Dear readers,

If you were to walk down the new Campus Boulevard in Aachen today, two magnificent light sculptures would immediately catch your eye: the Aachen-based artist Annette Sauermann has adorned the outer walls of two buildings, the new homes of the Fraunhofer IPT and ILT, with 156 m² large network drawings featuring 6560 LED modules that are arranged in chains with a total length of 410 meters. These works of art are meant to create an animated and constantly changing, kaleidoscopic flux of light, colours and forms. The drawings were unveiled in February 2015 and given the name “Networks of Knowledge” because they are meant to represent our mission: lively and pulsating, constantly changing networks.

Networks and change: these are also key aspects of the relationships with our partners from business and industry. “Connected, adaptive production” – this motto has been chosen to provide the new leitmotiv for our future portfolio of skills and services. “Connected”, because we acquire and transfer relevant technological knowledge quickly and efficiently, and “adaptive” to reflect our ability to design production processes that automatically adapt to new requirements and optimize themselves. While “production” remains our core business: the ability to control industrial processes safely and reliably, even when they reach their limits of performance.

Over the past few years, we have done a lot to strengthen our business activities systematically and to adjust our service portfolio to the requirements of our clients. Today, the business units that account for 70 percent of our total revenue adequately represent our main activities. They will continue to provide the ideas and strategic impulses for major projects.

One good example of how such projects can be successfully managed and developed for the benefit of everybody involved is provided by an initiative of our “Turbomachinery” business unit. The Innovation Cluster “Adaptive Production for Resource Efficiency in Energy and Mobility”, a multi-year joint venture featuring 22 partners from industry and science, last year provided the launch pad for the establishment of the “International Center for Turbomachinery Manufacturing”, the ICTM, which will take the excellent cooperation to a new level.

We are also delighted – and even a little bit proud – to announce that our Paderborn-based project group “Mechatronic Systems Design” has been positively evaluated following a five-year development stage. On 1 January 2016, the project group has been converted into the Fraunhofer Research Institution for Mechatronic Systems Design IEM which will now go its own way under the leadership of Ansgar Trächtler. We are looking forward to working closely together with our colleagues from Paderborn and are certain that the new Fraunhofer IEM will continue to develop successfully.

My special thanks – also on behalf of Christian Brecher, Robert Schmitt and Günther Schuh – go not only to those who have actively shaped the events and developments that I have described in the preceding paragraphs but also to those who have enabled them through their reliability, flexibility and personal engagement: mainly our members of staff, but also our clients, partners, sponsors and friends – or, in short, the “Networks of Knowledge” that have already paved the way for our achievements of the past. We are looking forward to exciting new challenges and a successful 2016!

Aachen, February 2016

Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. Fritz Klocke
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IN PROFILE: THE FRAUNHOFER IPT

Anybody who wants to launch his products and services successfully on today’s global market must learn to exceed his own limitations and to shape the process of change, thinking on his feet and remaining forever willing to adapt himself to the continuously changing requirements.

The Fraunhofer IPT has decades of experience in the production technologies it utilizes in order to provide companies with a strong basis for the digitization of production processes, machine tools and equipment. Our technological expertise is complemented by new production organization methods and by the design of industrial software systems. The portfolio of the Fraunhofer IPT extends from the evaluation and design of technologies and process chains through planning and control concepts to quality management control circuits. The institute currently employs around 460 people who are dedicated to applying their creativity to methods, technologies and processes for a connected, adaptive production.

Rather than considering production activities as individual operations, our work involves looking at all production processes and the links between all the elements of the overall process in their entirety – from research and development through the acquisition of raw material and services to the final production stages and assembly. This interdisciplinary view allows us to approach and develop solutions which require thinking beyond the narrow confines of any particular discipline.

Industries, products and technologies

Our business units combine the skills and the knowledge of the individual departments, the Fraunhofer CMI and our partner institute at the RWTH Aachen University, the Laboratory for Machine Tools and Production Engineering WZL. This interdisciplinary view – which is informed by and aligned with the perspective of industrial researchers – allows us to approach and develop solutions which require thinking beyond the narrow confines of any particular discipline.

Our range of services reflects the needs, requirements and challenges of a number of industries, technologies and product groups:

- Automotive industry including suppliers
- Energy
- Life sciences
- Mechanical engineering
- Optical industries
- Precision engineering and microtechnology
- Turbomachinery
- Tool and die making

Technologies that provide a cutting edge

We put great importance on our continuous contacts and exchanges with industrial corporations and the permanent updating of our equipment. This allows us to ensure that we always remain abreast of the latest technological trends and developments – and that we can provide you with that all-important competitive edge in your production technologies. Our laboratories and production facilities feature state of the art technology and cover an area of 5,000 m². The entire Fraunhofer IPT occupies an area of app. 9,000 m².
OUR FORMULA FOR SUCCESS: TECHNOLOGY PLUS HUMAN RESOURCES

More than 460 highly committed and creative people are currently helping the Fraunhofer IPT to achieve its vision and to implement its various projects. All of the Institute’s employees contribute their skills and knowledge to cross-departmental, interdisciplinary teams: our flat-hierarchy organizational structure which reflects the duty of each individual to assume responsibility for the entire project creates space for innovative ideas and ensures that our highly motivated workforce strives hard to achieve the jointly identified objectives.

We firmly and unconditionally believe in professionalism, partnership and efficiency. We did not discover the importance of these values for the purpose of phrasing a mission statement, but in the daily routines of our Institute. For many years, these principles have guided and informed the work of everybody at the Fraunhofer IPT. The Fraunhofer IPT therefore provides its employees with an excellent working environment and a platform for their professional and personal development, enabling them to assume a wide range of responsibilities at the Institute, in academic science or other research institutions, in the industry and in the wider society. The Fraunhofer IPT is committed to assisting the global knowledge transfer, to ensure that society as a whole will eventually benefit from the skills and the expertise of gifted scientists.

Careers start at the Fraunhofer IPT

The basic principles of human resource management have changed little since the Fraunhofer IPT was established more than 30 years ago: it is our objective to provide young scientists with a comprehensive project work experience and to allow them, during this period of roughly five years, to complete their doctoral theses. In the space of five years, some of our employees may become Group Managers or Business Field Managers and, subsequently, assume the responsibilities of a Head of Department. They remain on average for another five years at the Institute, which means that at least one such vacancy arises in any given year, providing a talented young scientist with the opportunity of meeting the challenges of managerial responsibility.

In order to help them reach these objectives, the employees of the Institute are immediately – starting with the moment of their arrival – subjected to an intensive training and preparation schedule designed to allow them to accomplish their future tasks. For this purpose, we use – in close cooperation with the WZL of the RWTH Aachen University – the “Karrierepool WZL Aachen PS GmbH”. This personnel consulting service has been designed to support the scientific members of staff at the Fraunhofer IPT and the WZL in planning the next steps of their careers and in implementing these career plans. The organization establishes contacts between the young scientists and corporations in search of suitable candidates for their R&D departments and managerial positions. Nearly all members of our scientific staff are taking advantage of these services to plan their subsequent careers. In 2015, 23 of our young scientists have left the Institute for a job in an industrial corporation.

Excellent conditions for young engineers

The objective is to involve more women in the scientific work that we perform at the Fraunhofer IPT: this is why we have intensified our cooperation with the Femtec network in 2015. Femtec.GmbH and its partner organizations – which include the Fraunhofer Gesellschaft – have established a unique network which is designed to provide women in the fields of science and technology with help and support. The program aims to encourage outstanding female students of the scientific and engineering departments in TU9 universities (Germany’s top science and technology colleges) as well as the ETH Zurich. In October 2015, 50 Femtec students visited the Fraunhofer ILT and IPT in Aachen. They were provided with an initial insight into the routines and different research activities of both institutes and were given the opportunity of experiencing the technology “live” during guided tours of the research facilities and laboratories. During a panel discussion, the students could discuss career opportunities and perspectives in science and research with members and staff of the Fraunhofer IPT and ILT.

In order to allow our male and female members of staff to reconcile their careers and family lives more effectively, the Fraunhofer IPT is offering them part-time occupation schemes. Some young parents in our scientific staff have gone on parental leave, taking advantage of the chance to share the
first few months of their children’s lives with their partners. The Fraunhofer IPT has also established a “parent-child office” to allow young parents an early return into employment. The Fraunhofer IPT’s management is keen to assist its employees in their search for nursery day care centres and child care for school holidays or emergencies.

**Professional personnel marketing to combat the lack of skilled employees**

Due to this personnel policy of ours, we need to recruit about 25 young scientists per year to fill our staff vacancies. Despite a general fall in the number of candidates over the past few years, we have so far managed to fill these vacancies every year. Almost a third of new employees already started working at the Fraunhofer IPT during their studies as student workers or writing theses. In the past few years, also the proportion of candidates who completed their studies at universities outside the Aachen region has substantially increased.

In order to improve its chances of recruiting qualified candidates on this highly competitive section of the labor market, the Fraunhofer IPT has continued the Fraunhofer-wide personnel marketing campaign at selected campuses across Germany. During a series of job fairs (whose corporate participants included the Fraunhofer IPT), the RWTH Aachen University student canteen exhibited large, three-dimensional letter sculptures that spelled out the word DOCH (“it does work”), the central motto of the Fraunhofer recruitment campaign. Large numbers of posters were placed in university buildings, in the bus lines that are going past the Fraunhofer Institutes and all over the Aachen town center to provide information about the Fraunhofer job opportunities and to strengthen the brand on the employment market.

The Fraunhofer IPT also contributed videos to the online career platform “whatchado.com”. On this platform, employees from different enterprises with various career backgrounds talk about what they do for a living and what they did to get there. The video portal provides young people with an overview of the large variety of jobs on the labor market and is meant to inspire and inform their career choices in terms of industries and employers. In November 2015, 13 employees of the Fraunhofer IPT, ILT and IME outlined their career profiles in front of the “whatchado.com” cameras. You can watch the clips on the platform’s web page.

In October 2015, the Fraunhofer IPT hosted the first edition of its newly conceived “Talent Take Off” event, one of its many programs to encourage budding young scientists and engineers. The four-day event had been customized for first- and second-year students of mathematics, informatics, science and technology, combining skills training with opportunities of experiencing applied research activities as well as visits of the Fraunhofer facilities and discussions with their scientists and students. An additional one-day professional training workshop was also open to students of the Fraunhofer IPT. The event was attended by 19 young people from the Aachen region and across Germany.

On top of that, the Fraunhofer IPT also hosted another series of information events in 2015 for students, allowing them to find out more about the Institute and its various activities, to interview staff members about the working conditions and to establish personal contacts.

**Internal communication – Networking and speaking to one another**

Internal communication moved up on the Fraunhofer agenda in 2015 and became one of the Institute’s main strategic topics:

Early in the year, after the completion of the building works, premises on the third floor were given over to a new “communication zone”. This area has been designed as a space for informal discussions, coffee breaks and short meetings.
to encourage mutual exchanges. The zone comprises a small kitchen with a coffee machine, various seating areas and a large whiteboard where staff members can add their own ideas and suggestions.

Under the motto “Mehr drin” (“More to explore”), the Fraunhofer IPT hosted the fifth edition of its internal “IP Tin-sdie” information event on 26 September 2015. In 36 short presentations, employees from different business units talked about their projects and strategically important initiatives. The event was designed to encourage the establishment of cross-departmental networks, to assist in the development of new ideas and to make the relevant technologies more accessible through exhibitions and tours of the research facilities.

Coinciding with this event, both the form and the editorial content of the internal news outlet “Newspool” – published both as a staff magazine and on the Intranet – was subjected to a major redesign in line with the changing requirements of the Institute’s employees.

From 11 to 25 November 2015, the Fraunhofer IPT took part in the Fraunhofer-wide employee survey. The anonymous questionnaires were designed to reveal potentials for further improvement and provide executives with feedback for their activities. The response rate of 85 percent significantly exceeded the rate from the previous survey in 2011. The responses will be evaluated in early 2016 through a previously defined follow-up process, and improvements of the current system will be performed soon after.

Changes in personnel

Prof. Dr.-Ing. Christian Brecher was appointed Deputy Director of the Fraunhofer IPT with effect from 1 January 2015. He thereby assumed important additional responsibilities for the management and development of the Fraunhofer IPT, on top of his responsibility for the “Production Machines” division.

On 1 January 2015, Christoph Baum became the head of the new department for “Ultra-Precision Technology and Plastic Replication”, becoming the third Head of Department within Prof. Dr.-Ing. Christian Brecher’s “Production Machines” unit, joining Dr.-Ing. Christian Wenzel (department for “Machine Optimization and Automation”) and Dr.-Ing. Michael Emonts (department for “Fiber-Reinforced Plastics and Laser Systems Technology”).

The facility management and maintenance department and the electrics workshop have merged in early 2015, in recognition of the extensive overlap of their briefs and activities. The management of the technical laboratories and workshops has been assigned to Dirk Nehr, the facility management and maintenance brief is covered by Franz Dovern, and the electrics workshop is managed by Stefan Trepel.

As per 1 January 2016, Dr.-Ing. Thomas Bergs has concentrated exclusively on his business management commitments. The department for “High-Performance Cutting” will be managed by Dr.-Ing. Florian Degen.
TO CONSIDER THE ENTIRE PROCESS

On behalf of our clients, we develop and optimize solutions for modern production facilities. Rather than considering production activities as individual operations, our work involves looking at all production processes and the links between all the elements of the overall process in their entirety: When we analyze our client’s processes, we take in everything from research and development through the acquisition of raw material and services to the final production stages. At the same time, we keep an eye on all the relevant business and management processes.

Research and development

Right at the early phases of product emergence – the research and development phase – we can use our expertise to help our customers identify new technologies, create concepts and develop prototypes. We place a great deal of importance on getting equipment, material and processes to perform optimally, giving our client’s products the best chances of competing in the market.

Purchasing

Whatever a company cannot make itself, it buys in from its suppliers. Companies need to be able to rely on their suppliers to provide top quality goods and services at reasonable prices, so we take a close look at their supply base and the services it provides. We structure the purchasing market for our clients, help them to choose the right partners and develop individual courses of action using tried-and-tested methods in order to optimize their purchasing costs.

