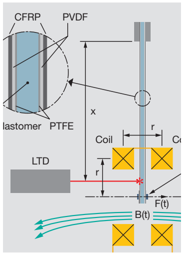
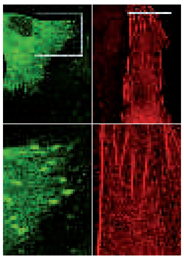
Empa Activities 2006

Report on technical and scientific activities

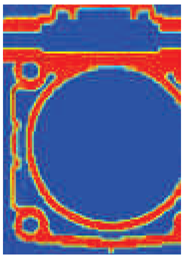
Advanced Materials
and Surfaces



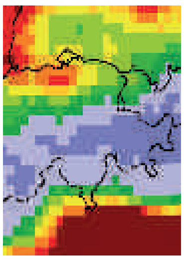
Civil and
Mechanical Engineering



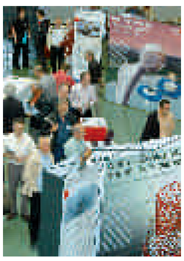
Materials and Systems
for Protection
and Wellbeing of the
Human Body



Information, Reliability
and Simulation Technology



Mobility, Energy
and Environment



Technology Transfer

Empa Academy

EMPA

Materials Science & Technology

Empa Activities 2006
Welcome

Technology Transfer à la Empa:
Innovative solutions for industry and society

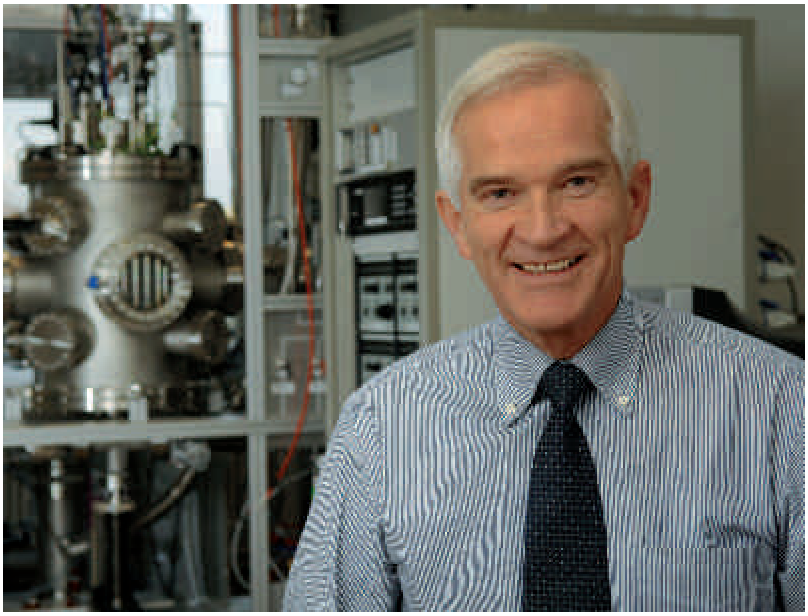
“Empa Activities 2006”, our annual science and engineering report, represents a distillate of our research and development activities in this past year. The selected examples illustrate the diversity and broadness of our activities in application-oriented research and development, knowledge and technology transfer, teaching and high-tech services to industry and public agencies.

As a Swiss institute of materials science and technology, being part of the ETH Domain, we are proud to offer you a fascinating insight into some of Empa’s results from use inspired application-oriented research into new material properties and phenomena, engineering and environmental technology as well as systems development. Most of the projects presented in “Activities 2006” were carried out within Empa’s five Research Programs

- Nanotechnology
- Adaptive Material Systems
- Materials for Health and Performance
- Technosphere – Atmosphere
- Materials for Energy Technologies

These strategic programs embody the “heart and soul” of Empa’s R&D activities. Through interdisciplinary approaches Empa scientists and engineers elaborate and offer innovative full chain solutions to pressing needs of industry and society.

In view of urgent needs to limit the effects of rising greenhouse gas emissions and the resulting climate change, Empa topics of particular importance are energy efficiency in buildings, mobility and transport; the development of sustainable energy technologies and novel energy carriers such as hydrogen as well as understanding and monitoring technology-related emissions of pollutants and their diffusion on a global scale, including the development of state-of-the-art monitoring devices for new pollutants appearing (at first) in minuscule amounts.



Moreover, we employ state-of-the-art nanotechnological methods for the conception of novel functional materials, for instance, for thermoelectric or photovoltaic energy converters, and we engineer materials for optimized high-temperature use in turbines.

With respect to the more classical tasks of Empa regarding the safety and reliability of materials, we are currently studying potential environmental and health hazards associated with free nanoparticles.

