

## INDUSTRY 4.0 – CONNECTED, ADAPTIVE PRODUCTION

Our Partner



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The Fraunhofer IPT has already implemented numerous aspects of connected, adaptive production in its research and development projects with partners from a wide range of industrial sectors. Selected examples of successes in this field are outlined in the following pages of this brochure. The Fraunhofer IPT can advise and support you and your company with regard to these areas:

## Connecting technology know-how and process knowledge

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# THE FOURTH INDUSTRIAL REVOLUTION

What has come to be known as the “Fourth Industrial Revolution” is being shaped predominantly by production digitization and networking. Buzzwords such as the “Internet of Things and Services” and “Cyber-physical Production Systems” promise increased networking of autonomous and self-optimizing production machines and intelligent products which can be customized to manufacture highly individual outcomes. Much of this remains a vision – for the time being. However companies with the will to succeed in the fiercely competitive global markets need to consider today the role they wish to play in “Industry 4.0” tomorrow.

Industry 4.0 requires a holistic view of production systems with all of the process chains involved in the product development process. Working on the fundamental principle of “Connected, adaptive production”, the Fraunhofer IPT develops production processes and the associated production machinery along with the corresponding metrology, then interconnects all of the system components with one another.

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. Their 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.

To enhance the productivity and efficiency of manufacturing companies is the declared aim of the Fraunhofer IPT. We draw on our expertise to provide answers to a number of questions relating to Industry 4.0, which will arise in the near future.

# INDUSTRY 4.0



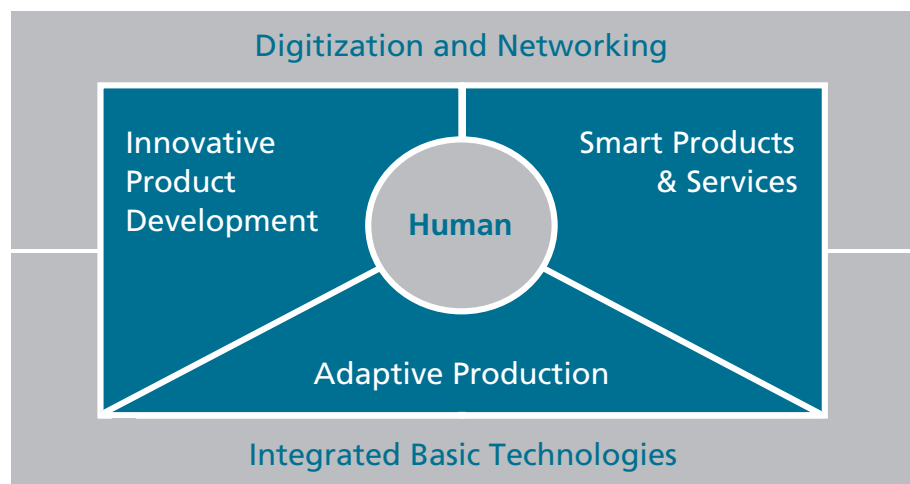
# CONNECTED, ADAPTIVE PRODUCTION

Inter-connectivity and adaptivity in production are forming a strong foundation for Industry 4.0. 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.

The starting point is the networking of equipment and software systems, smart control and sensor systems permitting the acquisition and subsequent provision of all technology and process-related information. Either alone or with our

