-surface microstructure of Ni-Pt (SCH1)

Prof. W. Stark, Functional Materials Laboratory, D-CHAB:
http://www.fml.ethz.ch
- Functionalization of graphene sheets (STA1)

Prof. A. R. Studart, Complex Materials, D-MATL:
http://www.complex.mat.ethz.ch/
- Fabrication of Microfluidic Devices for Controlled Emulsification (STU1)

Prof. G. Tröster, Electronics Laboratory, D-ITET:
http://www.ife.ee.ethz.ch/
- *Flexible temperature sensors (TRO1)*

Prof. J. van Bokhoven, Heterogeneous Catalysis, D-CHAB:
http://www.vanbokhoven.ethz.ch
- Catalysts (BOK1)

Prof. H. von Känel, Laboratory for Solid State Physics, D-PHYS:
http://www.solid.phys.ethz.ch/
- Epitaxial germanium for X-ray detectors (KAE1)

Prof. J. Vörös, Laboratory of Biosensors and Bioelectronics, D-ITET:
http://www.lbb.ethz.ch/
- LBB Nanofabrication (VOE3)

Prof. V. Vogel, Biologically Oriented Materials, D-MATL:
http://www.nanomat.mat.ethz.ch
- Micro- and nanofabrication for biological applications (VOG1)

Prof. W. Wegscheider, Advanced Semiconductor Quantum Materials, D-PHYS:
http://www.mbe.ethz.ch/
- High-mobility (WEG1)

Prof. E. Windhab, Institute of Food Science and Nutrition, D-AGRL:
http://www.agrl.ethz.ch
- Nanomembranes for dynamically enhanced dispersion processes (WIN1)

External Projects

Dr. U. Sennhauser, EMPA:
http://www.empa.ch/
- Nanofabrication for EMPA (EMP4)

Dr. J. Gobrecht, PSI:
- PSI SwissFEL project (GOB1)

Prof. G. Patzke, Institute of Inorganic Chemistry, University of Zurich:
http://www.aci.uzh.ch/
- Metal oxide nanowires for application in portable sensors (PAT1)

Prof. A. Schilling, Physik-Institut, University of Zurich:
http://www.physik.uzh.ch/groups/schilling/staff.html
- Physics of Superconducting Thin Films and Nanostructures and Applications as Single-Photon Detectors (SCI1)

Collaboration with Industry

The ETH Zurich Board supports collaboration with industry. The main goal is not production, but collaboration in research and development. For this purpose, the industrial partners can profit from attractive rates for the use of the FIRST-lab infrastructure.

In 2010, FIRST supported researchers from the following companies:

- ABB Schweiz AG
- Enablence Switzerland AG
- Exalos AG
- IBM Research GmbH
- Kistler Instrumente AG
- Oclaro Zürich
- Rainbow Photonics
- Sensirion AG
- SUV-Detectors

The type of collaboration ranged from standard inspection and processing to prototype epitaxial layer delivery, and to proof-of-concept support for innovative processing techniques.

FIRST Publications 2010

M. I. Amanti, G. Scalari, F. Castellano, M. Beck, and J. Faist
"Low divergence terahertz photonic-wire laser"
Optics Express 18 (2010) 6390.

E. Amstad, A. U. Gehring, H. Fischer, V. V. Nagaiyanallur, G. Haehner, M. Textor, and E. Reimhult
"The influence of electronegative substituents on the binding affinity of catechol derived anchors to Fe3O4 nanoparticles"
Journal of Physical Chemistry C (2010) published online

D. Austin, N. Mullin, I. Luxmoore, I. C. Sandall, A. G. Cullis, A. Bismuto, J. Faist, J. K. Hobbs, and L. R. Wilson
"X-shaped plasmonic antenna on a quantum cascade laser"
Applied Physics Letters 96 (2010) 151105.

D. Austin, N. Mullin, A. Bismuto, I. Luxmoore, A. M. Adawi, D. G. Revin, M. Soulby, J. W. Cockburn, Q. Jiamg, A. B. Krysa, A. G. Cullis, J. Faist, J. K. Hobbs, and L. R. Wilson
"Transmission properties of plasmonic metamaterial quantum cascade lasers"
Photonic Technology Letters 22 (2010) 1217.