Our innovative results on fibers, textiles and medtech materials and devices, widely recognized by industry and public agencies, received several awards in 2006.

With our efforts on smart material systems exhibiting adaptive and controllable properties like shape, stiffness, viscosity, diffusitivity or reflectivity, we further strengthened our engineering activities aimed at developing devices for medical as well as for air and space technologies.

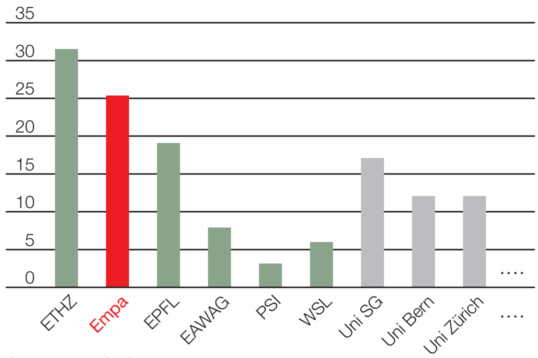
The overall goal of all of Empa's activities is to strengthen and boost innovation for Swiss industry and to increase the quality of life for the public at large, thus fulfilling its role in bridging the gap between the generation of scientific knowledge and its implementation for practical applications. This process, known as "technology transfer", was one of the foci of Empa's endeavors in 2006.

We were more than pleased, in early 2006, when we learned about the results of a study by the ETH Zurich's Swiss Economic Institute KOF, carried out for the ETH Board to analyze the interactions between Swiss industry and the country's publicly funded R&D institutions. In a survey to industry about the number of contacts/collaborations with R&D institutions, Empa was ranked second after ETH Zurich.

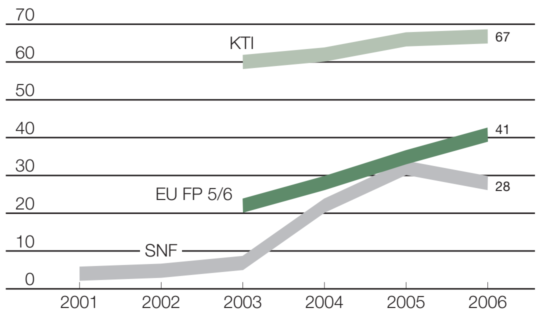
Other performance indicators such as the number of scientific publications, their average impact factor – up from 1.72 in 2005 to 2.5 last year – or the amount of third party means also manifest that 2006 was a highly successful year for Empa. A particular "highlight" is Empa's technology transfer activities, which are rapidly picking up speed. Invention disclosures ("patent applications") were at 22, up from 18 a year earlier; the number of technology transfer contracts with our industry partners reached 168 (up from 93 in 2005), including 10 licensing agreements (up from 4). Altogether, the revenues generated through our technology transfer activities more than doubled (CHF 103 000 vs. CHF 48 000 in 2005).

With "Empa Activities 2006" we hope to have aroused your curiosity concerning Empa's ongoing activities; if you are eager to learn more about Empa, please visit our homepage *www.empa.ch* or feel free to contact us directly via *PORTAL@empa.ch.*

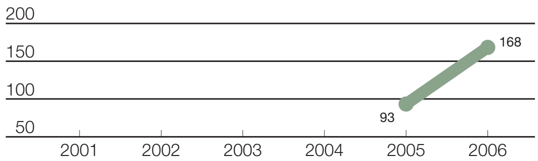
Louis Schlapbach, CEO Empa



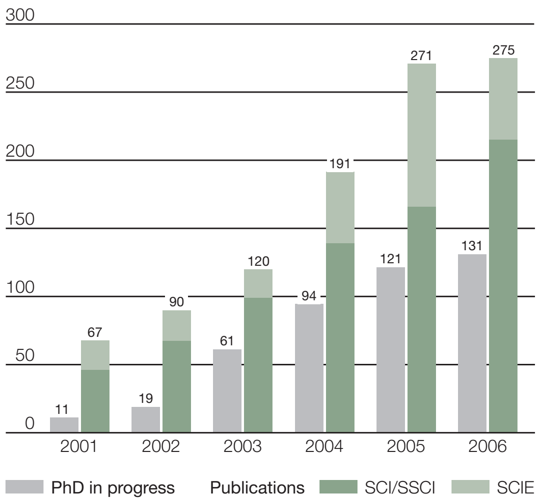
Survey by KOF/ETH:
Number of collaborations between Swiss industry and R&D institutions



Projects running at Empa



Number of technology transfer contracts Empa – Industry partners



Focused ion beam modifications of indium phosphide photonic crystals

We used focused ion beam (FIB) to structure and modify InP / InGaAsP based photonic crystal (PhC) power splitters. The power splitters (PS) include a central hole in the Y-junction to reduce reflections and to increase bandwidth and output power of the arms. The device performance strongly depends on the position, diameter, and depth of the hole. This makes the device attractive as a benchmark for FIB fabrication.