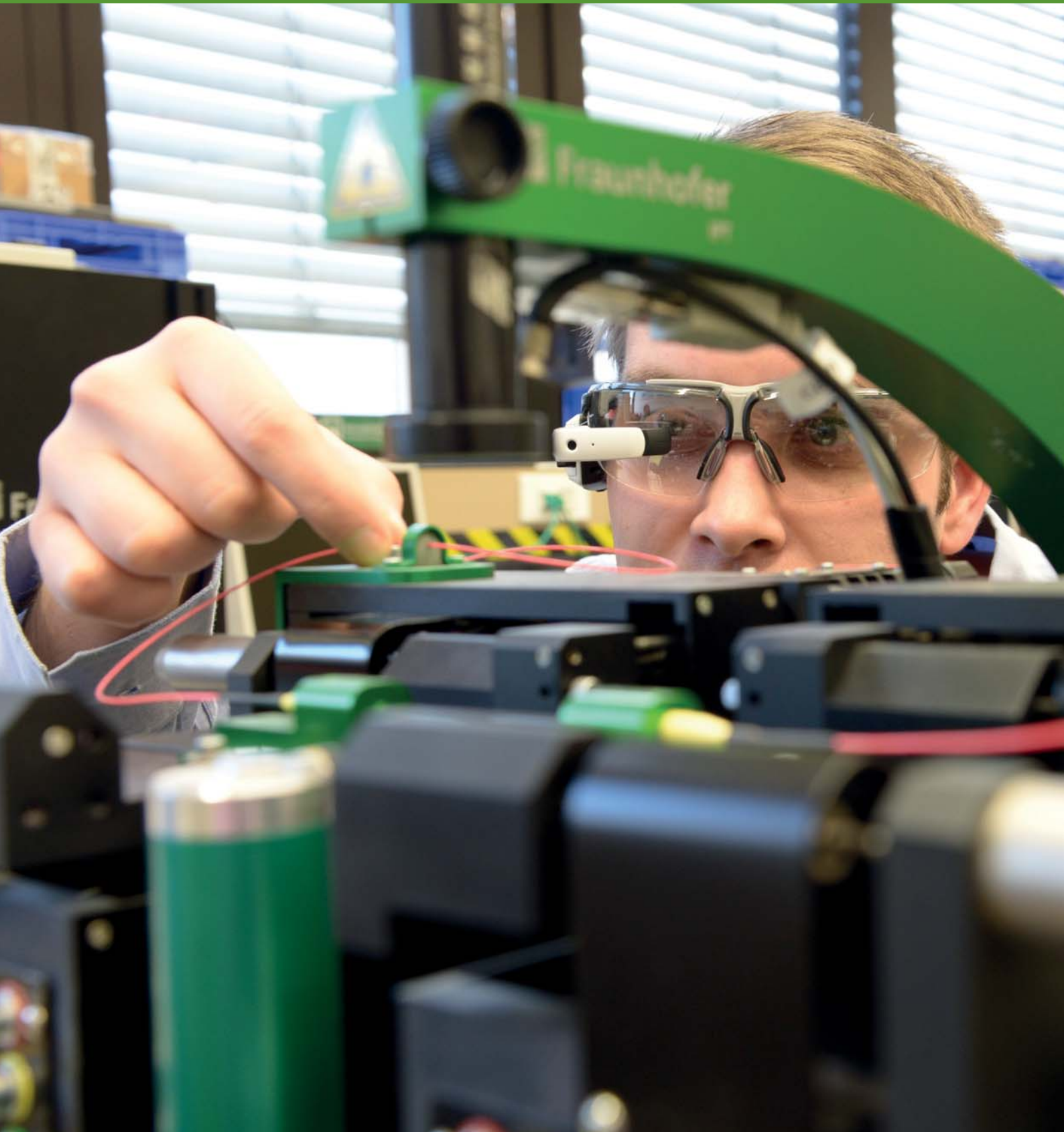
cooperation partners, who are usually from the Fraunhofer network and from the RWTH Aachen University, we develop the IT infrastructures such as industrial cloud concepts for smart services, which are required in order to evaluate such large volumes of data and utilize them effectively.

Thus, we transform our customers' production systems into highly flexible, interconnected and adaptable units – completely in line with the principles of Industry 4.0.





# CONNECTING TECHNOLOGY KNOW-HOW AND PROCESS KNOWLEDGE



## SMART GLASSES 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 despite the fact that they have enormous potential in terms of process quality, productivity and transparency. They could connect employees very much more efficiently than is currently the case with production planning and quality systems, thereby supporting them in their activities. The vision of fault-free production thus moves another step closer.

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. The personal smart glasses system also enables individual employees to pass on process-related information, thereby contributing to continuous improvement.

Previous experience demonstrates that the use of smart glasses reduces error rates by over 50 percent, depending on the application and that lead times can be shortened by approximately one third.