Production

The Fraunhofer IPT is seen by its clients as an experienced partner for all issues related to production – and not without good reason. Whether we are determining their status quo, analyzing their production concept, selecting technology, designing a system, or developing, optimizing and implementing processes, they can rely on our motivated team of experts representing different disciplines and many years of expertise. We never look at concepts, technologies and systems in isolation, but see them within the context of our client’s industrial practice.

Management

In some situations, it becomes necessary to critically review one’s fundamental management processes, the technology strategy or the strategic and operative management as a whole. We analyze structures and processes at all phases of research and development, purchasing and production and help our partners to develop a new, more promising approach without abandoning best practices. We consider it particularly important that their employees stand firmly behind any changes, especially in sensitive areas.
MISSION STATEMENT

Applied research and consulting

The task of the Fraunhofer IPT is to transfer research findings into economically viable and unique innovations in the field of production. The Fraunhofer IPT promotes and conducts applied research, implements research results in an industrial context, and provides relevant and effective consulting services for the direct benefit of industry, thereby contributing significantly to the competitiveness of companies.

Excellent and exceptional

The Fraunhofer IPT offers research and consulting services of excellent quality on the basis of scientifically recognized procedures and using state-of-the-art facilities. It is the goal of the Fraunhofer IPT to achieve technological and opinion leadership in its key focus areas with respect to contract research at both a national and international level.

Transparent development guidelines

The Fraunhofer IPT works according to standard development guidelines that coordinate the competence areas of the individual departments and allow them to be integrated on a project basis. Value is also placed on interdisciplinary collaboration with recognized partners from industry and research. The Fraunhofer IPT uses these synergies to offer system solutions from a single source.

Qualified and motivated employees

The performance of the Fraunhofer IPT is determined to a decisive degree by the technical and social competence of its staff. With a high level of commitment to the Institute and exceptional motivation and professionalism in projects, the employees of the Fraunhofer IPT are the foundation of our success. The Fraunhofer IPT provides its employees with an excellent working environment and a platform for professional and personal development that equips them for challenging tasks at the Institute as well as in other areas of science, in industry and in society. “Knowledge transfer via people”, i.e. external transfer of know-how gained at the Institute, is actively encouraged at the Fraunhofer IPT.

Culture and values

The working environment at the Fraunhofer IPT is marked by mutual respect, content transparency, openness, cooperation, understanding and trust. Collaboration with our partners also rests on these values.

Customer orientation

All activities of the Fraunhofer IPT are carried out for the direct benefit of the customer. Customer satisfaction is a decisive success indicator for the Fraunhofer IPT. Our capabilities and professionalism in contract research lead to long-term partnerships.

Efficient organization

The excellent work of the Fraunhofer IPT is based on optimum internal procedures and sound use of methods. Administrative and technical departments as well as marketing and media design are actively incorporated into our services, enabling the engineering departments to concentrate on technological and methodological innovations. All organizational units of the Fraunhofer IPT therefore play a role in ensuring the high level of customer satisfaction.

Economic success and entrepreneurship

Economic success is crucial to the self-management and to the strategic development of the Fraunhofer IPT. The independent financing of the Institute allows the technological potential in future issues to be approached in a targeted way, so that promising solutions may be derived for the customer.
## Executive director
Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. Fritz Klocke

## Managing chief engineer
Dr.-Ing. Thomas Bergs MBA

### Process technology
Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. Fritz Klocke

### Production machines
Prof. Dr.-Ing. Christian Brecher

### Production quality and metrology
Prof. Dr.-Ing. Robert Schmitt

### Fine machining and optics
Dr.-Ing. Olaf Dambon

### Fiber-reinforced plastics and laser systems technology
Dr.-Ing. Michael Emonts

### Production quality
Dipl.-Ing. Eike Permin

### High performance cutting
Dr.-Ing. Florian Degen

### Precision machines and automation
Dr.-Ing. Christian Wenzel

### Production metrology
Dipl.-Phys. Niels König

### Laser material processing
Dr.-Ing. Kristian Arntz

### Ultra precision technology and polymer replication
Dipl.-Ing. Christoph Baum
Board of directors
Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. Fritz Klocke, Prof. Dr.-Ing. Christian Brecher, Prof. Dr.-Ing. Robert Schmitt, Prof. Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh

Technology management
Prof. Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh

Strategic technology management
Dipl.-Ing. Dipl.-Wirt. Ing. Markus Wellensiek

Operative technology management
Dipl.-Ing. Toni Drescher

Services
Dr.-Ing. Thomas Bergs MBA

Administration
Josef von Heel

IT, building services and PR
Dr.-Ing. Thomas Bergs MBA

Strategic research planning
Dipl.-Ing. Axel Demmer

Strategic business planning
Dipl.-Ing. Torsten Moll
EQUIPMENT

Our laboratories and production facilities feature state of the art technology and cover an area of 5000 m². We put great importance on our continuous contacts and exchanges with industrial corporations and the permanent updating of our equipment. In the year 2015 we invested an amount of 4.3 Mio Euro for machinery and infrastructure.

Grinding and polishing machines and systems

– D40 Diamantbearbeitung
– Polierzelle PM3
– Moore Nanotech 350 FG
– Moore Nanotech 500 FG
– Walter Helitronic Vision 400 L
– ABB IRB 4400 Zelle 1
– ABB IRB 4400 Zelle 2
– Satisloh All
– Synchrospeed 120SL
– Uschi Sphromatic
– Toshiba ULG-100D(H3)
– Toshiba ULG-100D(SH3)
– Elb SWN 10 NC-K
– Schneider Surfacing Center SCG100-1
– Schneider Surfacing Center SCG100-2

Precision and high performance machining centers

– LT Ultra MTC 410
– Precitech Nanoform 250
– Weika
– Kern Micro
– Kern Pyramid Nano
– Mikromat 8V HSC
– Moore Nanotech 350 FG
– Leifeld PNC/CNC 75
– Monforts RNC 400 Laserturn
– Minimill
– DMG HSC55 linear
– CNC Drehmaschine - Gildemeister
– DMU50
– Maho 600 E2
– Alzmetall GS 1000
– Alzmetall AB 4/HAST
– Alzmetall AX 3-T
– Mössner Rekord
– Weiler Commodor 75 GS
– Weiler Primus LZ-G
– Mikron HPM 800U HD
– Monforts Unicen 1000

Equipment for optics replication of glass and plastics

– Arburg Spritzgussmaschine 720 A
– Arburg Spritzgussmaschine mit Handhabungssystem
– Moore Nanotech 065 GPM
– Toshiba GMP-207 HV
– Toshiba GMP-211 V
– Laminiereinheit zum Rollprägen
– Rollprägeanlage
– HEX02
– Moore Nanotech 140GPM
– Toshiba GMP 311V
– FFUP
– Füller Glaspresse

Coating systems

– PVD-Beschichtungsanlage: Cemecon 800/9
– Galvanik Nickel-Phosphor
**Lasers and auxiliary equipment**

- Kern Evo
- Mikron HSM 600U
- Pro-PKD Laserbearbeitungssystem
- Laserline Diodenlasersystem LDF 5000-40
- Trumpf TruMicro 2220
- MA micro automation MicroCell compact
- Trumpf TruCoax 2000
- Satisloh GI-3PL
- Mobile Montagezelle
- Sysmelec Montageaufbau
- Häcker Automation VICO X Tec
- Bolenz + Schäfer Portal
- IR-Thermoforming-Prüfstand
- Kuka 360-2
- Stanzmaschine Boschert
- Alzmetall LOB
- Monforts LaserTurn

**Specialist equipment**

- Flexpaet
- LT Ultra MMC 1100-2Z
- LT Ultra MMC1300
- UHM
- HEGA Ultraschallreinigungsanlage
- Grosskammer-REM
- Mikro-Pullwinding-Anlage
- Schunk PowerCube SCARA Roboter
- Zwei-Photonen-Lithographie-System Nanoscribe Photonic Professional

**Data processing and simulation tools**

- Triamec Prozessüberwachungsgerät
- Zemax

**Metrology and testing equipment**

- Zeiss O-Inspect Koordinatenmessgerät
- Schwingungsprüfstand
- Rauheitsmessgerät Taylor Hobson Form Talysuit Series
- Rundheitsmessgerät Talyround 262
- Koordinatenmessgerät Werth Video Check IP
- Profilometer FRT Micro Prof 100
- Mikro-Härteprüfer Leco M-400-H
- Härteprüfer Wolpert UH-250
- Formprüfinterferometer Zygo Verfire und Wyko 6000
- Laserscanningmikroskop Leica DM RXE
- Koordinatenmessgerät Werth VideoCheck UA
- Mahr Formtester MMQ 400 mit optischer Antastung
- Wellenfrontmessgerät Trioptics Wavemaster
- Steinbachler Comet 5 Streifenprojektionssystem
- Deflektometriesystem 3D Shape SpecGage 3D
- Weißlichtinterferometer Bruker NPFLEX und Contour GT-K
- Werkzeugmessmaschine Walter Helicheck Plus
- 3D-Mikroskop Alicona InfiniteFocus G4
- Mahr LD 260 Aspheric
FACTS AND FIGURES

Budget

The financial structure of the Fraunhofer-Gesellschaft distinguishes between operational and investment budgets. The operational budget includes all personnel and material costs, external profits and funding. The Fraunhofer-Gesellschaft’s integrated financial plan allows for transfers between budgets.

Operational budget

The operational budget amounted to approx. 31.6 million euros in 2015, with 71 percent self-financing.

Contract research

Profits generated through research in national and state funded projects increased slightly, contributing 8.4 million euros to the institute’s financing (32 percent).

Profits generated through EU-funded projects decreased to 2.2 million euros. EU projects are not fully-financed, calling for a contribution from the research institute. Fraunhofer Institutes therefore limit their applications for such projects.

The Fraunhofer IPT took on projects in cooperation with industrial partners which, combined with the profits from contract research for industry, business and trade associations, contributed 11.1 million euros to the institute’s finances (57 percent).
Personnel structures at the Fraunhofer IPT

An average of 459 staff was employed at the institute in 2015, with around 214 permanent staff members in scientific and non-scientific departments (circa 57 percent scientific staff). Remarkable is the high proportion of young employees aged 25 to 35, mostly graduates starting their career at the Fraunhofer IPT as scientific staff. Besides, there is a continuously strong base of non-scientific staff of all ages.

Personnel structures at the Fraunhofer CMI

The Fraunhofer Center for Manufacturing Innovation CMI in Boston, USA, employed a staff of 32 in the past year, 17 of which were permanent scientific staff with a support staff of two.
Each of the Fraunhofer Institutes has a Board of Trustees to advise the management of the Institute and the Management Board of the Fraunhofer-Gesellschaft. They include personalities from academic life, business and government. The members of the Board of Trustees of the Fraunhofer IPT in the year under review were as follows:

**Chairman of the Board of Trustees**

Dr.-Ing. Stefan Nöken  
Hilti AG, Schaan/Liechtenstein

**The members of the Board of Trustees**

Prof. Dr.-Ing. Eberhard Abele  
Institute of Production Management, Technology and Machine Tools of Technische Universität Darmstadt

Prof. Dr.-Ing. Kirsten Bobzin  
Surface Engineering Institute, RWTH Aachen University

Dr.-Ing. Uwe H. Böhlke  
Oerlikon Balzers Coating AG, Balzers/Liechtenstein

Dr.-Ing. Matthias Fauser, Grabenstätt  
Hans-Dieter Franke  
Management Partner MPower GmbH, Winnen

Dr.-Ing. Markus Hilleke, Siegen  
Manfred Nettekoven  
Chancellor of the RWTH Aachen University

MR Hermann Riehl  
Federal Ministry of Education and Research, Bonn

MdL Karl Schultheis  
Member of the North Rhine-Westphalian Landtag, Düsseldorf
At present, the Fraunhofer-Gesellschaft maintains 67 institutes and research units. The majority of the nearly 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2.1 billion euros. Of this sum, more than 1.8 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft’s contract research revenue is derived from industrially as well as from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development. With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer. Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers. As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society.

Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired. The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787-1826), the illustrious Munich researcher, inventor and entrepreneur.

www.fraunhofer.de
EXCELLENT COOPERATION

Our membership in networks and cooperative projects gives us the ability to solve interdisciplinary problems that would otherwise be beyond the scope of a single institute. The extensive research spectrum covered by the Fraunhofer-Gesellschaft and the proximity to the RWTH Aachen University gives us access to a far greater pool of knowledge to draw from.

In Aachen, we cooperate closely with the Laboratory for Machine Tools and Production Engineering WZL of the RWTH Aachen University in all our areas of expertise. The four senior professors at the WZL are also the directors of the Fraunhofer IPT. For decades now, the WZL has become a global synonym for successful and future-oriented research and innovation in the field of production technology. In six different work areas, research activities not only relate to fundamental theories and findings but are also adapted to industrial applications and requirements. Furthermore, practical solutions are worked out for the purposes of rationalising production.

Since spring of 2011 the Fraunhofer IPT supported the setup of the Fraunhofer Project Group for Mechatronic Systems Design in Paderborn. This project group works on the development of mechatronic systems for control engineering, software engineering and product engineering. With effect from 1 January 2016, the project group has been converted into the independent Fraunhofer Research Institution for Mechatronic Systems Design IEM. It is managed by Professor Ansgar Tachtler.

International clients based in the USA are provided with on-the-spot services via the Fraunhofer Center for Manufacturing Innovation CMI in Boston.

Partners within the Fraunhofer-Gesellschaft

Within the Fraunhofer Gesellschaft, we are a member of the Fraunhofer Group for Production, an association of seven Fraunhofer institutes that supports joint production-oriented research and development projects. By combining a vast variety of skills, competences and experience from individual institutes, the Alliance provides its clients with integrated one-stop solutions for product development, production technologies and systems, production processes and organization as well as logistics.