C. R. E. Baer, C. Kränkel, C. J. Saraceno, O. H. Heckl, M. Golling, R. Peters, K. Petermann, T. Südmeyer, G. Huber, and U. Keller
"Femtosecond thin-disk laser with 141 W of average power"
Optics Letters 35 (2010) 2302.

H. Bartolf, K. Inderbitzin, L. B. Gómez, A. Engel, and A. Schilling
"Nanoscale fabrication by intrinsic suppression of proximity-electron exposures and general considerations for easy & effective top-down fabrication"
Journal of Micromechanics and Microengineering 20 (2010) 125015.

H. Bartolf, A. Engel, A. Schilling, K. Il'in, M. Siegel, H.-W. Hübers, and A. Semenov
"Current assisted, thermally activated flux liberation in ultrathin nanopatterned NbN superconducting meander structures"
Physical Review B 81 (2010) 024502.

C. Bergeles, K. G. Shamaei, J. J. Abbott, and B. J. Nelson
"Single-camera focus-based localization of intraocular devices"
IEEE Transactions on Biomedical Engineering 57 (2010) 2064.

R. Bianchetti, S. Filipp, M. Baur, J. M. Fink, C. Lang, L. Steffen, M. Boissonneault, A. Blais, and A. Wallraff
"Control and tomography of a three level superconducting artificial atom"
Physical Review Letters 105 (2010) 223601.

A. Bismuto, R. Terazzi, M. Beck, and J. Faist
"Electrically tunable, high performance quantum cascade laser"
Applied Physics Letters 96 (2010) 141105.

C. R. Bolognesi, and N. Grandjean
"GaN HEMTs advance to ultrahigh bandwidths 205-GHz (Al In)N/GaN HEMTs"
Compound Semiconductor 16 (2010) 15.

D. Bozyigit, C. Lang, L. Steffen, J. M. Fink, C. Eichler, M. Baur, R. Bianchetti, P. J. Leek, S. Filipp, M. P. da Silva, A. Blais, and A. Wallraff
"Antibunching of microwave frequency photons observed in correlation measurements using linear detectors"
Nature Physics 10 (2010) published online

M. Csontos, Y. Komijani, I. Shorubalko, K. Ensslin, D. Reuter, and A. D. Wieck
"Nanostructures in p-GaAs with improved tunability"
Applied Physics Letters 97 (2010) 022110.

L. X. Dong, X. Y. Tao, L. Zhang, X. B. Zhang, and B. J. Nelson
"Plumbing the depths of the nanometer scale: attogram mass transport via nanochannels"
IEEE Nanotechnology Magazine 4 (2010) 13.

S. Dröscher, P. Roulleau, F. Molitor, P. Studerus, C. Stampfer, K. Ensslin, and T. Ihn
"Quantum capacitance and density of states of graphene"
Applied Physics Letters 96 (2010) 152104.

A. Engel
"Comment on 'Superconducting transition in Nb nanowires fabricated using a focused-ion beam'"
Nanotechnology 21 (2010) 168001.

K. Ensslin, S. Gustavsson, U. Gasser, B. Küng, and T. Ihn
"A quantum mechanics lab on a chip"
Lab on a Chip 10 (2010) 2199.

P. Fallahi, S. T. Yilmaz, and A. Imamoglu
"Measurement of a heavy-hole hyperfine interaction in InGaAs quantum dots using resonance fluorescence"
Physical Review Letters 105 (2010) 257402.

Y. Fedoryshyn, M. Beck, P. Kaspar, and H. Jaeckel
"Characterization of Si volume- and delta-doped InGaAs grown by molecular beam epitaxy"
Journal of Applied Physics 107 (2010) 093710.

J. M. Fink, L. Steffen, P. Studer, Lev S. Bishop, M. Baur, R. Bianchetti, D. Bozyigit, C. Lang, S. Filipp, P. J. Leek, and A. Wallraff
"Quantum-to-classical transition in cavity quantum electrodynamics (QED)"
Physical Review Letters 105 (2010) 163601.