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

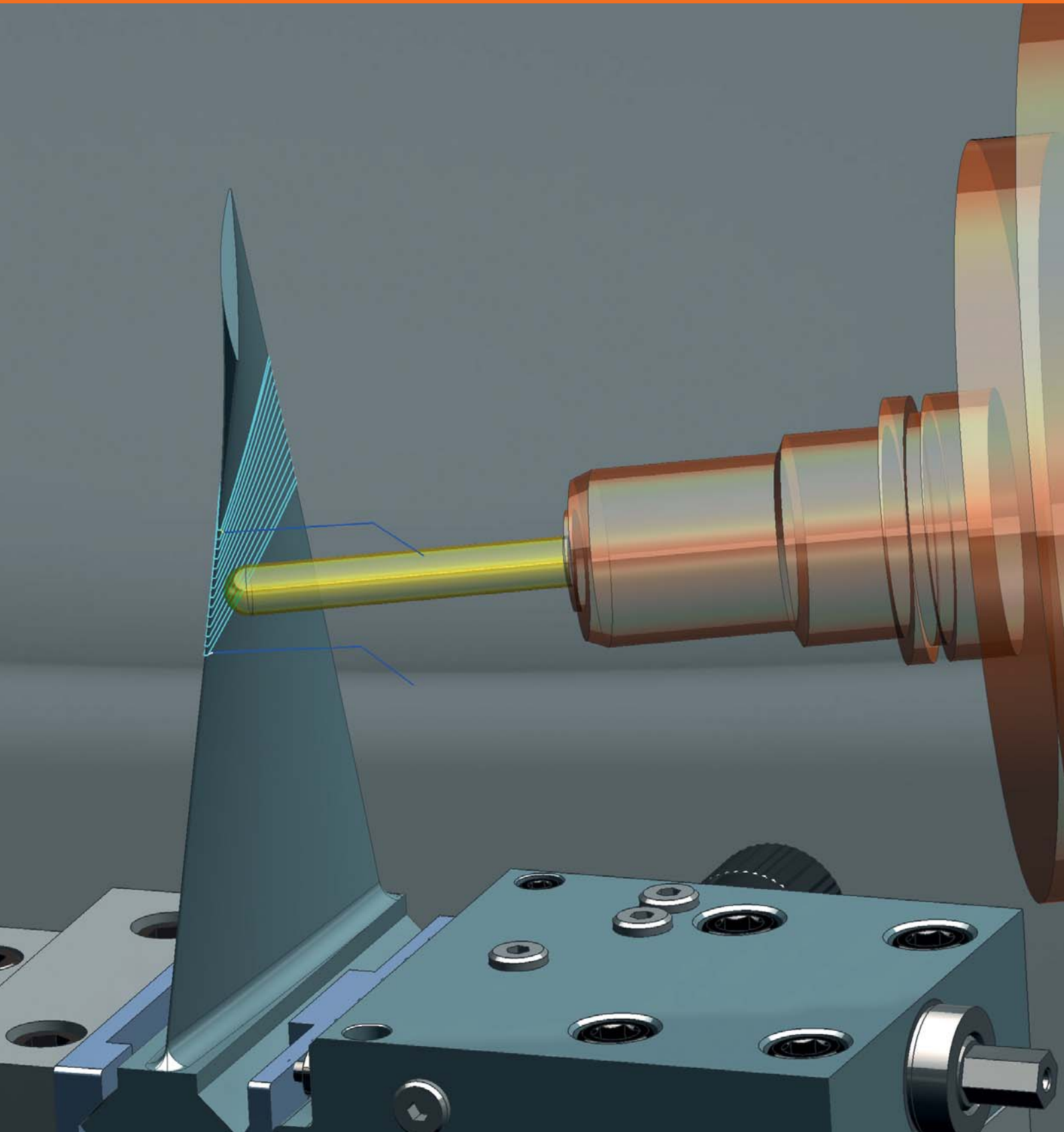
glasses. The sequences can be displayed in detail in the view field of the glasses and augmented with additional information in the form of images, audio and video data and even 3D models. The quality of manual processes can be improved significantly in this way.

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.

"oculavis" has been used effectively in manual control cabinet assembly processes, for example, to achieve a considerable reduction in the error rate in test runs. The system supports the worker and provides the necessary information – entirely as required and on-demand – from images of the storage location of components to video-based assembly instructions. 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.

**FASTER AND MORE EFFICIENTLY  
WITH WEARABLE DISPLAYS**

# CONNECTING TECHNOLOGY KNOW-HOW AND PROCESS KNOWLEDGE





# 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.

A repair process chain must adapt to the specific details of the damage sustained by the part which is to be repaired for example. This is the point at which the traditional approaches pursued by the CAx programming are stretched to their limits: manual adaptation of manufacturing process chains to particular products, cases of damage and disturbances is a costly operation and the development of specialist software for certain products or product families quickly breaks the budget of most companies.

Additive manufacturing methods such as laser deposition welding are the obvious choice for the repair of turbo-machines used in aerospace or for energy generation. This involves first removing the worn and defective areas of the turbine blades and then reconstructing it so that it corresponds with the original nominal geometry.