In various other Fraunhofer Alliances (car manufacturing, big data, additive manufacturing, lightweight construction, imaging techniques), collaborate with other institutes, jointly developing and marketing certain products and services within the Fraunhofer Gesellschaft.

On the RWTH Aachen Campus

On the Melaten campus of the RWTH Aachen University, eleven research clusters, focusing on different areas, are currently under development, a project in which the Fraunhofer IPT is also closely involved. The clusters will provide facilities where companies and institutes can share their resources as well as their knowledge and exploit synergies. The close geographic proximity will help them to coordinate their activities, speed up research studies and improve their results, reducing research costs and development costs.
In September 2015, the campus hosted the launch of the ACAM Aachen Center for Additive Manufacturing GmbH, a joint venture of the Fraunhofer IPT and the Fraunhofer Institute for Laser Technology ILT. The ACAM has been designed to serve as an interface for a community of experts in the field of additive manufacturing technologies. Soon after, in October 2015, the “International Center for Turbomachinery Manufacturing – ICTM” was inaugurated, a joint venture of the Fraunhofer ILT, the WZL and the Chair for Laser Technology LLT of the RWTH Aachen University. Along with 25 industrial partners, the ICTM will conduct research on the production and repair of turbomachinery.

**The interface between science and manufacturing**

The publicly funded research studies of the Fraunhofer IPT receive support from two federal government ministries (Education and Research, Economy and Energy), from the AiF (the Federation of Industrial Research Associations), the federal state of North Rhine-Westphalia, priority programs and special research projects of the German Research Association DFG and the European Commission:

**Bilateral industrial projects**

Short to medium-term contract research for industrial clients with individual commissioning and joint, long-term problem-solving projects in areas in which competition is minimal.

- Advice on technologies and methods
- Feasibility studies, analysis and assessments
- Techniques, machines and methods
- Prototype and machine construction

**Public funding**

Medium to long-term research projects carried out by a network of research and industrial partners.

- Joint BMBF projects and EU projects
- Coordination of industrial project consortia
- Advice on national and EU research contracts

**International projects**

- Market evaluation
- Site establishment
- Know-how transfer

**Strategic preliminary research**

- Special research fields and fundamental projects contracted out by the German Research Foundation (DFG)
- Participation in internal Fraunhofer development and cooperation programs
- Studies, incl. standalone studies and studies that are conducted by consortiums (together with manufacturing corporations)

**Services**

- Market studies
- Design and small series
- Measuring activities
- Simulations
SPIN-OFFS

Aachen Center for Additive Manufacturing GmbH

The Aachen Center for Additive Manufacturing aims to enable manufacturers of any size to integrate additive manufacturing techniques profitably into their production processes. The ACAM community welcomes industrial partners and offers them a wide range of services from project development to staff training, feasibility studies, business consultancy and access to information about the latest technologies.

Aixtooling GmbH

Aixtooling GmbH was founded in 2005 as a spin-off company of the Fraunhofer IPT, with the vision of establishing precision molding of optical glass as a standard technology for the optical industry in Europe. The company has extensive competencies in every significant component of the process chain for the replicative fabrication of precision glass optics. The core competencies of Aixtooling GmbH are mold design, process layout, and the fabrication of ultra-precision molding systems.

Innoclamp GmbH

Innoclamp GmbH was established in 2015 in Aachen and is specialized in the development and construction of automatic clamping systems for the high-precision arrangement of complex free-formed workpieces in machine tools and their low-vibration fixation. Innoclamp designs serial products as well as unique clamping and automation solutions that have been customized to meet the production requirements of individual customers.

Innolite GmbH

Innolite GmbH was founded in August 2008 as a Fraunhofer IPT spin off. Their core business has since been the ultra-precision mold-making for the replication of plastic optics as well as the direct manufacturing of metal optics. In 2009 the first successful projects in the field of plastic injection compression molding were completed. A decisive contribution to our customers was first made possible thanks to the close cooperation with our partners Arburg and the Institute of Plastics Processing IKV of the RWTH Aachen University.

The Invention Center is located on the campus of RWTH Aachen University and offers its partners access to technology and opportunities of acquiring additional innovation management qualifications while also providing optimized solutions for technological challenges. In close coordination with the TIME Research Area, the Fraunhofer IPT, the WZL and KEX Knowledge Exchange AG, the Center is provides a technology expertise that allows executives who are planning the future of their manufacturing businesses to acquire a deeper understanding of the process from the original product idea via the drawing board to the large series production in an industrial environment.
KEX Knowledge Exchange AG

The KEX Knowledge Exchange AG is a professional information provider for technology and market information, founded in 2013. Intelligent knowledge management systems, complete accessibility to exclusive sources of information and a unique network of experts allow effective scanning, scouting and monitoring of technologies and markets. By means of a demand-specific compilation and assessment of information, the KEX is best placed to support a wide range of business decisions.

polyscale GmbH & Co. KG

polyscale develops, manufactures and distributes micro-structured components with optical features. A complex production process allows new properties of structured surfaces, opening various fields of applications. polyscale concentrates on LED-driven technologies to develop and manufacture light guide plates. polyscale's light guide solutions provide customized products for various industries to meet the highest possible standards of performance, efficiency and individuality.

MABRI.VISION GmbH

MABRI.VISION GmbH is a start-up company that develops non-destructive optical measurement technologies for plastic and glass products. The company designs and manufactures measuring equipment for the off-line and in-line-quality assessment of transparent and semi-transparent materials, specifically focusing on the detection of barrier layers in injection-molded or extruded products. The technology is based on optical coherence tomography and enables the non-destructive optical imaging of cross sections.

son-x GmbH

son-x GmbH was founded in the summer of 2011 in Aachen, Germany, as a spin-off company of the Fraunhofer IPT that offers tooling systems for ultrasonic-assisted ultra-precision machining. By means of this technology, son-x enables direct machining of hardened steel and other materials with single-crystal diamond tools in an optical quality. Through the long-term experience of son-x's employees in the field of ultra-precision machining and optics manufacturing, a strong basis of know-how could be established.

Aachener Werkzeugbau Akademie GmbH

The WBA Aachener Werkzeugbau Akademie GmbH concentrates the competencies of the Fraunhofer IPT and the Laboratory for Machine Tools and Production Engineering WZL of the RWTH Aachen University for tool, mold, and die making companies. The WBA was founded in 2010 and owns a tool shop for demonstration purposes. The corporation offers continuing education programs as well as a master's program in collaboration with the RWTH Aachen University. In the partnership model of the WBA, small and medium sized companies are able to work on research projects that have a practical orientation. Besides, the WBA answers technological and organizational questions of companies of the industry.

oculavis GmbH

oculavis GmbH is set to be established in April 2016 and will focus on the development of a modular Internet-of-things platform to increase the productivity of manufacturing jobs. Initial software modules will support service employees during maintenance tasks or production workers during quality assurance activities through data glasses. The software modules can be customized at request, in line with the requirements of each industrial client corporation.
Fraunhofer Project Group for Mechatronic Systems Design becomes Research Institution

From the spring of 2011 until late 2015, the Fraunhofer IPT supported the development of the Fraunhofer Project Group for Mechatronic Systems Design in Paderborn, which conceived, created and improved mechatronic control, software and production development systems. With effect from 1 January 2016, the project group has been transformed into the independent Fraunhofer Research Institution for Mechatronic Systems Design IEM. It is managed by Professor Ansgar Tachtler. On 13 November 2015, the Federal and Federal State Committee of the Fraunhofer Gesellschaft decided to convert the group into a permanent institution and to incorporate it into the integrated financing scheme (federal government and state government funds).

This level of autonomy had always been the declared objective of the project group. In less than five years since the group’s establishment in 2011, the Paderborn-based scientists managed to develop a market-oriented research profile on the basis of strong ties with regional manufacturers. As an additional boost for its mission, the project group received start-up funding from the federal state government of North Rhine-Westphalia.

The proximity to the industrial landscape of the region is one of the Fraunhofer IEM’s key strengths. Its research focus has been clearly guided by the requirements of local manufacturers, mainly small and medium-sized enterprises with highly specific product development requirements. The Fraunhofer IEM has the capacities to customize its products to their needs, positioning itself as the first and primary partner for medium-sized clients.

The Fraunhofer IEM is developing its research profile in close coordination with the Heinz Nixdorf Institute of the Paderborn University. The structure of a dual institute allows the development of an interdisciplinary and application-oriented top-quality research approach. The research is focused on innovative technologies (“Industry 4.0”) as well as on methods and instruments for a cost-efficient development of complex systems. More specifically, the Fraunhofer IEM is currently developing cross-industry application techniques of so-called Augmented Reality Technologies (AR). Computer-assisted models of real environments hold out the promise of considerable benefits for manufacturers. Assisted by a grant from the Federal Ministry for the Economy, the Fraunhofer IEM and its partners intend to provide medium-sized enterprises with access to AR technologies. The Paderborn-based Fraunhofer IEM is an active research and management partner in the “Leading Edge Cluster” for Intelligent Technology Systems in the region of Ostwestfalen-Lippe (“it’s OWL”), playing key roles in several important research projects of the federal government and making sizeable contributions to the economic development of the region.

As per 1 January 2016, the Fraunhofer Research Institution for Mechatronic Design Technology had a workforce of 71 full-time employees and many part-time undergraduate assistants. The IEM, which is domiciled at Paderborn’s Zukunftsmeile, the “Future Zone”, is planning to recruit 20 more people during the next 12 months.
INTERNATIONAL ACTIVITIES

International joint ventures assume an ever growing importance for the Fraunhofer IPT. We cooperate with top-quality universities, internationally renowned research institutions und global corporations on many sites across the world in order to jointly pave the way for technological progress and development.

Fraunhofer Center for Manufacturing Innovation CMI

The Fraunhofer Center for Manufacturing Innovation CMI cooperates closely with the Fraunhofer IPT in many areas. In collaboration with Boston University, the Fraunhofer CMI conducts advanced research and development leading to engineering solutions for a broad range of industries, including biotech/ biomedical, photonics, and renewable energies. Engineers, faculty partners, and students at the Fraunhofer CMI transfer the results of basic research into advanced technologies that meet the needs of both domestic and global client companies. The primary focus is on the development of innovative high-precision automation systems, instruments and medical devices.

This partnership allows the Fraunhofer IPT and CMI to provide their clients with production technology research and development services close to their production facilities, while also creating the conditions for a sustainable technology transfer between European and American manufacturers. The Fraunhofer CMI works closely together with Boston University and its office on the BU campus is built right next to the University’s Manufacturing Engineering Department. The training of highly qualified engineers in an international environment is also something they care about very deeply.

“Centre for Embedded Bioanalytical Solutions” in Ireland

In close coordination with Dublin City University, the Fraunhofer IPT is currently establishing the “Centre for Embedded Bioanalytical Solutions” in Ireland, an innovative one-stop point of call for contract research into microfluidic systems in bioanalytics. The joint venture will mainly focus on the so-called lab-on-a-chip systems that are made from plastics. The Irish partners contribute their expertise in design and technical specifications of applications in medical technology, environmental technology and the food industry, while the Fraunhofer IPT provides its production technology know-how. The Fraunhofer CMI will also be integrated into the projects.

“Powertrain Manufacturing for Heavy Vehicles Application Lab” in Sweden

The project center for the joint research platform will be established by a large consortium that features two large Swedish manufacturing corporations, the KTH Royal Institute of Technology in Stockholm and the RISE (Research Institutes of Sweden), and the Fraunhofer IPT, IWU and ITWM. In a “Memorandum of Understanding” from March 2015, the partners expressed their wish to perform joint research and development activities on a “Powertrain Manufacturing for Heavy Vehicles Application Lab” with the objective of establishing a common innovation cluster.

“Design and Production Engineering in Complex High Tech Systems” in the Netherlands

The Fraunhofer IPT intends to take its cooperation with the University of Twente in the area of “Design and Production Engineering in Complex High-Tech Systems” to a new level. On 24 August 2015, during the CIRP conference, Professor Reimund Neugebauer and Professor Fritz Klocke signed a “Memorandum of Understanding” with Victor van der Chijs and Professor Fred van Houten from the Dutch University, in which both partner organizations express their wish to cooperate more closely in the future. The University of Twente was already one of 18 Fraunhofer IPT partners in the EU project “FibreChain”. Both organizations are also working together under the “ambliFibre” project of the EU.
CONNECTED, ADAPTIVE PRODUCTION

The Fraunhofer IPT concluded a thorough review of its strategic processes in 2015 by adopting a new leitmotiv for its work, making clear where it stands on the issue of “Industry 4.0”. Dr.-Ing. Thomas Bergs, Managing Chief Engineer of the Fraunhofer IPT, describes how his Institute arrived at its current position – and how it sees the path into the future.

Why a new leitmotiv for our work?

“Industry 4.0” is a phrase that has very much caught the public attention ever since the media began to use it in the spring of 2011. That was five years ago, but we struggled for quite some time to formulate a clear strategy of what we were going to do about it. Ask five people for their personal view, and you will receive five different answers. We ourselves have made this experience in many internal conversations and even in discussions with our clients who expressed a need for guidance and advice in issues of research and development. Before we could address this urgent demand, we had to adjust our portfolio of skills and services to match the new requirements of Industry 4.0 – without undermining or even abandoning the foundation of our technological expertise.

What impact does this have on our working relationship with the manufacturing industry?

Our unique selling point has always been our expertise in virtually all areas of production technology. Our vast array of technical equipment allows us to manage innovative technologies and to evaluate their potential values for the manufacturing industry. Our business units have acquired the capacities required to assess entire process chains for the manufacturing of highly sophisticated components and products of leading high-tech industries. Our ability to model these techniques and technologies on a nearly full scale and to simulate their use in realistic scenarios allows us to create virtual copies of entire production systems with all their processes and process chains. This is the key that enables us to research new technologies in the environment of cyber physical systems, the Internet-of-things, big data analyses and real time production, verifying their potential use and profitability for our clients. Or, in the words of one member of our Board of Trustees: “If there is one research institution capable of bringing Industry 4.0 to the shop floor, it is the Fraunhofer IPT.” These words have provided a huge incitement for us to steer the Fraunhofer IPT decisively towards connected, adaptive production processes.