M. Fischer, G. Scalari, K. Celebi, M. Amanti, C. Walther, M. Beck, and J. Faist
"Scattering processes in terahertz InGaAs/InAlAs quantum cascade lasers"
Applied Physics Letters 97 (2010) 221114.

D. R. Frutiger, B. E. Kratochvil, K. Vollmers, and B. J. Nelson
"Small, fast, and under control: wireless resonant magnetic micro-agents"
International Journal of Robotics Research 29 (2010) 613.

U. Gasser, S. Gustavsson, B. Küng, K. Ensslin, and T. Ihn
"Phonon-mediated back-action of a charge readout on a double quantum dot"
Nanotechnology 21 (2010) 274003.

M. Geiser, C. Walther, G. Scalari, M. Beck, M. Fischer, L. Nevou, and J. Faist
"Strong light-matter coupling at terahertz frequencies at room temperature in electronic LC resonators"
Applied Physics Letters 97 (2010) 191107.

C. Graetzel, B. J. Nelson, and S. N. Fry
"Frequency response of lift control in drosophila"
Journal of the Royal Society Interface 7 (2010) 1603.

C. Graetzel, B. J. Nelson, and S. N. Fry
"A dynamic region-of-interest vision tracking system applied to the real-time wing kinematic analysis of tethered drosophila"
IEEE Transactions on Automation Science and Engineering 7 (2010) 463.

R. Grundbacher, K. Chikkadi, and C. Hierold
"Thin film transistors with a ZnO channel and gate dielectric layers of HfO2 by atomic layer deposition"
Journal of Vacuum Science and Technology B 28 (2010) 1173.

J. Güttinger, T. Frey, C. Stampfer, T. Ihn, and K. Ensslin
"Spin states in graphene quantum dots"
Physical Review Letters 105 (2010) 116801.

O. H. Heckl, C. Kränkel, C. R. E. Baer, C. J. Saraceno, T. Südmeyer, K. Petermann, G. Huber, and U. Keller
"Continuous wave and mode-locked Yb:YCOB thin disk laser: first demonstration and future prospects"
Optics Express 18 (2010) 19201.

T. Helbling, C. Roman, and C. Hierold
"Signal-to-noise-ratio in carbon nanotube electromechanical piezoresistive sensors"
Nano Letters 10 (2010) 3350.

M. Hoffmann, O. D. Sieber, D. J. H. C. Maas, V. J. Wittwer, M. Golling, T. Südmeyer, and U. Keller
"Experimental verification of soliton-like pulse-shaping mechanisms in passively modelocked VECSELs"
Optics Express 18 (2010) 10143.

M. Huefner, F. Molitor, A. Jacobsen, A. Pioda, C.Stampfer, K. Ensslin, and T. Ihn
"The aharonov–bohm effect in a side-gated graphene ring"
New Journal of Physics 12 (2010) 043054.

A. Hugi, R. Maulini, and J. Faist
"External cavity quantum cascade laser"
Semiconductor Science and Technology 25 (2010) 083001.

T. Ihn, S. Gustavsson, U. Gasser, R. Leturcq, I. Shorubalko, and K. Ensslin
"Time-resolved charge detection and back-action in quantum circuits"
Physica E 42 (2010) 803.

T. Ihn, J. Güttinger, F. Molitor, S. Schnez, E. Schurtenberger, A. Jacobsen, S. Hellmüller, T. Frey, S. Dröscher, C. Stampfer, and K. Ensslin
"Graphene single-electron transistors"
Materials Today 13 (2010) 44.

K. Il'in, D. Rall, M. Siegel, A. Engel. A. Schilling, A. Semenow, and H.-W. Hübers
“Influence of thickness, width and temperature on critical current density of Nb thin film structures”
Physica C 470 (2010) 953.

L. Isa, K. Kumar, M. Müller, J. Grolig, M. Textor and E. Reimhult
“Particle lithography from colloidal self-assembly at liquid-liquid interfaces (SALI)”
ACS Nano 4 (2010) 5665.

A. Jacobsen, I. Shorubalko, L. Maag, U. Sennhauser, and K. Ensslin
“Rectification in three-terminal graphene junctions”
Applied Physics Letters 97 (2010) 032110.