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Since the invention of the laser, progress in photonics has been closely related to the development of optical materials which allow to control the flow of electromagnetic radiation. Photonic crystals (PhC) are a promising class of optical materials, characterized by a periodic arrangement of dielectric materials which lead to the formation of an energy band structure for electromagnetic waves. Flexibility in lattice period, symmetry, and material is provided by advances in micro- and nano-structuring. This leads to numerous applications in linear, nonlinear and quantum optics like waveguides, bends, add-drop filters, splitters or active devices like integrated optical amplifiers or lasers. In principle, a III-V semiconductor direct bandgap material like indium phosphide (InP) allows to integrate complete optical circuits on a chip.

We studied focused ion beam (FIB) structuring and modifications of InP / InGaAsP based photonic crystal (PhC) power splitters. State-of-the-art PhC structuring with FIB is already known for other materials. We first investigated the sputtering behavior and reaction products of InP irradiated by 30 keV Ga^+ ions. The InP / InGaAsP PhC were fabricated by electron beam lithography in combination with inductively-coupled plasma reactive ion etching (EBL/ICP-RIE) and modified subsequently by FIB. Splitting ratio and spectral response were measured using the port-to-port end-fire technique and compared to devices fabricated with EBL/ICP-RIE only.

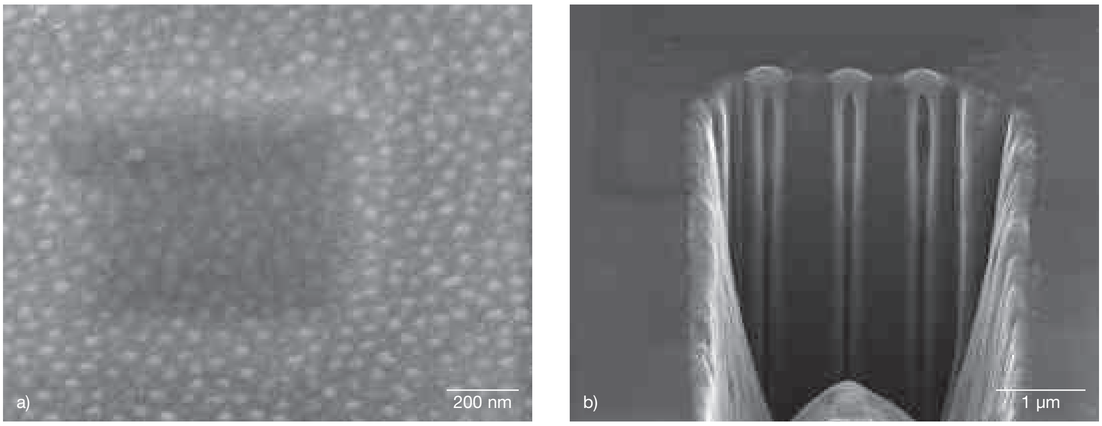

Fig. 1: *a) In-Ga islands on InP (fluence: 4.9 x 10^{17} cm^{-2}), b) holes with AR > 4.*

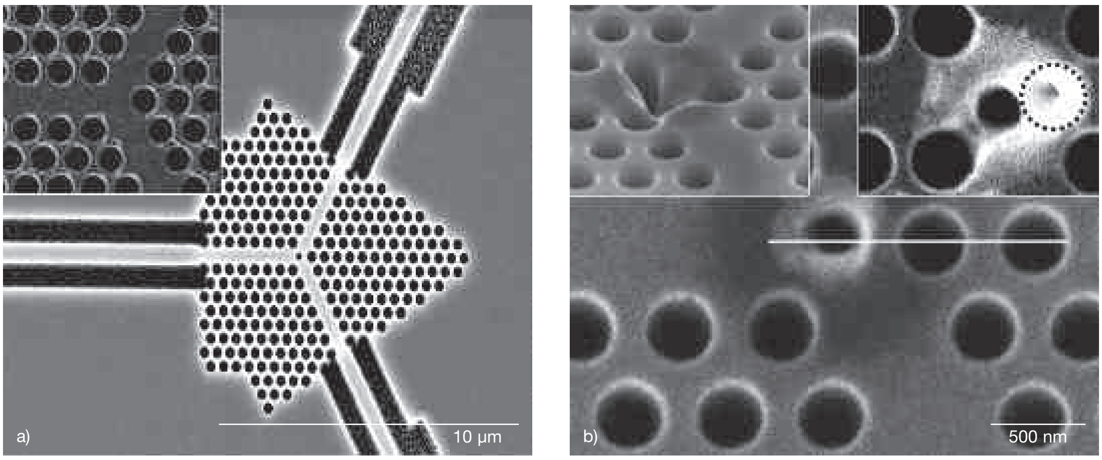

Fig. 2: *a) PhC power splitter (EBL/ICP-RIE) with and without central hole (inset), b) FIB fabricated central hole with offset, funnel shape (left inset), redeposition (right inset/dashed circle).*