Where do we stand today – and where are we going?

Ask us today for our contribution to Industry 4.0, and we shall give you a clear reply. We intend to develop a “connected, adaptive production” with three central areas of activity: the connection of know-how in technology and process technology, the design of adaptive processes and the creation of process chains – all on the foundation of our deep understanding of the technologies that are involved in production processes, equipment and measuring or sensor technologies. One important step was the establishment of a dedicated unit that concentrated all the required in-house skills in one place – software development, networking and digitalization – to explore insufficiently used as well as unknown innovation potentials. The establishment of a Fraunhofer Service Center for “connected, adaptive production” could turn out to be a key milestone on our way into the future: we are currently planning to build this Center – in close cooperation with our neighbours, the Fraunhofer Institutes ILT and IME – later in 2016 here in Aachen, using our own funds and financial assistance from the federal state government. This can also provide a highly useful launching pad for the planned participation of the three Fraunhofer Institutes in the Excellence Initiative of the RWTH Aachen University. Our new leitmotiv has already sharpened our profile and changed the way in which the outside world – including our clients – perceives us. But our employees, too, stand to benefit: connectedness and adaptiveness have always been, after all, important elements of successful research activities.

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Smart devices in production

Whereas smart devices such as tablets and smartphones have long become established parts of our everyday lives, these technologies are much less in evidence in the industrial environment. But smart glasses are particularly suitable for use in a number of production processes: these permit the employee to obtain information in real time and in a location which may not be the point at which value is added thereby exerting a positive influence on throughput times and error rates. Our oculavis smart glasses solution consists of an app, the smart glasses themselves and a web-based environment to model the application scenario which communicates with the glasses. The sequences can be displayed in detail in the view field of the glasses and augmented with additional information in the form of images, audio and video data and even 3D models.

Process variations are generated automatically by the software and can be allocated to specific orders on the basis of QR codes or NFC tags, for example. The system additionally provides the option of analyzing contextual information such as times, error reports or suggestions for improvement before deriving measures which can be implemented in order to improve the process. If required, the machine’s communication protocol OPC Unified Architecture provides the operator with extensive insights into machine data and status information, while the integrated videophone function enables a quick clarification of queries regarding the production process.

Data consistency in the CAX process chain

Computer-assisted process chain planning and design via software systems are more important than ever in the age of Industry 4.0. In recent years, there has been a shift in computer-assisted planning of process chains (CAX) from fixed to flexible manufacturing process chains. In accordance with the principle of “mass-customization”, manufacturing process chains must adapt dynamically to inputs and disturbances in order to achieve the expected outcome. The fundamental requirement for continuous, flexible CAX process chains is data consistency.

Within the framework of the “Adaptive production for resource efficiency in energy and mobility – AdAM” innovation cluster, the Fraunhofer IPT has collaborated with over 20 project partners to develop a continuous part and process data chain for adaptive machining. A digital image of the actual part including the manufacturing information, which is also required, was first generated in a product data model. The production process can be simulated in a virtual model on the basis of this data during the work station phase in order to acquire information about the contact conditions of the
milling tool. This shortens the ramp-up period and reduces the need for costly preliminary tests on the actual part.

**Machine-to-machine communication**

Industrial manufacturing still requires an enormous amount of manual support: this begins with the development of machine programs and extends through parameterization and organizing processes and cycles to manual quality control. This prolongs setup and rigging times and requires experienced machine operators, who intuitively pass on information between process stages and refer it to planning systems such as MES.

The Fraunhofer IPT is developing new M2M technology which will enable production networks to be expanded and designed to be more adaptive. The aim is to achieve automated exchange of information between planning systems, production machines and measuring instruments without the need for humans to exert direct control. Total data consistency throughout the micro-structured free-form optics was achieved, for example, within the framework of the trans-regional special research field SFB/TR4 “Process Chains for the Replication of Complex Optics Components”. The process steps and in particular the range of manufacturing, replication and metrological machine systems were all interconnected in one network and linked to the corresponding planning systems. Consistent data formats and standardized interfaces such as OPC Unified Architecture, for example, ensure continuous networking throughout the entire process chain regardless of the machines involved.

**Big Data: Processing large volumes of data efficiently**

As a result of the burgeoning use of sensors along with networked equipment with complex software systems, the data flow into manufacturing is increasing rapidly. Only when suitable data processing systems are in place and when the truly relevant information can be extracted from such expansive volumes of data, knowledge can be acquired. Adaptive optical systems for high-speed microscopy permitting relevant information to be extracted quickly from copious amounts of measurement data is one such example.

The parallelization of computer operations is one way of processing such large volumes of data. The fast processors of the graphics card are used instead of the main processors to evaluate the microscopy data. The graphics processors can perform a number of calculations at the same time and independently of one another. They can also record the large volumes of data generated in wavefront metrology in real time. Adaptive optics compensate immediately for any interference in the imaging by analyzing the deviations and transforming them into specific actuator instructions. Microscopy systems which adapt correctly within on-going operations can be developed in this way, for example. Further areas of application for large-scale calculations at the Fraunhofer IPT include signal processes in optical coherence tomography (OCT) and the so-called “Pyramidal View” used to view and analyze big image data.

**Next generation technologies for Industry 4.0**

Systematic collection and analysis of relevant information precedes all strategic planning. This applies particularly to the introduction of appropriate technologies for manufacturing or networking, for example. Targeted scanning, scouting and monitoring open up new approaches, which can protect companies from nasty surprises arising as a result of rival technologies or market players. Risks in relation to competing technologies or opportunities arising from increasing technological maturity, attractive prices or lower costs, can be detected swiftly and reliably. Within the framework of the “Industry 4.0 audit” the Fraunhofer IPT evaluates the status quo of its production and of the associated value-added structures in terms of Industry 4.0 principles such as digitization, networking or flexibility. Systematic waste and the reasons for it in the production process are identified in the course of this evaluation. Concepts for solutions which have previously been found to be effective such as adaptive control systems for optimum networking in conjunction with efficient production are derived with the help of the systematic approach to identifying suitable technologies in the course of the audit.
ONLINE/OFFLINE PROCESS AND PROCESS CHAIN ADAPTIVITY

The term adaptivity is synonymous with a new form of flexibility and adaptability of production processes and process chains which are self-adapting and optimizing. In its research and development projects, the Fraunhofer IPT addresses the challenges associated with planning both individual steps and the entire production process, in a virtual environment and in a simulation-assisted process then implements these in the corresponding machines, equipment and software systems.

Lowering production costs via smart control algorithms

Developments such as increasing diversity in the range of variations available or new supply concepts from the energy sector are driving demands for the capacity to provide vast amounts of information swiftly and, in some cases, globally. The Fraunhofer IPT develops concepts of this nature, which make it possible to incorporate these goal dimensions. Only when all of the corresponding production data are available, when ERP, machine and operation data, energy controlling and MES have been networked, will companies acquire a completely new level of transparency regarding their production facilities and processes.

The Fraunhofer IPT along with its partners in the “eMES” research project is therefore extending the production planning and control area to include energy-oriented order planning which, in conjunction with smart grids, will continue to permit flexible energy and cost efficient planning even in the face of rising energy costs. Short reaction times and control loops are essential elements in the ability to react adequately to load peaks. To achieve this, it is vital to ensure that operating and machine data, product-related master data and machine-related energy data are available – in real time, if possible.

To this end, ERP and machine-oriented energy measuring systems are connected to the central MES and appropriate interfaces are developed. Transparency can thus be achieved in relation to the current production progress status, capacities and energy consumption. The opportunities and risks associated with direct intervention in load management can be utilized via synchronized communication with the energy suppliers.

Flexible production systems for “Batch Size 1”

Personalized therapies are assuming an increasingly important role in modern medicine: The majority of the concepts relating to individualization are patient-centered and focus on complex and correspondingly high-cost medical products such as dentures, exoprostheses or osteosynthesis material. Economically efficient manufacture of highly customized products, i.e. “Batch Size 1” is an important aim in this context. The central challenge facing production engineering is the need to enable companies to produce these customized products industrially and, at the same time, economically.

The Fraunhofer IPT is working on production systems which will be capable of manufacturing medical, personalized disposables cost-efficiently. The Fraunhofer IPT in conjunction with eight project partners is developing a pilot production system within the publicly funded OPENMIND project, which will enable demand-driven production of customized, minimally invasive guidewires. These guidewires are used during minimally invasive procedures such as positioning catheters into blood vessels for diagnostic or therapeutic purposes. Unlike metallic wires, the new guidewires can also be used in magnet resonance imaging systems (MRI) and are thus suited for radio-sensitive individuals such as babies or pregnant patients.

The aim is to close the gap between economically efficient mass production and customized made-to-order production.

In order to attain this goal, separate machining steps were previously connected and conflated in one automated, continuous process. This does not have any adverse effect on the high quality requirements since all relevant system components work in a network and all process and product parameters are filed in a central database. On the basis of the process model and historical data sets, data mining is used to optimize process parameter records for known product configurations continuously and use them for new product configurations. In this way, an adaptive and cost-effective
production operation develops, which is oriented towards meeting acute need and extends as far as “Batch Size 1”.

**Self-optimizing production processes**

Self-optimization is an important control principle in adaptive systems. The extension of classical control principles to include autonomous goal redefinition makes it possible to establish artificial intelligence in technical systems. In conjunction with the availability of real time information, this paves the way for the creation of robust and at the same time flexible production systems even in highly dynamic Industry 4.0 environments.

In the “Integrative Production Technology for High-Wage Countries” Cluster of Excellence, the Fraunhofer IPT along with institutes and facilities affiliated with the RWTH Aachen University is investigating new means of applying the principles of artificial intelligence to expand significantly the range of applications and services in which closed control loops can be used. The overriding goal is to make machines and equipment more autonomous and more intelligent in order to enhance their flexibility as well as their robustness when exposed to interference factors. Self-optimization as an approach to flexible and reactive automation makes an important contribution in this context.

In collaboration with the research partners in the excellence cluster, the scientists will transfer the principle of self-optimizing control from production processes to a number of other applications – from assembly through welding to optimization of weaving looms. The goal of the research work is always to achieve a significant reduction in the effort and cost involved in the initial process set-up. In this case, a previously unattainable level of flexibility was achieved – and with it, an important step toward the automation of low volume production series and the manufacture of individual products. The intensification in control of these processes in comparison with that achieved in classical applications increases their robustness and therefore their reliability very considerably, even given the rapidly changing parameters in highly flexible factory operation.

**Smart sensor systems for machine tools**

The efficiency of machine tools is based largely on highly developed electro-mechanical sub-assemblies. However, smart, embedded systems have so far failed to advance very far. However, adaptive production can be achieved only when autonomous, sensor-assisted systems are integrated in machine tools. Only then machines and equipment are able to control the production process to an optimum degree, even under changing conditions. As a result of higher sensor density, it is now possible to create a sufficiently wide base of information to allow the embedded systems to take over process control functions.

The Fraunhofer IPT is developing smart sensor systems which will be integrated within the machine in order to collect the required process and product information in-process and to make it available to the control systems. One of the main challenges in this context will relate to the need for process-oriented information processing, i.e. how to transform raw data such as electric currents into concrete statements regarding process forces or vibrations.

In the “Sens4Tool” research project a multi-sensor tool holder capable of recording size, force, moments, vibrations and tool temperature within an on-going process, is being developed in a collaborative venture with several industrial companies. In addition to the sensor, a data processing sub-assembly will be integrated within the tool holder. This permits interpretable information regarding tool wear or material faults in the part, for example, to be acquired during the machining process.
IN-DEPTH TECHNOLOGICAL UNDERSTANDING FOR HIGH-PERFORMANCE PRODUCTION

One of our primary aims is to save time, resources and costs by enhancing technical limits of production processes. For this purpose, we develop production systems and process chains which will increase the efficiency of our clients’ productions.

Automation in complex production environments

The concept of interconnecting and monitoring process chains in control units and control stations is already well established in some sectors of industry and in some applications, particularly in continuous process engineering. Continuous data acquisition for flexible and adaptive control of discreet and highly automated process sequences – even in complex production environments, is part of Industry 4.0. The cultivation of living cells is an example of process sequences in complex environments.

In the collaborative “StemCellFactory” project, the Fraunhofer IPT along with partners from research and industry developed a fully automated production platform for the production of stem cells. This platform has numerous quality assurance and cell processing components, which are interconnected via a central control station. In addition to the quality assurance and processing devices, the platform has a range of basic functionalities at field level and some safety-relevant systems equipped with a programmable logic controller. This is integrated within the production platform as an additional module and is connected with the control station.

In addition to this, the platform has a range of logging functions which ensure data consistency at process and device levels. The data are collected, processed and saved systematically. A user-friendly operator interface displays these data to the operator and supports the evaluation of the data. The “StemCellFactory” is an example of how even highly customized production processes can be designed, with connected, adaptive systems, to be extremely flexible and efficient.

Technologies operating in threshold ranges

Adaptive control concepts for production facilities can be implemented, given systematic networking of process simulation, in closed and open loop control and quality monitoring systems. Ideally, control systems of this nature harness existing process knowledge, thereby permitting highly flexible manufacture. Optimum machine parameters, on which the control systems can draw, can be determined via integrated process simulations. This eliminates the need for costly iterations on the physical part until the optimum process parameters are identified.

The open loop control unit receives direct feedback relating to the on-going process and the condition of the part and the tool via a supplementary online quality monitoring facility linked to the closed loop control unit. This permits processes to be run at full throttle without risking part quality. Networking of all system and software solutions via suitable interfaces and data processing is a fundamental requirement. It is vital that the data are structured in databases, imported continuously, and evaluated using suitable analysis methods.

In the EU “ambliFibre” research project, the Fraunhofer IPT in collaboration with international partners is developing an adaptive control concept of this nature for winding systems used to produce parts made of thermoplastic-based composite materials. It is intended that the facility will be just as suitable for use in the highly flexible production of products such as pipes for the oil and gas industries as for the pressure vessels used in the automotive sector.