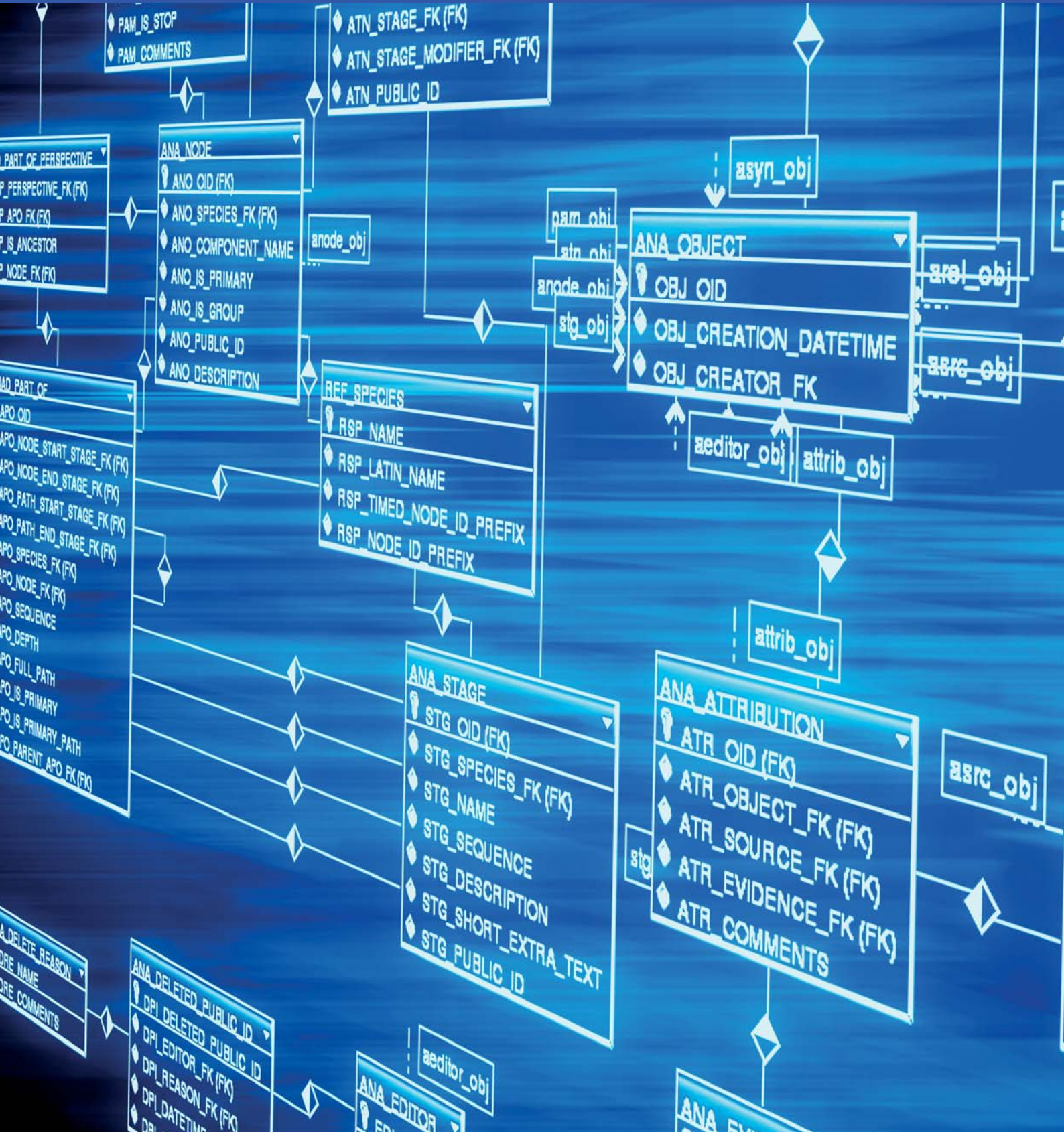
Within the framework of the "Adaptive production for resource efficiency in energy and mobility – AdaM" innovation cluster, the Fraunhofer IPT has collaborated with over 20 project partners to develop a continuous part and process data chain for adaptive machining.

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.

The Fraunhofer IPT uses a "CAx-Framework" which was specially developed by engineers at that institute for planning and simulation. With the appropriate software modules, the framework links various manufacturing processes to continuous, computer-assisted process chains (CAx process chains). The workflow-based programming method deployed, enables the user to design process chains in a flexible and user-friendly way. The laser deposition welding and milling processes, for example, can be linked to form a continuous CAx process chain on the basis of the CAx-Framework. This ensures data consistency throughout the entire product lifecycle. The data are made available to the appropriate employees via a product lifecycle management system (PLM).