The modifications were made with a dual beam FIB instrument using Ga^+ ions with currents of 1 pA and 10 pA and various dwell times to study the hole formation as a function of fluence. The shapes of milled structures were measured in scanning electron microscopy (SEM) images of FIB cross-sections. The lattice constants a were varied from 375 – 500 nm to cover a broad range of the reduced-frequency u = a/λ from 0.24 – 0.32. One PS per a was used as reference with the central hole in the Y-junction fabricated by EBL/ICP-RIE. The others were modified by FIB.

The milling was done in concentric circles in sequence of their radii ending with the outmost circle. The dwell time was calculated with a resulting profile proportional to ~ $r^{1.5}$, r being the radius. This procedure was found to give the most parallel walls. Aspect ratios > 4 could be achieved (Fig. 1).

It was shown that sputtering leads to In droplets on the surface of InP (Fig. 1). Two other effects were observed, which are expected to influence the waveguiding properties because the main optical mode reaches the PhC surface. Certain holes were funnel-shaped due to the ion distribution. Others showed redeposition of sputtered material which partially covered neighboring holes (Fig. 2). All these effects are expected to be reduced by using a suitable etchant gas, such as I_2 or Cl_2, analogous to ICP-RIE. Figure 2a shows micrographs of PhC-PS as fabricated by EBL/ICP-RIE with and without (inset) central hole. Close-ups of FIB fabricated central holes are depicted in Figure 2b. A central hole with offset is shown, as well as a hole with funnel-shape (left inset) and one with redeposition covering neighboring holes (right inset).

The optical characterization of the PS fabricated by EBL/ICP-RIE shows a flat transmission of 50% for both branches over the reduced-frequency range. Devices with a FIB-milled central hole show 5 dB and 20 dB lower transmissions for the lower and upper branches, respectively (Fig. 3). A shift of the central hole of 18 and 60 nm with respect to the input waveguide axis leads to a splitting ratio between the branches of 5 – 12 dB. This variation occurs because the central hole offsets were not the same for all lattice constants. The overall lower transmission for the FIB-fabricated structures can be explained by the funnel shape of the central hole and the redeposition.

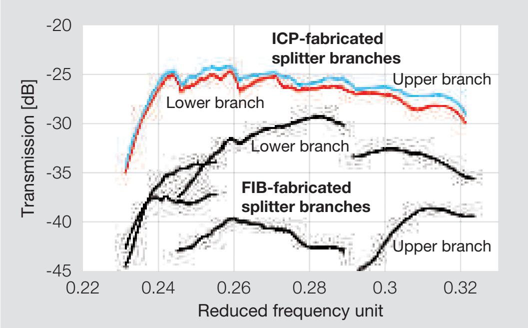

***Fig. 3:** Comparison of transmission: EBL/ICP-RIE only (grey), FIB-milled central hole with offset (black). Smoothed graphs to eliminate Fabry-Perot fringes (facet to facet cavity).*

The splitting ratio can be varied via the central-hole offset. Thus, ratios other than 50 : 50 can be achieved. Simulations confirm the measurements. In Figure 4, the power splitting versus central hole shift relative to lattice constant is plotted for the measurements (triangles) and the simulations (circles). Although effects like the funnel-shape of the holes, non-circularity, and asymmetry are not included in the calculation, but contribute to the variation, the agreement is good.

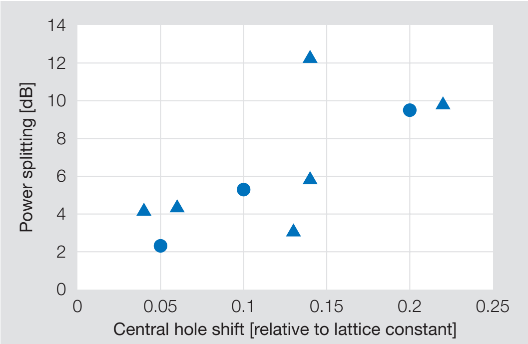

***Fig. 4:** Power splitting versus central hole shift: theory (circles), measurements (triangles).*

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