To this end, the thermal characteristics in the process zone are analyzed by the simulation software integrated within the machine and the level of thermal energy required for winding is determined. At this point, it is necessary to ensure on one hand that there is a sufficient level of matrix system
fusing whilst on the other hand that neither the system nor the materials overheat during the manufacturing process. The machine control unit can regulate and adapt the output of the heat source on the basis of the data analysis.

Continuous monitoring of the winding quality ensures that the production system can approach the maximum process speed without any adverse effect on product quality – a major boost for productivity.

**Optimizing products and processes via Data Mining and Predictive Analytics**

Automated systems for the collection and analysis of machine, tool and quality data contribute to the enhancement of product and process quality. Frequent reference is made to the “Single Source of Truth” in the context of Industry 4.0. All relevant production data are filed once, in structured form – completely free of any redundancy. Only when this has been achieved, is it possible to conduct detailed and purposeful data analyses.

The Fraunhofer IPT develops and implements systems of this nature for a range of technologies and manufacturing methods. Interactions and dependencies within the whole manufacturing chain are revealed using appropriate data analysis software and potentials for optimization are derived as illustrated by the example of a technology database for the manufacture of replicative optics.

The technology database for the precision molding of optics contains information relating to all processes up and down stream such as the preparation of the forming tools via machining processes, tool coatings, quality analyses of the optic and of the forming tool decoating. This is achieved by recording all relevant product and process parameters along with their quality indicators in the technology database. The information is connected and filed clearly in the form of relational data structures – fully in accordance with the principle of a “Single Source of Truth”. A user-friendly front-end permits historical data records to be swiftly retrieved via filter functions. In order to identify patterns and dependencies within the process chain, a standardized SQL database with data-mining software such as “Rapid Miner” is used to evaluate these data records.

Thus optimum parameters, process conditions and process strategies for increasing the efficiency of manufacturing and product quality can ultimately be derived from neural networks, decision trees or correlation analyses and fed back into the system. The technology database and the subsequent analysis operation permit end-to-end data acquisition, holistic analysis of production data throughout the process chain and the derivation of optimum process settings. In comparison with the outcomes of conventional approaches such as Design of Experiments (DoE), the basis and quality of the data available for the identification and analysis of process dependencies and optimum parameters are considerably more wide ranging and detailed.
OUR BUSINESS UNITS

Being successful in the field of production technology requires the ability to overcome one's limitations and the willingness to react fast and flexibly in the face of sudden changes. In our business units we take a close look on the strategic demands of different industries, being well known for our profound knowledge of their individual needs and scopes and for driving further developments.

In our business units we use the wide expertise of our departments and provide comprehensive solutions to our customers. By continuously addressing the issues and challenges of our project partners, we not only acquire the inspiration for our future research studies but also develop our technological know-how. This steady and intensive exchange enables us to develop and to implement customized and innovative solutions for the benefit of our clients.

Depending on the task we employ our enhanced network and involve partners, in particular the Fraunhofer CMI and the Laboratory for Machine Tools and Production Engineering WZL of the RWTH Aachen University. This enables us to solve interdisciplinary problems.

For the latest information from our business units and for news about their service range, go to our web page:

www.ipt.fraunhofer.de/businessunits
TURBOMACHINERY

The “Turbomachinery” business unit of the Fraunhofer IPT researches and develops technologies for the production and repair of turbo engine components in applications such as aeronautical engineering, power generation, car manufacturing and oil and gas production. Daniel Heinen, head of the business unit, explains which technological developments will attract and reward specific attention over the next few years.

What are today’s key technological challenges for turbomachinery manufacturers?

Higher levels of efficiency and lower emissions are the key objectives in the development of modern turbo engines. This is why highly heat-resistant materials and complex, frequently thin-walled geometries and integrated components are so important. The industrial processes must be dynamic as well as stable in order to combine high levels of surface quality with acceptable production times. In order to deliver this, we need to develop quick and standardized ways of designing different process chains to manufacture individual components and ways of optimizing the industrial processes through highly efficient models and software tools. Our expertise and experience allow us to provide turbo machinery manufacturers with support in all areas of the development and production chains: from materials science and management to the design and characterization of highly dynamic machine tools, from the development of damping clamping systems and optical measuring technology to the simulation and modelling of individual technologies, processes and process chains.

How can turbomachinery manufacturers benefit from the networking of technological know-how and process technology?

Given the complex nature of turbo engine components, the comprehensive simulations of production processes and the sophisticated sensors that are required to identify and represent real geometries generate huge amounts of data. These data must then be further processed and calibrated or adjusted many times along the process chain. This is why technological development departments must strive to ensure high levels of data consistency and continuity, with robust processes that can be adjusted further down the line. The Fraunhofer IPT has a wide range of experience with such tasks from previous research and development projects and considerable methodological skills, on the level of Manufacturing Execution Systems (MES) as well as CAx systems. By providing seamless data chains for a wide variety of products throughout their life cycles, we have the skills and the background required to deploy effective and innovative manufacturing or maintenance processes and technologies with maximum levels of flexibility.

What impact does a higher level of online/offline adaptivity in processes and process chains have on turbomachinery manufacturing?

At the Fraunhofer IPT, we are currently developing new CAD methods of manipulating models, for example by morphing modelled surfaces or by protocolling all changes of a component’s geometry throughout its life cycle by using “digital twins”. By combining models and simulations in a CAx environment with machine-integrated measuring technology and the recirculation of these measuring data into process planning and ultimately into the ongoing production process, we are taking the optimization of turbo engine manufacturing processes to new levels – and save our partner companies time and money. Adaptive clamping systems and customized control systems – that have been specially adapted to the requirements of turbomachinery manufacturers – help us to ensure that the finished components will be able to comply with even the most stringent safety requirements, despite the use of complex geometries and materials that are quite often difficult to machine and to process.

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International Conference for Turbomachinery Manufacturing 2015

Higher levels of efficiency and lower emissions: these were the key objectives of the innovations in technology and production technology that were presented to the 240 participants of the conference. The third edition of the ICTM conference was hosted on 25 and 26 February in Aachen by the Fraunhofer ILT and IPT.

Speakers at the conference included high-ranking experts from industries such as aviation, aerospace engineering and power generation, representatives of system suppliers who convert new technological discoveries into practice-oriented applications and members of research institutions at the interface between the development and the deployment of turbo engines.

The presentations focused on recent advances and current trends of production technology as well as on aspects such as the maintenance, repair and overhaul (MRO) of turbo engines in airplanes or power stations (gas and steam turbines). Other topics included process development and advances in material science. It was also asked what kind of an impact these innovations will have on production technologies, MRO operations and life cycle strategies.

The experts furthermore identified the challenges and opportunities that may result from technological progress. On the one hand, it was pointed out, 3D design, new methods of construction, new production tools and new materials pose challenges in connection with their effective integration into existing or new manufacturing strategies. On the other hand, however, successfully integrated solutions also provide new and huge efficiency potentials.

At the end of the first day of the conference, the participants had the opportunity of finding out more about ongoing projects and their (initial) results during a walking tour of 41 experimental stations in the facilities and laboratories of the Fraunhofer ILT and IPT as well as the WZL of the RWTH Aachen. This part of the conference was very popular with the participants.

Completion of the Fraunhofer Innovation Cluster “Adaptive Production for an Efficient Use of Resources in Energy Production and Mobility – AdaM”

For the foreseeable future, energy producers and consumers will continue to depend on fossil fuels since renewables cannot yet cover our needs fully or reliably. Car manufacturers, airlines and utilities therefore require new drive concepts with lower emissions and more efficient fuel consumption systems. The Fraunhofer Innovation Cluster “Adaptive Production for an Efficient Use of Resources in Energy Production and Mobility – AdaM”, which completed its work in 2015, had been designed to provide a contribution to a sustainable rise in the efficiency with which natural resources are used in energy production and mobility. The development effort focused on new concepts and designs of turbo engine components with a measurably higher degree of efficiency and lower CO₂ emissions in the energy conversion process. The idea was to achieve this objective through flexible and at the same time robust production and repair chains as well as through easy-to-adapt individual technologies for the turbo engine production.

The new technologies and methods were demonstrated through different components including two components with specifically complex geometries: the “guide blade cluster” and the “multi-BliR”. Both demonstrators served to establish, to optimize and to demonstrate the overarching process chains, applying different technologies from different sub-projects.

For the “guide blade cluster” demonstrator, an entire manufacturing process chain – from the designer’s drawing board via
additive manufacturing through selective laser melting (SLM) to the finishing processes – was implemented and analyzed. Different process chains were evaluated from design and manufacturing perspectives, using a method that combined a wide range of criteria, and tested for their resource and energy efficiency. SLM was used to develop a newly designed compressor stator segment that provided the potential for a reduction of CO₂ emissions. The example of the “multi-BlIr” process chain showed how individual manufacturing and repair technologies can be adapted and combined. It was demonstrated how multi-level compressor components can be successfully repaired. Such repairs are a basic requirement for any attempt to extend the life cycle of turbo engine components.

The development works were performed in close cooperation with leading industrial corporations from the Land North Rhine-Westphalia including Siemens Power Generation (Mülheim an der Ruhr) and MAN Diesel & Turbo SE (Oberhausen) as well as many small and medium-sized suppliers. For the OEMs and suppliers from NRW state, the project provided a unique platform to strengthen their own competitive position as well as the position of their home state. It is now planned to develop and extend this platform. The Fraunhofer Innovation Cluster was funded by the industrial partner corporations (with a total of 5 million euros) and (with 2.5 million euros each) the NRW state government (reference no. PRO/0042) as well as the Fraunhofer Gesellschaft.

The success of the cooperation between research institutions and industrial enterprises and the growing demand for joint venture research and technology development projects also provide the foundation for the “ICTM – International Center for Turbomachinery Manufacturing” in Aachen.

Fraunhofer and RWTH Aachen University launch the ICTM International Center for Turbomachinery Manufacturing

On 28 October 2015, the “ICTM – International Center for Turbomachinery Manufacturing” was established. The new Center is a joint venture of the Fraunhofer IPT and ILT, the WZL and the Institute for Laser Technology of the RWTH Aachen University and 26 renowned industrial companies. The new Center will concentrate on research about the production and repair of turbo engines. The industrial partners of the ICTM Aachen want to use the new institution to accelerate innovations, to assemble experts, to unite forces and to ensure the highest possible standards of pre-competitive research. The new network’s partner companies include turbine manufacturers, large corporations as well as SMEs from various parts of the process chain.

The Center has been established on the foundations that were laid by the Innovation Clusters “TurPro” and “AdaM” and stands to benefit from the close cooperation of the scientific institutions that were involved in these predecessor projects. The ICTM Aachen has been designed to develop technological innovations through a long-term cooperation between industrial partners, eventually converting its acquired technological know-how into practice-oriented applications.

The ICTM Aachen is being managed by a ten-member-strong steering committee that comprises representatives from the business partners and the research institutions. The Center will start with ten joint venture research projects and a budget of roughly 500,000 euros. It has been launched without any financial assistance from federal or regional governments and is therefore one of the few independent networks that have developed out of the successful Fraunhofer Innovation Clusters. Originally, the research had been intended to concentrate on airplane turbines, but the focus was soon widened to include turbines for applications in energy production, car manufacturing and the oil and gas industries.
What has caused the trend towards lightweight construction, and how are enterprises supposed to react?

Over the past few years, lightweight construction has developed into a solid trend: a growing awareness for environmental concerns, for sustainability and for an efficient use of resources has not only prompted a turnaround in the energy policy of the German government but also moved up the corporate agenda. This is mainly true for industries such as aeronautics and car manufacturing where less weight is more, but also purely performance-oriented sectors of the economy stand to benefit: oil and gas producers, for example, can use riser systems made from fiber-reinforced plastics to penetrate ultra deep water fields down to a level of 3000 metres. This works because FRP pipes combine a low weight with high and customizable levels of rigidity which are individually adjustable to changing outside conditions and high levels of chemical resistance. The Fraunhofer IPT is developing technologies, equipment, tools and software for the processing of fiber-reinforced plastics including joining, forming, separation and handling as well as quality assurance procedures, enabling our clients to integrate fiber-reinforced materials, high-performance metals, ceramics and multi-material systems into innovative series products.

What impact will Industry 4.0 have on the production of lightweight components?

Industry 4.0 delivers the key to the affordable mass production of lightweight components by helping to cut waste through stable and reproducible manufacturing processes. This poses a huge challenge specifically for FRP manufacturing, since this material is only made from semi-finished products and matrix materials during the production process itself. Large numbers of possible combinations create vast bands of possible process variations, potentially limiting reproducibility. With more efficient networks, however, it will be possible not only to acquire data during manufacturing but even to feed them back into the production process straight away.

This way, manufacturers can create “digital shadows”, virtual representations of the production process or the products. Such digital shadows can be generated by the integration of optical fibres together with suitable measuring systems into fibre-reinforced composites. Not only will it be possible to subject the production to comprehensive supervision and monitoring with such data, but one may even optimize the manufacturing operation through “in-process learning” mechanisms.

What do enterprises have to do to manufacture high-quality but affordable lightweight products?

The degree of automation in FRP manufacturing lines is currently rather low, while the high demand for individualized products – down to batch sizes of 1 – at affordable prices provides a huge potential for further growth. Many enterprises must now take two steps at once: on the one hand, they need to automate their production lines to ensure high levels of reproducibility for mass production, to cut waste and to reduce their costs. At the same time, they must be able to adapt their production processes to changing requirements. This is a specifically challenging combination for small and medium-sized enterprises. The Fraunhofer IPT business unit for “Lightweight Production Technology” helps our business partners to produce lightweight construction products in large series and to provide their end customers with efficiently manufactured, more environment-friendly products at affordable prices.

Through the Aachener Center for Integrative Lightweight Production (AZL), we are integrated into a network that comprises more than 60 international enterprises and act as a direct research partner for the lightweight production industry.