A. Jacobsen, I. Shorubalko, L. Maag, U. Sennhauser, and K. Ensslin
“Rectification in three-terminal graphene junctions”
Applied Physics Letters 97 (2010) 032110.

A. Jacobsen, F. M. Koehler, W. J. Stark, and K. Ensslin
“Towards electron transport measurements in chemically modified graphene: The effect of a solvent”
New Journal of Physics 12 (2010) 125007.

P. Kaspar, Y. Jeyaram, A. Foelske, R. Kötz, and H. Jaeckel
“Silicon nitride hardmask fabrication using a cyclic CHF_3-based reactive ion etching process for vertical profile nanostructures”
Journal of Vacuum Science and Technology B 28 (2010) 1179.

U. Keller
“Ultrafast solid-state laser oscillators: a success story for the last 20 years with no end in sight”
Applied Physics B 100 (2010) 15.

U. Keller
“Breakthroughs in photonics 2009: femtosecond to attosecond optics”
IEEE Photonics Journal 2 (2010) 225.

G. Klatt, F. Hilser, W. Qiao, M. Beck, R. Gebs, A. Bartels, K. Huska, U. Lemmer, G. Bastian, M.B. Jonston, M. Fischer, J. Faist, and T. Dekorsy
“Terahertz emission from lateral photo-dember currents”
Optics Express 18 (2010) 4939.

F. M. Koehler, A. Jacobsen, K. Ensslin, C. Stampfer, and W. J. Stark
“Selective chemical modification of graphene surfaces: distinction between single- and bilayer graphene”
Small 6 (2010) 1125.

Y. Komijani, M. Csontos, I. Shorubalko, T. Ihn, K. Ensslin, Y. Meir, D. Reuter, and A. D. Wieck
“Evidence for localization and 0.7 anomaly in hole quantum point contacts"
Europhysics Letters 91 (2010) 67010.

M. Kummer, J. J. Abbott, B. E. Kratochvil, R. Borer, A. Sengul, and B. J. Nelson
“OctoMag: An electromagnetic system for 5-DOF wireless micromanipulation”
IEEE Transactions on Robotics 26 (2010) 1006.

B. Küng, S. Gustavsson, T. Choi, I. Shorubalko, O. Pfäffli, F. Hassler, G. Blatter, M. Reinwald, W. Wegscheider, S. Schön, T. Ihn, and K. Ensslin
“Measurement back-action in quantum point contact charge sensing”
Entropy 12 (2010) 1721.

P. J. Leek, M. Baur, J. M. Fink, R. Bianchetti, L. Steffen, S. Filipp, and A. Wallraff
"Cavity QED with separate photon storage and qubit readout modes"
Physical Review Letters 104 (2010) 100504.

V. Liverini, A. Bismuto, L. Nevou, M. Beck, and J. Faist
"Midinfrared electroluminescence from InAs/InP quantum dashes"
Applied Physics Letters 97 (2010) 221109.

V. Liverini, A. Bismuto, L. Nevou, M. Beck, F. Gramm, E. Mueller, and J. Faist
"InAs/AlInAs quantum-dash cascade structures with electroluminescence in the mid-infrared"
Journal of Crystal Growth (2010) ICMBE (published online)

P. Ma, P. Kaspar, P, Strasser, and H. Jäckel
"Compact and integrated TM-pass photonic crystal waveguide polarizer in InGaAsP-InP"
IEEE Photonics Technology Letters 22 (2010) 1808.

P. Ma, P. Kaspar, and H. Jäckel
"Low-loss photonic crystal defect waveguides and taper designs in InP/InGaAsP for TM-polarized light"
Japanese Journal of Applied Physics 49 (2010) 06GG06.

L. Mahler, A. Tredicucci, F. Beltram, C. Walther, J. Faist, H. E. Beere, and D. A. Ritchie
"High-power surface emission from terahertz distributed feedback lasers with a dual-slit unit cell"
Applied Physics Letters 96 (2010) 191109.

L. Mahler, A. Tredicucci, F. Beltram, C. Walther, J. Faist, H. E. Beere, D. A. Ritchie, and D. S. Wiersma
"Quasi-periodic distributed feedback laser"
Nature Photonics 4 (2010) 165.