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Multi-Material-Head: System solution for automated fiber-reinforced plastics processing

Engineers at the Fraunhofer IPT have developed a robot-based fiber placement system – the Multi-Material-Head – which processes all standard unidirectional semi-finished fiber composite materials automatically. The Institute presented the flexible, modular system as a customizable system solution for small-scale serial production as well as for research and development purposes at the leading European Fair for composite technologies, the JEC Europe 2015 in Paris, from 10-12 March 2015.

The Multi-Material-Head is now also available as a customizable system solution and offers all the components required for processing semi-finished goods made of fiber-reinforced plastics (FRP). The system is designed to process thermoplastic tapes and thermoset pre-pregs as well as dry-fiber rovings. Accordingly, the fiber placement system can be equipped with various heat sources, usually lasers, hot-air systems or infrared beamers. The Multi-Material-Head can be integrated swiftly and economically in existing facilities and can be adapted to meet a range of requirements. This makes it particularly suitable for small batch production or for rapid retooling for research and development purposes.

Clients can draw on the expertise of the Fraunhofer IPT to select the most suitable individual components and modules for their own manufacturing environment. The Multi-Material-Head, for example, can be used as an end effector on all commercially available standard robots and portal systems. Winding axes and or placement molds can be added for the manufacture of fiber-reinforced plastic hollow profiles or laminates. The Fraunhofer IPT also offers advice on the use of laser safety cabins. Users of the Multi-Material-Head can obtain these optional modules – including robots, winding axes and placement molds as well as suitable laser safety cabins when a laser is used as the heat source – as a complete system if required, directly from the Fraunhofer IPT.

The Fraunhofer IPT supports industrial clients throughout the entire process: from the production of application-oriented demo-parts, plant, equipment and process development through design and construction of the entire customized system until commissioning is complete. In addition to implementing industry standard control hardware and software, the Fraunhofer IPT offers users thorough on-site training.

Automated production of tailored thermoplastic composite blanks for lightweight applications

Thermoplastic composite blanks consist of fiber-reinforced materials, i.e. of fibrous tissues or fabrics that have been embedded in a thermoplastic matrix. These materials can be re-shaped under a controlled induction of heat during a thermoforming process. In the “E-Profit” research project, the Fraunhofer IPT and its partners have jointly developed an automated production line for the manufacturing of such tailored composite blanks from unidirectional fiber-reinforced tapes. These blanks are characterized by optimized stress properties and a reduced production of waste.

Manufacturers from the automotive industry, aviation and mechanical engineering have already declared a specific interest in the use of load-optimized composite blanks, mainly because such blanks can be more conveniently processed than conventional lightweight materials: cycle times are shorter and fewer material, as well as fewer energy resources, are required, while the technical quality of the components is comparable or even superior.

Fraunhofer IPT and its partners have developed a safe and robust facility within the “E-Profit” project which uses infrared radiation as a heat source to weld together the individual sheet layers. This independent system requires no extra equipment or accessories such as robots or casings and can be used for a large number of applications, thanks to its variable, large-surface consolidation section. The facility is already
working with delivery speeds of up to 1 m/s and can produce tailored composite blanks with a maximum total width of 1 m. Consolidation is taking place during the production process – which means that, in contrast to many conventional techniques, no additional downstream consolidation process is required. The laminates can be customized for each application and for individually required stress profiles, since the fibers can be aligned in a variety of different patterns. With the facility from the “E-Profit” project, it is now possible – for the first time ever – to manufacture tailored composite blanks with optimized stress properties and a reduced production of waste in an automated production line, to reshape them, to functionalize and to trim them.

The research and development project “E-Profit” was funded by the German Federal Ministry of Education and Research (BMBF) within the Framework Concept “Research for Tomorrow’s Production” and managed by the Project Management Agency Karlsruhe (PTKA).

**Structural health monitoring of lightweight composites**

For a long time, measuring structural changes within lightweight design components had only been possible to achieve through ultrasonic or tomographic processes. In many industrial areas but also in everyday life, intact structures often play a vital role: the early detection of hidden defects in airplane structures and automobile bodies or invisible defects in rotor blades of wind turbines is crucial in order to prevent a sudden failure of the components and serious accidents. Particularly carbonfiber-reinforced plastic (CFRP) components with complex geometries and fiber layers make it difficult to predict strains and stresses inside of the components based on finite element methods. Moreover, such predictions are, depending on the actual strain of the component, rather vague.

Optical Fourier Domain Reflectometry enables to measure strain gradients and temperature changes underneath the surface by using optical fibers. Consequently, damages and strains within fiber-reinforced composites can be unveiled. Unlike traditional straingauges, fiber-optic measurement processes do not require a high amount of cabling since one single sensor fiber supports up to several million measuring points. The small diameter of optical fibers, which is similar to that of a human hair, enables the embedding of sensors in the material during production.

In structural health monitoring, fiber-optic sensors can be used for the early detection of interior and exterior damages of components. Measurements in different time lapses enable to obtain a solid understanding of the strains and signs of ageing under realtime conditions. Improved form geometries, target-oriented input and customized production processes on the basis of measured data will save material and costs, resulting in higher resource efficiency.
TOOL AND DIE MAKING

What opportunities result from strengthened networks in the tool and die making industry?

Tool and die making companies can increase their technological and structural competitiveness: mobile communication, compact sensor arrays and sophisticated production control systems allow them to make their corporate processes transparent and flexible – with real time representation. This is a big opportunity for tool manufacturers. Tool-integrated sensor systems may, for example, serve to predict maintenance intervals, to prevent operating errors and to plan overhaul operations. Data mining is a highly interesting development for tool and die making companies, since it allows them to create a level playing field for comparisons between one-off products: companies can recognize patterns in highly diversified component ranges, optimize the organizational and technological aspects of their processes and improve their product quality. Networks between customers and suppliers also facilitate the planning of delivery dates in scattered manufacturing networks and the exploitation of spare capacities by using transparent resource management methods. This shortens cycle times and allows the enterprises to put their tools to more productive and more efficient forms of use in a mass production environment.

How can the Fraunhofer IPT support and assist its partner companies?

We have provided our business partners within the industry with skills and advice for many years, which means that we have acquired a profound understanding of the relevant technologies to share with our clients. Our benchmarking database comprises more than 1,000 updated data sets from international tool and die making companies. We use our comprehensive machinery to explore individual technologies such as hard metal cutting, establishing optimized machining parameters and cutting data as well as matching tool geometries and chip formation patterns. We provide our clients with customized advice about individual technologies such as milling, die-sinking, wire spark erosion, turning and polishing and help them to extend their process limits. Any such expertise in individual technologies must of course be embedded in a profound understanding of the integrated process chain with all of its interactions, since ultimately it is the final result that counts: the tool. Through our close cooperation with the WZL of the RWTH Aachen University and the WBA Aachener Werkzeugbau-Akademie, we are in a position to provide our clients with both standardized and customized offers that help them to prepare their companies for the challenges of intense global competition.

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Automatic finishing operations in mold and die construction

The process chain of tool and die manufacturing typically includes mechanical CNC milling operations and a subsequent fine machining. This manual polishing is the only part of the process chain that has not been automated. It accounts for approx. 50 percent of manufacturing time and 15 percent of the tool's final costs. Another problem is that the results of the polishing process – in terms of quality – depend very much on the polisher's individual skills. And even if the polisher works quickly, this is a time-consuming task which also creates long-term health risks for those assigned to perform it. This is why the Fraunhofer IPT and four industrial partners have developed a process under the publicly funded “IntegFINISH” research project that is capable of assigning much of the manual work to the milling machine. The result of the project has demonstrated that it is possible to automate polishing processes through already existing milling machines, finishing tools and dies by making intelligent use of current capacities.

Initially, the project partners tested various existing polishing tools on workpieces made from flat steel. The Fraunhofer IPT then developed industrial processes by deploying the new components in actual machine tools. Components and systems were analyzed through measurements of the spindle's contact force and rotational speed, the level of surface roughness and the volume of machined material and through analyses that were designed to establish the suitability of the CAM software. By measuring and analyzing the surface quality of a demonstrator component that had been machined and subsequently polished, target parameters for the automation were established. The result of the polishing process – in terms of surface quality, machining performance (quantity of material processed) and polishing tool wear – was evaluated after a full cycle of the IntegFINISH system.

Finally, the IntegFINISH system was integrated into a milling machine of a production line. Surface qualities after finishing improved from Ra > 1 μm to values of Ra < 0.1 μm with processing times falling by up to 50 percent in comparison with a manual process. The matt and glossy “brush finishing” complies with the quality requirements of many molding dies, punching dies and bending tools. These results hold out the promise of potentially great advantages for manufacturing companies, and the consortium now expects the IntegFINISH solution to catch on quickly across the industry.

Micro-structures for venting of plastic injection molds

The plastic injection molding process is used to manufacture large volumes of high quality, plastic products economically - however, this works only when the mass of plastic injected into the mold tool fills it completely to produce a finished part with no surface defects. Mold venting is crucial in this context. Therefore the Fraunhofer IPT is collaborating with three partners from industry in a research project to explore ways of using micro-structures in order to improve injection mold tools.

The objectives of the R&D project “VentOpt” are the realization of the mold venting by functional microstructures placed in the parting plane of the mold and the further development of an existing simulation software, which then allows an application oriented design of the venting structures. The functionality of the venting and the influence of typical process parameters, such as filling pressure, tool temperature and the characteristics of the plastic material used, will therefore be analyzed.

To ensure that only air and not the molten plastic leaks out, the complex and filigree venting structures have to be machined precisely into the parting plane of the mold. Here the Fraunhofer IPT uses the laser surface structuring technol-
ogy. To assist the tool and mold maker with the layout of the venting already in the mold design phase, an innovative simulation software for the venting will be developed. For the validation of the simulation results, a special injection tool is manufactured within the project. It is equipped with several temperature and pressure sensors. Ideally, the plastic products manufactured using the new micro-structured tools are burr-free with greatly enhanced surface and part quality.

The German Federal Ministry of Education and Research approved the collaborative “VentOpt” project (contract number 02PK2371), in which the companies Simcon Kunststofftechnische Software GmbH, FKT Formenbau und Kunststofftechnik GmbH und Komos GmbH have entered into a collaborative venture with the Fraunhofer IPT.

Wettbewerb “Excellence in Production” kürte Audi AG zum “Werkzeugbau des Jahres 2015”

Audi AG’s in-company tool manufacturing division has re-claimed the crown as the overall winner of the “Excellence in Production” competition in their sector of industry. The coveted trophy was presented to Michael Breme, Manager of the Audi Tool Manufacturing Division, on the occasion of the formal evening ceremony which is part of the annual international “Tool and Die Making for the Future” Colloquium before an audience of approximately 280 in the Coronation Room of Aachen City Hall. In addition to the overall victory, Audi won the distinction in the “Internal toolmaking with over 50 employees” category. The other finalists in this category, Phoenix Contact GmbH & Co. KG in Blomberg and The toolmaking division of ZF Friedrichshafen AG in Schweinfurt, the overall winner in 2012, were awarded a certificate.

The winner in the “Internal toolmaker with less than 50 employees” category is Kirchhoff Automotive Deutschland GmbH in Attendorn, Sauerland. Other finalists in the “Internal toolmaker with less than 50 employees” who also distinguished themselves clearly from the others were Festo Polymer GmbH in St. Ingbert, Schaan in Liechtenstein-based Hilti Aktiengesellschaft and Huf Tools GmbH in Velbert.

The winner in the “External toolmaker with less than 50 employees” was Wiro Präzisions-Werkzeugbau GmbH & Co. KG based in Olpe in the Sauerland. The other participants who progressed to the final round were Croner Präzisionsformenbau GmbH based in Sachsen bei Ansbach, Hanns Engl Werkzeugbau O.H.G in Bolzano, Italy, and Wesko GmbH in Stollberg (Erzgebirge).

The best “External toolmaker with more than 50 employees” was Meissner AG based in Biedenkopf-Wallau (Lahn). The other finalist in this category was the Fischer GmbH, based in Geringswalde (Saxony).

The Fraunhofer Institute for Production Technology IPT and the Laboratory for Machine Tools and Production Engineering WZL at the RWTH Aachen University along with an expert jury, selected the best tool and mold production companies in four categories following detailed comparisons of all entrants and visited their manufacturing facilities to acquire first-hand experience of their manufacturing environments: The ten jurors from industry, politics and science then selected the 13 finalists, the winners in each category and the overall winner. In total, 295 tool and mold production companies participated in the competition. This was the twelfth year of the “Excellence in Production” competition. On the day following the awards ceremony, selected companies presented their strategies for success at the 15th International “Tool and Die Making for the Future” Colloquium held in the Quellenhof Hotel in Aachen.
What trends will have the largest impact on the production of optics over the next few years?

The trend towards ever more compact optical systems with high levels of functional integration and growing performance density shows no signs of abating – neither for consumer goods such as mobile phones and cameras nor for high-value industrial goods such as components for laser technology or telecommunications. Technical challenges including small apertures, steep and aspherical functional surfaces and narrow bands of permissible variation for forming or positional accuracy combine with huge cost pressures and a need to produce high quantities. Simply put, manufacturers are faced with the challenge of producing optical components with complex geometries cost-efficiently from materials that are difficult to process and of integrating these components into affordable devices. The market for infra-red optics is also expected to extend in volume over the next few years. In order to meet the rising demand, we and our business partners are currently developing technologies and consistent process chains for a direct and replicative production of optical components and systems. We also develop and test high-performance ultra-precision machines with suitable measuring equipment to automate manufacturing processes.

Companies that are capable of manufacturing complex optical surfaces from challenging materials within extremely narrow bands of permissible variation while maintaining their ability to operate their processes reliably even near the performance limits of the current technologies are well equipped to face the challenges of the future.

How can enterprises cope with and manage the growing dynamism of the market?

Well-organized process chains and production chains add value and guarantee high levels of productivity: this is something we have known for many years. But many enterprises still spend time and energy on the optimization of individual production lines or processes by adding – sometimes many – correction loops. It would be faster and more efficient to apply any such iterations to the systems into which the individual manufacturing operations are embedded. If you know the manufacturing history of any given component, you can tell which downstream processing step must be modified in which way in order to improve the component quality cost-efficiently. A detailed model of the product and its manufacturing process can provide the basis for an automated assessment. The active adjustment of optical components, for example, demonstrates how models can serve to get a grip on complexity: the behavior of optical systems varies according to the positional changes of individual elements in multiple degrees of freedom, but also depending on their forms and levels of surface roughness. This is why these systems are often so difficult to align. Detailed models are capable of resolving many of the resulting problems, since they can be deployed to facilitate production planning, the modification of parameters and a transfer to other production sites.

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The “Optics” business unit of the Fraunhofer IPT analyzes the production, testing and assembly of complex high-end optics and optical systems. Reik Krappig, head of the business unit, talks about the current trends within the industry and about the challenges it will face in the next few years.
Study on the Future of Optics Production

Design, materials, production technologies and metrology strongly determine the contestability of companies in the optics business. Thus, the aim of the “Study on the Future of Optics Production” is to attain a detailed overview of future trends for efficient manufacturing of optical components.

On 12 November 2015, the Fraunhofer IPT, ILT, IOF as well as the Institute of Plastics Processing and the Department of Glass and Ceramic Composites at RWTH Aachen University started the joint study with an industrial consortium. The study focuses on four groups of themes which were predefined by the industrial companies: freeform optics, miniaturization, functionalization, and materials. The project aims to identify future challenges in optics production and to come up with corresponding attempts to a solution.

Together with the other participants, the researchers at Fraunhofer and RWTH Aachen University strive to develop a perspective on optics production for the next decade, based on scientifically sound expert lectures and a detailed analysis of international market structures, product trends and future technological challenges. The industrial partners particularly profit from the five research institutes’ technology skills and their broad network of industry contacts which thematically cover nearly all areas of the optics sector and its users.

An open and flexible assembly platform for optical systems

The build-up of laser systems requires extremely high levels of accuracy and precision in the alignment of the individual optical components. In order to automate this task in a flexible manner, the Fraunhofer has developed a facility that comprises an integrated micro-manipulator. With the new device, it is possible to align optical components of high-power diode lasers, miniaturized lenses and structured light projectors in an automated, high-precision process.

The new high-precision facility can perform a wide range of tasks during the assembly of optical components – not only for the active adjustment of such optics but also for the inspection and the arrangement of micro-components. Its adjustment unit covers six degrees of freedom and is used in combination with a portal system, allowing an optical assembly working area of up to 500 x 500 mm².

Since the users can select the system in nearly any known programming language, it can be integrated quickly and flexibly into different production environments. The facility can be customized to individual needs and may feature – for example – feeding modules and transfer systems. At the same time, the system is also capable of performing standard processes such as side-tab and bottom-tab assembly operations in order to produce large series in fully or partly automatic mode. Basic functions such as component tracking, process capability evaluations and effectiveness assessments are included in the standard version. The micro-manipulator can also be switched to manual when such a manual operation would consume less time than the configuration of the automatic mode.

Due to its open platform and its software concept, the facility provides many different programming options including LabVIEW, Python, C# and PLC. This ensures that users can create and manage their own assembly programs, without having to share sensible know-how with third parties.

The kinematics of the manipulator feature a parallel structure and are completely based on flexure hinges. This makes it possible to perform a loss-free transfer of the smallest steps to the end effector, avoiding adverse effects such as backlash and hysteresis. Piezo step motors act as actuators, combining an extremely high resolution of movements in the nanometer
dimension with relatively large travel ranges. This ensures very high levels of accuracy and provides the option of performing very small steps in all degrees of freedom.

Companies that perform assemblies of optical systems stand to benefit most from the new technology. Initial applications include the assembly of collimating optics for diode lasers or VCSEL, of solid state lasers with planar arrays, of endoscope lenses or of projectors for structured light.

Ceramics can help to cut the costs of photovoltaic and illumination optics

There is a high demand for low-cost optical components made from glass in photovoltaics and LED technology. Frequently, molded glass optics are subjected to a forming process – which allows the quick production of large series – to meet this demand. The production costs could even be further reduced if it were possible to manufacture tools with higher levels of resistance to the severe stresses of this process. That is why the Fraunhofer IPT is currently trying to find out – in a consortium with Füller Glastechnologie Vertriebs-GmbH and FCT Ingenieurkeramik GmbH – whether ceramics are a suitable material for tools with longer service lives that would allow the manufacturers to cut their production costs.

Glass components in highly concentrated photovoltaic arrays or LED lighting elements must be resistant against high temperatures and UV radiation. The preferred production technology is the non-isothermal injection molding, during which glass is heated and subsequently molded under high levels of pressure. Although the unit costs of this replication procedure are already very low in comparison with direct manufacturing costs, the competition on the global market forces the manufacturers to cut their costs even further.

The Fraunhofer IPT and its partners in the innovative SME project called “InnoForm” have chosen to concentrate their attention on the molding dies, since the chromium-plated steel dies that are commonly used are suffering from high levels of wear. Ceramic dies, it was thought, might – due to their hardness and high levels of heat resistance – extend the service lives of the dies significantly, shorten set-up times and cut down on material costs. In metal forming processes, ceramic dies can be used for up to 20 times as long as steel dies. The researchers are hoping that the production of optics provides a similarly high potential.

The project partners expect the ceramic forms to prove more durable, due to their high levels of chemical resistance and resistance to oxidation, and to exhibit superior thermal characteristics. It is also thought that the pressed components will have higher levels of dimensional accuracy and lower levels of surface roughness. Since the inductive techniques that are used to heat up the conventional steel dies cannot be used for ceramics, the partners are also experimenting with new heating concepts with a view to integrating them into future injection molding facilities. They also try to establish whether the design of the molds will be subject to any formal restrictions. The “InnoForm” project therefore addresses the entire process chain from development and simulation to the molding itself and its metrological assessment.
How can the know-how of the Fraunhofer IPT benefit the development of the life sciences?

Since we are approaching these issues from the manufacturing point of view, we can inform common projects with a new, interdisciplinary perspective. Personalized healthcare is a specifically interesting field for us, since its main point of reference is the patient with his individual demands and since it therefore requires customized products. The whole field of stem cell research and regenerative medicine provides an arena for the interdisciplinary cooperation of biotechnologies and production technologies, because only high degrees of automation and high-throughput technologies can provide the requirements of personalized healthcare.

The automation of manufacturing processes also allows the production of lab-on-a-chip systems in large series. This helps doctors to make quick diagnoses and to take prompt therapeutic action – which is specifically crucial when potentially fatal illnesses are involved. The Boston-based Fraunhofer CMI, our close partner in this field, is developing tests to identify resistance levels with unprecedented speed. This can save many lives.

How can we achieve a flexible automation of biotechnology processes?

One important field where machine technology with specifically high levels of adaptivity is required is the cultivation of adult stem cells. Companies that manage to develop automated processes of stimulating the growth of such cells quickly and safely will be able to test the effectiveness of pharmaceutical products with the patients' own tissue or to develop new therapies, for example healing the wounds of patients who are suffering from diabetes. This is an area where we can use our production technology skills and experiences in many ways – developing MES systems for automated cell cultures, integrating sophisticated metrology into laboratory processes through standardized interfaces and designing or evaluating process chains. The combination of our production know-how with the knowledge of biologists and medical scientists can prove to be enormously valuable: systematic representations of previously manual processes may help us to design facilities with autonomous control systems that allow us to automate biotechnology processes, relying on customized or adapted measuring technology.

What contributions can be made by networks and data processing?

Over the past few years, it has become possible to process ever larger amounts of data. The data that we acquire with specially developed sensors and measuring instruments can make it easier to diagnose illnesses and help doctors to develop individualized approaches to their patients. Laboratory assistants will in the future be able to count on the support of intelligent hardware networks. By tracing and monitoring each step of laboratory analyses and by backing up each such step with the required amount of data, errors will be significantly reduced. The safety of medical products also stands to benefit, since production processes will also be closely supervised.

The automated production of cell-based medical products will equally profit from high levels of data consistency. By integrating different measuring systems, cell cultures can be monitored in real time, and the data can be directly forwarded to inform the process control system. Based on this process, algorithms can be developed for an intelligent optimization of the production process.
Automated stem cell production for personalized medical care

The demand for automated solutions in biotechnology laboratory processes is growing faster than ever – and has extended beyond individual laboratory or analytic devices to affect entire production facilities. Automation increases throughput, reproducibility and product standardization while paving the way for continuous process monitoring. In order to represent the highly complex processes required for the automated production of cell-based products, the individual devices must be interlinked inside tightly controlled networks, and sophisticated measuring technology must be seamlessly integrated into the process control system. Six partner companies from the federal state of NRW have joined the Fraunhofer IPT for two BIO.NRW-funded research projects that aim to create a "StemCellFactory". The partners have jointly developed an automated prototype facility that makes it possible to produce humanly induced pluripotent stem cells – for the development of active pharmaceutical ingredients on an industrial scale and according to industrial standards while complying with all quality control requirements.

The Fraunhofer IPT developed an automated high-speed microscope for the process control and quality control systems. With this microscope, it will be possible to examine moving cell samples in a continuous scanning process. Additionally, several commercial analysis modules were integrated into the facility to comply with quality control and documentation obligations. The finished cell products were subsequently validated in expression analyses.

The facility and the integrated component systems have been designed to allow the representation of a wide range of cell culture processes. A centrally located articulated robot serves to connect and interlink the individual components of the compact and modular facility. The robot’s arm has been equipped with a new gripping technology that allows it to handle different types of consumables and to operate all of the stations. When switched to manual operation mode, the facility is also capable of learning new biological processes. The use of an industrial programmable logic controller (PLC) allows the easy integration of further industrial automation components. The PLC also performs basic safety functions. The platform integrates the quality assurance components and the cell processing components through one central level of control. An easy-to-read user interface allows the operator the convenient supervision and management of all processes and of all data that have been generated.

At the same time while the automated process sequences were developed, the demonstrator for the automated facility was constructed, assembled in the premises of LIFE & BRAIN GmbH in Bonn and put into operation. The demonstrator comprises reprogramming modules and allows the clonal selection of primary human iPSC cells, the 2D- and 3D-based expansion of hiPS cells and a differentiation into neural and cardiac cells.

A new generation of minimally invasive Instruments for Magnetic Resonance Imaging

Steady advances in imaging technology have contributed to the strong increase of minimally invasive medical interventions over the past few years. While such interventions – in the wake of this development – have become more complex and comprehensive, doctors still have only a relatively narrow range of standard surgery instruments at their disposal. It appears safe to say that even more interventions will be successfully performed if we manage to customize such instruments to the individual requirements of each surgeon.

The EU research project “OpenMind” (reference no.: 680820), which unites nine partners from six European countries, aims to develop a flexible technology for manufacturing such customized one-off instruments within the next three years.
The idea is to produce medical products from fiber-reinforced plastics rather than metal, making the instruments suitable for their use under X-ray applications, in computer tomography and for examinations or even surgeries under magnetic resonance imaging. The project partners expect the new production process chain to close the gap between the efficient production of fully standardized and individually manufactured medical products.

It is also planned that the production chain will continuously inform and improve the ongoing process: all process data from the production process will be analyzed and evaluated through data mining algorithms, allowing the users to predict the process data for future product configurations with greater ease and to shorten the product development and manufacturing phases by up to 50 percent. The project partners expect cost savings of up to 30 percent and anticipate that the products’ time-to-market will equally fall by 30 percent.

The production chain for the new tools will make use of the micro-pull winding technique. In combination with the use of innovative plastic materials, this technique is capable of adapting the rigidity and flexibility levels of the products by aligning the fibres in different ways. The first minimally invasive instrument that will be manufactured is a guide wire for catheter applications of the type that is frequently used in cardiac surgeries. Patients with stents, artificial heart valves or aneurysms may already benefit from the new customized instruments in a few years time.

**Novel Antibiotic Susceptibility Diagnostics**

Current standard methods for detecting antibiotic susceptibility are based on the ability of the bacteria to proliferate in the presence of antibiotics, and thus these techniques are time-consuming, costly, and insensitive, particularly for evaluation of slow-growing organisms. To develop a truly rapid susceptibility test, one must circumvent the need for growth. Therefore, Fraunhofer CMI is developing a microfluidic test that interrogates the response of cells to antibiotics in the presence of mechanical and/or chemical stressors and thereby obviates the time needed for growth. The core of the hypothesis is that by straining the cell, the cellular repair processes and associated biochemical pathways are induced. These pathways are often targets of antibiotics, e.g. cell wall biosynthesis, protein synthesis, DNA transcription. If the antibiotic hinders those repair processes, the cell will die under the continued application of stress.

The researchers of the Fraunhofer CMI have demonstrated the methodology for strains of Staphylococcus aureus that can identify pathogens within 20 minutes while standard tests will need 18-48 hours culture. The researchers are now continuing to design new microfluidic designs to improve the performance of the methodology, including using techniques such as computational modeling to enhance design optimization. Experiments with other gram-positive and gram-negative strains of bacteria have also shown promising first results which shall now be validated.
OUR COMPETENCIES

A central task of the Fraunhofer IPT is to transfer the current research directly into industrial practice. We conduct applied research, implement our results in an industrial context, and provide relevant and effective consulting services for the direct benefit of industry, thereby contributing significantly to the competitiveness of companies.

The basis of the Fraunhofer IPT’s success is the widespread expertise in all our departments. Here we focus on our research activities and the further development of production technologies. Therefore, we focus not only our research on industrially applicable production technologies but also offer many technological products and services in the areas of process technology, production machines, production quality and metrology, and technology management:

- In the area of Process technology, we develop new production processes for your applications and optimize those already existing: from process analyses of the conceptual development and consultation up to the practical realization, we create integrated solutions for our customers.

- We consider ourselves to be a competent and professional partner for the development and construction of production plant with which to individually and efficiently manufacture your complex products - from initial technical advice to final implementation.