D. Marti, M. Vetter, A. R. Alt, H. Benedickter, and C. R. Bolognesi
"110 GHz Characterization of coplanar waveguides on GaN-on-Si substrates"
Applied Physics Express 3 (2010) 124101.

M. Mattmann, D. Bechstein, C. Roman, K. Chikkadi, and C. Hierold
"Reduction of gate hysteresis above ambient temperature via ambipolar pulsed gate sweeps in carbon nanotube field effect transistors for sensor applications"
Applied Physics Letters 97 (2010) 153103.

M. Mattmann, C. Roman, T. Helbling, D. Bechstein, L. Durrer, R. Pohle, M. Fleischer, and C. Hierold
"Pulsed gate sweep strategies for hysteresis reduction in carbon nanotube transistors for low concentration NO2 gas detection"
Nanotechnology 21 (2010) 185501.

A. Mohan, M. Felici, P. Gallo, B. Dwir, A. Rudra, J. Faist, and E. Kapon
"Polarization-entangled photons produced with high-symmetry site-controlled quantum dots"
Nature Photonics 4 (2010) 302.

A. Mohan, P. Gallo, M. Felici, B. Dwir, A. Rudra, J. Faist, and E. Kapon
"Record-low inhomogeneous broadening of site-controlled quantum dots for nanophotonics"
Small 6 (2010) 1268.

F. Molitor, C. Stampfer, J. Güttinger, A. Jacobsen, T. Ihn, and K. Ensslin
"Energy and transport gaps in etched graphene nanoribbons"
Semiconductor Science Technology 25 (2010) 034002.

F. Molitor, H. Knowles, S. Dröscher, U. Gasser, T. Choi, P. Roulleau, J. Güttinger, A. Jacobsen, C.Stampfer, K. Ensslin, and T. Ihn
"Observation of excited states in a graphene double quantum dot"
Europhysics Letters 89 (2010) 67005.

A. Muller, and J. Faist
"The quantum cascade laser ready for take-off"
Nature Photonics 4 (2010) 291.

T. Müller, B. Küng, P. Studerus, S. Hellmüller, K. Ensslin, T. Ihn, W. Wegscheider, and M. Reinwald
"An in-situ tunable radio-frequency quantum point contact"
Applied Physics Letters 97 (2010) 202104.

S. Muntwyler, B. E. Kratochvil, F. Beyeler, and B. J. Nelson
"Monolithically integrated two-axis microtensile tester for the mechanical characterization of microscopic samples"
IEEE/ASME Journal of Microelectromechanical Systems 19 (2010) 1223.

M. Muoth, F. Gramm, K. Asaka, L. Durrer, T. Helbling, C. Roman, S. W. Lee, and C. Hierold
"Chirality assignment to carbon nanotubes integrated in MEMS by tilted-view transmission electron microscopy"
Sensors and Actuators B: Chemical (2010) published online

M. Muoth, S. W. Lee, K. Chikkadi, M. Mattmann, T. Helbling, A. Intlekofer, and C. Hierold
"Encapsulation of electrical contacts for suspended single-walled carbon nanotubes by atomic layer deposition"
Physica Status Solidi (B) 247 (2010) 2997.

M. Muoth, T. Helbling, L. Durrer, S.-W. Lee, C. Roman, and C. Hierold
"Hysteresis-free operation of suspended carbon nanotube transistors"
Nature Nanotechnology 5 (2010) 589.

S. Nakamura, Y. Yamauchi, M. Hashisaka, K. Chida, K. Kobayashi, T. Ono, R. Leturcq, K. Ensslin, K. Saito, Y. Utsumi, and A. C. Gossard
"Nonequilibrium fluctuation relations in a quantum coherent conductor"
Physical Review Letters 104 (2010) 080602.

B. J. Nelson, I. K. Kaliakatsos, and J. J. Abbott
"Microrobots for minimally invasive medicine"
Annual Review of Biomedical Engineering 12 (2010) 55.