- The highest possible levels of quality, resulting in correspondingly high levels of efficiency of structure and workflow organization – this is, in the view of the Fraunhofer IPT, the key to competitiveness and innovative strength. The aim of the Fraunhofer IPT is to support its customers by implementing excellent results of applied research for a head start. We design and industrialize processes through effective measuring technology and an entrepreneurial understanding of quality.

- Sophisticated technology management is a significant factor in the success of technology oriented companies. Companies which remain resolutely customer-focused throughout the development, deployment and substitution phases, can build and maintain a competitive edge. We advise our customers in all disciplines of technology management – from the conceptual design to the elaboration of strategies, processes and methods for tailor-made technology management.

For the latest information about the expertise in our departments, go to our web page

www.ipt.fraunhofer.de/competencies
Laser material processing

The department for “Laser material processing” develops and validates processes that enable us to integrate laser radiation as an effective and efficient tool into the value chain. We develop laser beam joining technologies to the point where they are suitable for the industrial manufacturing of geometrically complex metal products. We use laser-beam structuring to produce high-precision 3D structures for applications in tribology, tool and die making and bionics. For hard and brittle materials, we develop hybrid processing technologies that enable the complete machining of complex-shaped components through process integration. The laser surface treatment on 5-axis-machining centers makes it possible to significantly extend the technical life of components and dies that are subjected to high levels of stress, to improve their technical properties and to repair the components in question.

Our services

- Laser beam structuring of 3D surfaces
- Laser beam joining technologies for customized applications
- Laser beam assisted forming and machining
- Anti-wear laser surface treatments
- Optimization of the anti-wear and anti-corrosion properties of tools and components
- Repairs of components and tools
- Machining of materials that are hard, brittle and difficult to machine
- Customized design of surface function and structure

High performance cutting

The “High performance cutting” department provides practical manufacturing solutions for components used in the production of turbomachinery, aircraft and tools. The focus is on simultaneous multi-axis milling and the turning of geometrically complex components made from super alloys, highly strengthened steels and lightweight and composite materials.

A deep understanding of technology, expert skills in the operation of complex systems and a unique machine pool provide the basis for R&D projects in a comprehensive and targeted way – all the way from the design of the machining processes, including tool design and clamping techniques, via the provision of technological consultation services to the successful production of the first prototypes.

Our services

- Machinability and tool design
- Process and system modeling
- Practice-oriented process design
- Design of clamping systems
- Consultancy and prototype manufacture
Fine machining and optics

The department for “Fine machining and optics” develops production and processing technologies for precision components, based on a profound understanding of the fundamental principles involved and with the objective of addressing actual and highly specific requirements of industrial environments. For these purposes, we are using the latest engineering and software technologies. The department’s technology portfolio includes ultra-precision grinding and polishing processes, diamond cutting technology as well as the molding of high-precision glass components for which we cover the entire process chain from mold design to the molding of the finished products. We also develop robot-based and machine-based grinding and polishing technologies, aiming to replace manual operations in tool and die making as well as in the production of components for turbomachinery with automatic machining processes.

Our services

- Basic research and process analyses in selected technologies
- Feasibility studies and technology design
- Profitability analyses and implementation strategies
- Production of components

Precision machines and automation technology

The Fraunhofer IPT department for “Precision machines and automation technology” develops precision machinery and customized devices, aiming to provide our clients with the integrated high-precision machines and components that match their specific requirements – from the conceptual design via the optimization of critical components to the development of suitable control systems and the implementation of complex cybernetic arrangements. The characterization of existing equipment is another focus of our work. We develop efficient and technologically reliable solutions for all automation tasks, no matter how complex or challenging. In addition to developing high-precision production equipment for the optical industry and for manufacturers of medical and biological technology, we also concentrate on the reel-to-reel production of functional foils and printed electronics.

Our services

- Conceptual design of individual machines and integrated facilities
- Construction of customized equipment
- Analyses and survey of existing systems
- Configuration and programming of control systems
- Characterization of production technology
Fiber-reinforced plastics and laser system technology

The department for “Fiber reinforced plastics and laser system technology” of the Fraunhofer IPT meets the growing demand for automatic processes of manufacturing fiber-reinforced components that are made from thermoplastics or duroplastics (FRP). Research and development services include the design of FRP components and the production of prototypes. The Fraunhofer IPT is also developing production facilities for laser-assisted tape laying and tape winding processes as well as for thermoforming operations. Another focus of the Institute’s research is the inline integration of sensors into FRP components that are exposed to specifically high levels of stress. The Fraunhofer IPT furthermore optimizes micro-pultrusion and micro-pullwinding processes, qualifying them for medical applications. The Institute also develops gripper systems for the reproducible handling of semi-finished FRP products. Another key focus of research is the development of customized equipment with integrated laser systems technology for machine-integrated combined machining and laser material processing as well as laser-supported machining.

Our services
- Development of customized equipment for the laser-assisted tape laying and tape winding of thermoplastic FRP prepregs
- New gripper technologies for the handling of semi-finished FRP products
- Design and production of FRP component prototypes
- Micro-pultrusion and micro-pullwinding of FRP profiles for applications in metrology and medical technology
- Optimization of thermoforming processes
- Integration of laser technology into production equipment
- Development of systems and processes for laser-assisted processes (machining, forming, shear cutting)

Ultra-precision technology and plastic replication

The competencies of the “ultra-precision technology and plastic replication” department are divided between the fields of ultra-precision surface machining and the replicative molding processes in injection molding or in continuous methods. Our competencies cover the entire process chain in the manufacture of optical polymer components. We develop and realize optical products to meet your requirements, from design to tool and mold-making through to injection molding and roll-to-roll processing. Alongside optical production as such, we plan and design special optical machines for our customers according to their individual specifications.

Our services
- Replication of ultra-precise plastic components
- Diamond cutting
- Piezo actuators in production
- Systems for the manufacture of complex optical freeform surfaces
- Development of precision and ultra-precision machines
Production metrology

The department for “Production metrology” of the Fraunhofer IPT develops new measuring solutions for industrial applications and new quality assurance methods for manufacturing companies. For these purposes, the department has been equipped with a comprehensive range of sophisticated measuring devices that are used for contract measuring services but that are also continuously optimized and developed in close coordination with partner organizations and technology providers. Our efforts are always keenly focused on the industrialization of processes.

Our services

• Optical metrology and imaging
  – Manufacturing and testing of optical components
  – Short coherent interferometry
  – Fiber optics
  – Biophotonics
  – Customized measuring systems

• Metrology for automated production
  – Automation of industrial manufacturing processes
  – Automation of biotechnology processes
  – Sensor integration and data feedback
  – Automated measuring systems
  – Assembly of fiber-optic systems
  – Contract measuring services

• Micro- and nano-production
  – 3D-lithography
  – Interference lithography
  – Development of resists
  – Characterization of structures

Production quality

The competitiveness of manufacturing companies is frequently a function of error-free and efficient production cycles. In the era of “Industry 4.0”, a consistent digitalization and the interlinking of machines, products and human resources into tight and efficient networks for the purposes of operating an adaptive production system are of crucial importance. Companies must know what methods, software tools and technologies are available, which of these stand to benefit them most and then decisively perform their implementation. Practical experience and well-established methods are the foundation for our comprehensive and customized consultation services in production organization and quality assurance.

Our services

• Production organization in the age of Industry 4.0
  – Production sequences, layouts, material flows and quality assurance in compliance with the principles of Lean Production, Six-Sigma and Industry 4.0
  – Selection of suitable means of transport, manufacturing equipment and measuring systems
  – Optimized consumption of energy and resources for existing production chains

• Software systems for production control and quality assurance
  – Systems: MES, BDE/MDE and CAQ
  – Algorithms and methods
  – MES or CAQ modules in research and development

• Information management and data analytics
  – Data structures
  – Tools for Six-Sigma, data mining and predictive analytics
  – Development of software modules for data analyses
  – Error, risk and reliability analyses
  – Smart wearables in production
Strategic Technology Management

Whether or not technology providers can prosper and survive is largely determined by the efficiency and effectiveness of their technology management. Companies that are keen on establishing long-term competitive advantages must identify current technology and market trends, recognize and anticipate any latent change in their customers’ requirements, continuously adapt and improve their range of goods and services and be constantly prepared to question their own business model. It is in this climate where technology management has evolved into a key element of successful business activity. New approaches, adaptive processes and sophisticated modern strategies are necessary to develop innovations (whether incremental or ground-breaking) and to assume an active role in the making of tomorrow’s world.

We cooperate closely with our clients to customize their technology management to their individual requirements and support them in the identification and analysis of existing skills and knowledge while assisting them in the establishment of core competences. Customized technology strategies allow our clients to make the right decisions and to make efficient use of their resources.

Our services

- Technology management processes and organization
- Business-model-focused technology management
- Core competence analyses/development
- Technology strategies
- Strategies for Industry 4.0 and additive manufacturing
- Technology planning/road mapping
- Technology platforms
- Strategies of how to exploit existing potentials
- Diversification strategies

Operative Technology Management

In an era of technological progress and growing customer demands, companies are confronted by multiple challenges, including trends such as Industry 4.0 or the demands of additive manufacturing. More information is available and easier-to-access than ever before, and as a result, it is also more difficult than ever to maintain an overview and a sense of direction. We can identify future technologies, products, markets, customers and competitors, providing an integrated foundation of information for target-oriented innovations.

From “incremental” and “disruptive” to “breakthrough” and “game-changing” – there are as many attributes to qualify innovations as there are corporate strategies of shaping their outcomes. Companies that want to develop disruptive innovations to create and penetrate new markets, first creating and then exploiting long-term competitive advantages, must continuously adapt existing innovation processes. New ideas with a high potential for competitive differentiation require broad-tent solutions – and highly iterative processes that are combined with specifications that provide a minimum of information. We assist companies that want to restructure their innovation systems and to develop successful innovation projects.

Our services

- Knowledge automation
- Network design
- Scanning, scouting and monitoring
- Technology and market analyses
- Identification of new applications
- Agile technology development
- Evaluation of technologies / technology chains
- Cost analyses and optimization
END-OF-YEAR REVIEW

**Fairs**
- Photonics West, 10.2.-12.2., San Francisco/USA
- JEC, 10.3.-12.3., Paris/F
- Hannover Messe, 13.4.-17.4., Hannover
- Control, 5.5.-8.5., Stuttgart
- SIAE Paris Air Show, 15.6.-21.6., Paris/F
- LASER, 22.6.-25.6., München
- Composites Europe, 22.10.-24.10., Stuttgart
- Fakuma, 14.10.-18.10., Friedrichshafen
- Blechexpo, 3.11.-6.11., Stuttgart
- productronica, 10.11.-13.11., München
- formnext, 17.11.-20.11., Frankfurt

**Conferences**
- ICTM – International Conference on Turbomachinery Manufacturing, 25.-26.2., Aachen
- Final Conference of Consortium Benchmarking in Purchasing, 18.6., Aachen
- Technology and Innovation Management Conference, 16.9., Aachen
- BFQ – Business Forum Qualität, 17.-18.9., Aachen

**Awards**

**Springorum-Gedenkmünze**
- **Johannes Kerkhoff**
  Master Thesis at the RWTH Aachen University “with honors” (1,0):
  “Entwicklung eines quantifizierenden Bewertungs- & Behandlungsmodells von Beschaffungsrisiken”

**Springorum-Gedenkmünze**
- **Florian Lindner**
  Master Thesis at the RWTH Aachen University “with honors” (1,0):
  “Entwicklung einer Systematik für das branchenübergreifende Benchmarking der energiebezogenen Leistung produzierender Unternehmen”

**Borchers-Plakette**
- **Markus Große Böckmann**
  Doctoral Thesis at the RWTH Aachen University “summa cum laude” (1,0):
  “Senkung der Produktionskosten durch Gestaltung eines Energieregelkreis-Konzeptes”

**Third prize at the “IHK-Gründungswettbewerb”**
- **Roman Kalocsay and Christian Kolvenbach**
  Innoclamp GmbH
  Spin-off of the Fraunhofer IPT, established 2015

**First prize of the “OptecNet Deutschland e.V. Photo Award”**
- **Guido Flüchter**
  Photo “Diffractive Lens”
Doctoral Theses


Cabral, G. F.: An improved approach to modelling and simulation of tool engagement and prediction of process forces in milling. Diss. RWTH Aachen, 2015


Hacker, P.: Methode zur Ableitung eines gestaltungsaufgaben-spezifischen Anforderungsraums für die Produktentwicklung. Diss. RWTH Aachen, 2015


Schug, P.: Modellierung, Bewertung, Analyse und Optimierung von CAx-Prozessketten. Diss. RWTH Aachen, 2015


Witte, A.: Einsatz optischer Messtechnik zur Qualitätssicherung eines Thermoplast-Wickelprozesses für die Faserverbundtankherstellung. Diss. RWTH Aachen, 2015

For more information on conferences, exhibitions and honors visit our website

www.ipt.fraunhofer.de/dates
The Fraunhofer IPT has the mission to convert scientific knowledge into economically viable innovations in the field of production technology. This is why we regard scientific papers as an important instrument to demonstrate our capacity to innovate – within the scientific community as well as to potential clients and project partners.

Recent Books

Schmitt, Robert (Hrsg.):
Apprimus-Verlag, Aachen, 2015
ISBN 978-3-86359-350-6

Brecher, Christian; Baum, Christoph; Meiers, Bernd; De Simone, Daniel; Krappig, Reik:
Kunststoffkomponenten für LED-Beleuchtungsanwendungen.
Springer Vieweg, Wiesbaden, 2016

Plutz, Martin; an Haack, Alexander; Schmitt, Robert; Jeschke, Sabina (Hrsg.):
Qualitätsskultur – Neue Wege zu einem erfolgreichen Qualitätsmanagement.
Symposion Publishing, Düsseldorf, 2015

A list of all scientific papers that have been published by the Fraunhofer IPT in 2015 can be downloaded via the “Fraunhofer-Publica” bibliography database under the following link:

http://publica.fraunhofer.de/institute/IPT/2015
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