L. Nevou, V. Liverini, F. Castallano, A. Bismuto, and J. Faist
"Asymmetric heterostructure for photovoltaic InAs quantum dot infrared photodetector"
Applied Physics Letters 97 (2010) 023505.

S. Oberti, D. Möller, A. P. Neild, J. Dual, F. Beyeler, B. J. Nelson, and S. Gutmann
"Strategies for single particle manipulation using acoustic and flow fields"
Ultrasonic 50 (2010) 247.

A. E. H. Oehler, M. C. Stumpf, S. Pekarek, T. Südmeyer, K. J. Weingarten, and U. Keller
"Picosecond diode-pumped 1.5-μm Er,Yb:glass lasers operating at 10-100 GHz repetition rate"
Applied Physics B 99 (2010) 53.

O. Ostinelli, A. R. Alt, R. Lövblom, and C. R. Bolognesi
"Growth and characterization of iron-doped semi-insulating InP buffer layers for Al-free GaInP/GaInAs high electron mobility transistors"
Journal of Applied Physics 108 (2010) 114502.

S. Pekarek, C. Fiebig, M. C. Stumpf, A. E. H. Oehler, K. Paschke, G. Erbert, T. Südmeyer, and U. Keller
"Diode-pumped gigahertz femtosecond Yb: KGW laser with a peak power of 3.9 kW"
Optics Express 18 (2010) 16320.

E. Pellicer, A. Varea, S. Pané, B. J. Nelson, E. Menéndez, M. Estrader, S. Suriñach, M. D. Baró, J. Nogués, and J. Sort
"Nanocrystalline electroplated Cu-Ni: metallic thin films with enhanced mechanical properties and tuneable magnetic behaviour"
Advanced Functional Materials 20 (2010) 983.

C. Rössler, T. Feil, P. Mensch, T. Ihn, K. Ensslin, D. Schuh, and W. Wegscheider
"Gating of high-mobility two-dimensional electron gases in GaAs/AlGaAs heterostructures"
New Journal of Physics 12 (2010) 043007.

C. Rössler, B. Küng, S. Dröscher, T. Choi, T. Ihn, K. Ensslin, and M. Beck
"Highly tunable hybrid quantum dots with charge detection"
Applied Physics Letters 97 (2010) 152109.

P. Roulleau, T. Choi, S. Riedi, T. Heinzel, I. Shorubalko, T. Ihn, and K. Ensslin
"Suppression of weak antilocalization in InAs nanowires"
Physical Review B 81 (2010) 155449.

B. Rudin, V. J. Wittwer, D. J. H. C. Maas, M. Hoffmann, O. D. Sieber, Y. Barbarin, M. Golling, T.Südmeyer, and U. Keller
"Novel ultrafast semiconductor laser with 6.4 W average output power"
Optics Express 18 (2010) 27582.

G. Scalari, M. I. Amanti, C. Walther, R. Terazzi, M. Beck, and J. Faist
"Broadband THz lasing from a photon-phonon quantum cascade structure"
Optics Express 18 (2010) 8043.

G. Scalari, D. Turcinkova, J. Lloyd-Hughes, M. Amanti, M. Fischer, M. Beck, and J. Faist
"Magnetically assisted quantum cascade laser emitting from 740 GHz to 1.4 THz"
Applied Physics Letters 97 (2010) 081110.

C. Schmidt, and V. Vogel
"Molecular shuttles powered by motor proteins: loading and unloading stations for nanocargo integrated into one device"
Lab on a Chip 10 (2010) 2195.

S. Schnez, J. Güttinger, M. Huefner, C. Stampfer, K. Ensslin, and T. Ihn
"Imaging localized states in graphene nanostructures"
Physical Review B 82 (2010) 165445.

D. M. Spori, T. Drobek, S. Zürcher, and N. D. Spencer
"Cassie-state wetting investigated by means of a hole-to-pillar-density gradient"
Langmuir 26 (2010) 9465.

M. C. Stumpf, S. Pekarek, A. E. H. Oehler, T. Südmeyer, J. M. Dudley, and U. Keller
"Self-referencable frequency comb from a 170-fs, 1.5-μm solid-state laser oscillator"
Applied Physics B 99 (2010) 401.

A. Subramanian, L. X. Dong, B. J. Nelson, and A. Ferreira
"Supermolecular switches based on multiwalled carbon nanotubes"
Applied Physics Letters 96 No. 7 (2010) 073116.

H. Sun, A. R. Alt, H. Benedickter, E. Feltin, J.-F. Carlin, M. Gonschorek, N. Grandjean, and C. R. Bolognesi
"205-GHz (Al In)N/GaN HEMTs"
IEEE Electron Device Letters 31 (2010) 957.

H. Sun, A. R. Alt, H. Benedickter, E. Feltin, J.-F. Carlin, M. Gonschorek, N. Grandjean, and C. R. Bolognesi
"Low-noise microwave performance of 0.1μm gate AlInN/GaN HEMTs on SiC"
IEEE Microwave and Wireless Components Letters 20 (2010) 453.

H. Sun, A. R. Alt, H. Benedickter, C. R. Bolognesi, E. Feltin, J.-F. Carlin, M. Gonschorek, and N. Grandjean
"Ultrahigh-speed AlInN/GaN high electron mobility transistors grown on (111) high-resistivity silicon with fT = 143 GHz"
Applied Physics Express 3 (2010) 094101.

H. Sun, A. R. Alt, H. Benedickter, E. Feltin, J.-F. Carlin, M. Gonschorek, N. Grandjean, and C. R. Bolognesi
"100-nm-Gate (Al In)N/GaN HEMTs grown on SiC with fT = 144 GHz"
IEEE Electron Device Letters 31 (2010) 293.

H. Sun, D. Marti, S. Tirelli, A. R. Alt, H. Benedickter, and C. R. Bolognesi
"Millimeter-wave GaN-based HEMT development at ETH-Zürich"
International Journal of Microwave and Wireless Technologies 1 (2010) 1.

X. Y. Tao, L. X. Dong, X. N. Wang, B. J. Nelson, and X. D. Li
"B4C nanowire - carbon microfiber hybrid structures and composites from cotton t-shirts"
Advanced Materials 22 (2010) 2055.

R. Terazzi, and J. Faist
"A density matrix model of transport and radiation in quantum cascade lasers"
New Journal of Physics 12 (2010) 033045.

S. Tirelli, D.Marti, H. Sun, A.R. Alt, H. Benedickter, E. Piner, and C. R. Bolognesi
"107-GHz (Al Ga)N/GaN HEMTs on silicon with improved maximum oscillation frequencies"
IEEE Electron Device Letters 31 (2010) 296.

C. Walther, G. Scalari, M. I. Amanti, M. Beck, and J. Faist
"Microcavity laser oscillating in a circuit-based resonator"
Science 327 (2010) 1495.

S. T. Yilmaz, P. Fallahi, and A. Imamoglu
"Quantum-dot-spin single-photon interface"
Physical Review Letters 105 (2010) 033601.

Y. Zeng, O. Ostinelli, R. Lövblom, A. R. Alt, H. Benedickter, and C. R. Bolognesi
"400 GHz InP/GaAsSb DHBTs with low-noise microwave performance"
IEEE Electron Device Letters 31 (2010) 1122.

Y. Zeng, R. Lövblom, O. Ostinelli, and C. R. Bolognesi
"(Ga In)P emitter composition effect on the performance of (Ga In)P/GaAsSb/InP DHBTs grown by MOCVD"
Physica Status Solidi C 7 (2010) 2490.

H. Zhang, G. Scalari, J. Faist, L. A. Dinbar, and R. Houdre
„Design and fabrication technology for high performance electrical pumped terahertz photonic crystal band edge lasers with complete photonic band gap"
Journal of Applied Physics 108 (2010) 093104.

L. Zhang, K. E. Peyer, and B. J. Nelson
"Artificial bacterial flagella for micromanipulation"
Lab on a Chip 10 (2010) 2203.

L. Zhang, T. Petit, Y. Lu, B. E. Kratochvil, K. E. Peyer, R. Pei, J. Lou, and B. J. Nelson
"Controlled propulsion and cargo transport of rotating nickel nanowires near a patterned solid surface"
ACS Nano 4 (2010) 6228.