**DATA CONSISTENCY SPEEDS UP THE DEVELOPMENT OF THE RIGHT PRODUCT**

# CONNECTING TECHNOLOGY KNOW-HOW AND PROCESS KNOWLEDGE



# 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 set up 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.

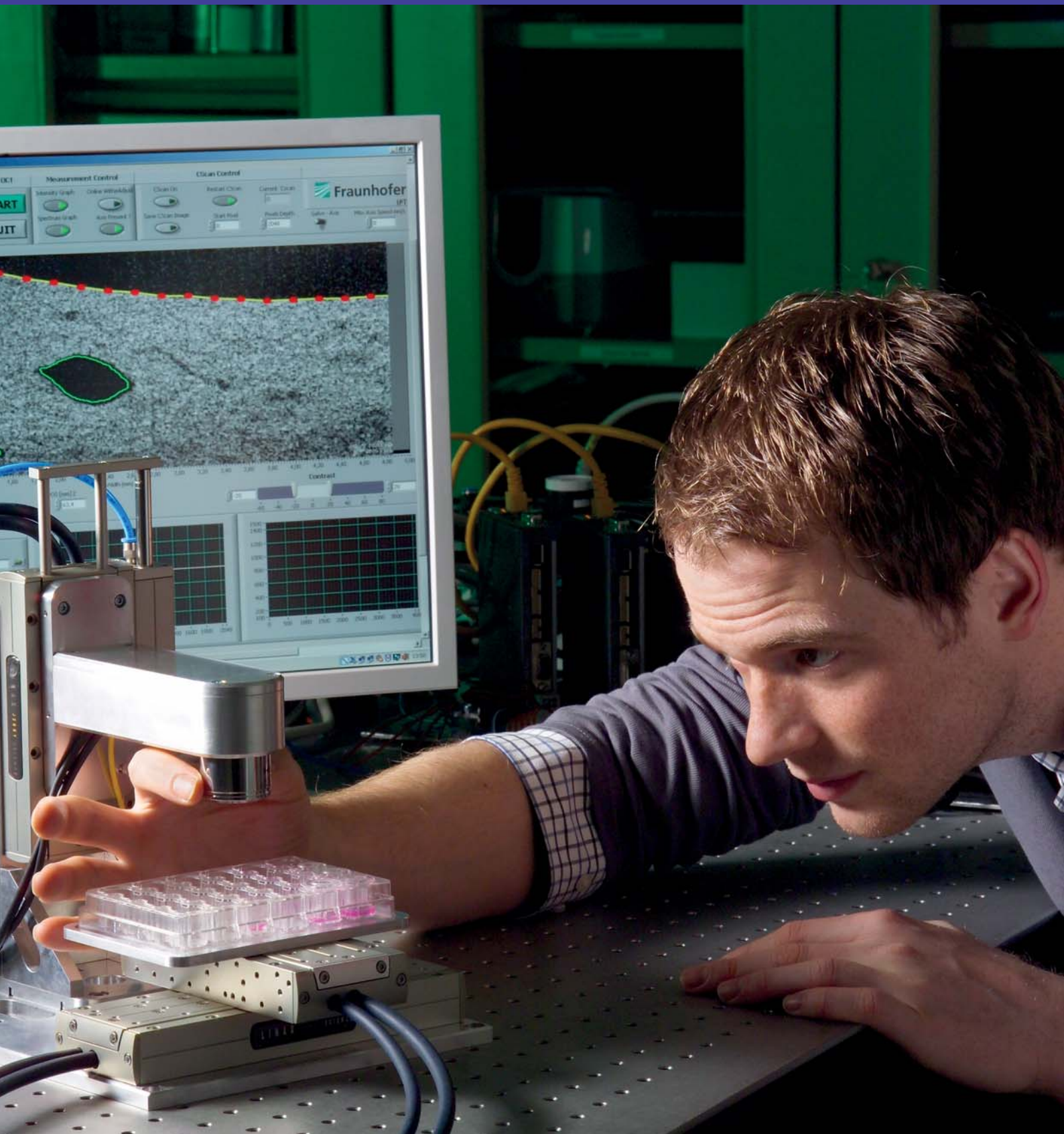
So far, very few companies have automated the connections between various process steps such as pre-machining and part measurement. In many companies, there is a lack of automated cycles to regulate data exchange between measuring systems and machine tools, integrated interfaces and standardized data formats. 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.

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. The fully integrated communication solutions were developed in accordance with industrial standards and also feature robust, operator-friendly control solutions for the implementation of higher levels of automation.

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.



# CONNECTING TECHNOLOGY KNOW-HOW AND PROCESS KNOWLEDGE





# 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. Just recording and filing such large volumes of data in a structured manner takes a considerable amount of time and effort. Initially, instead of bringing about the intended transparency, this can lead to somewhat chaotic conditions. 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. The Fraunhofer IPT is therefore developing efficient concepts for rapid data processing and evaluation and is transforming these into applications with real-time capability.

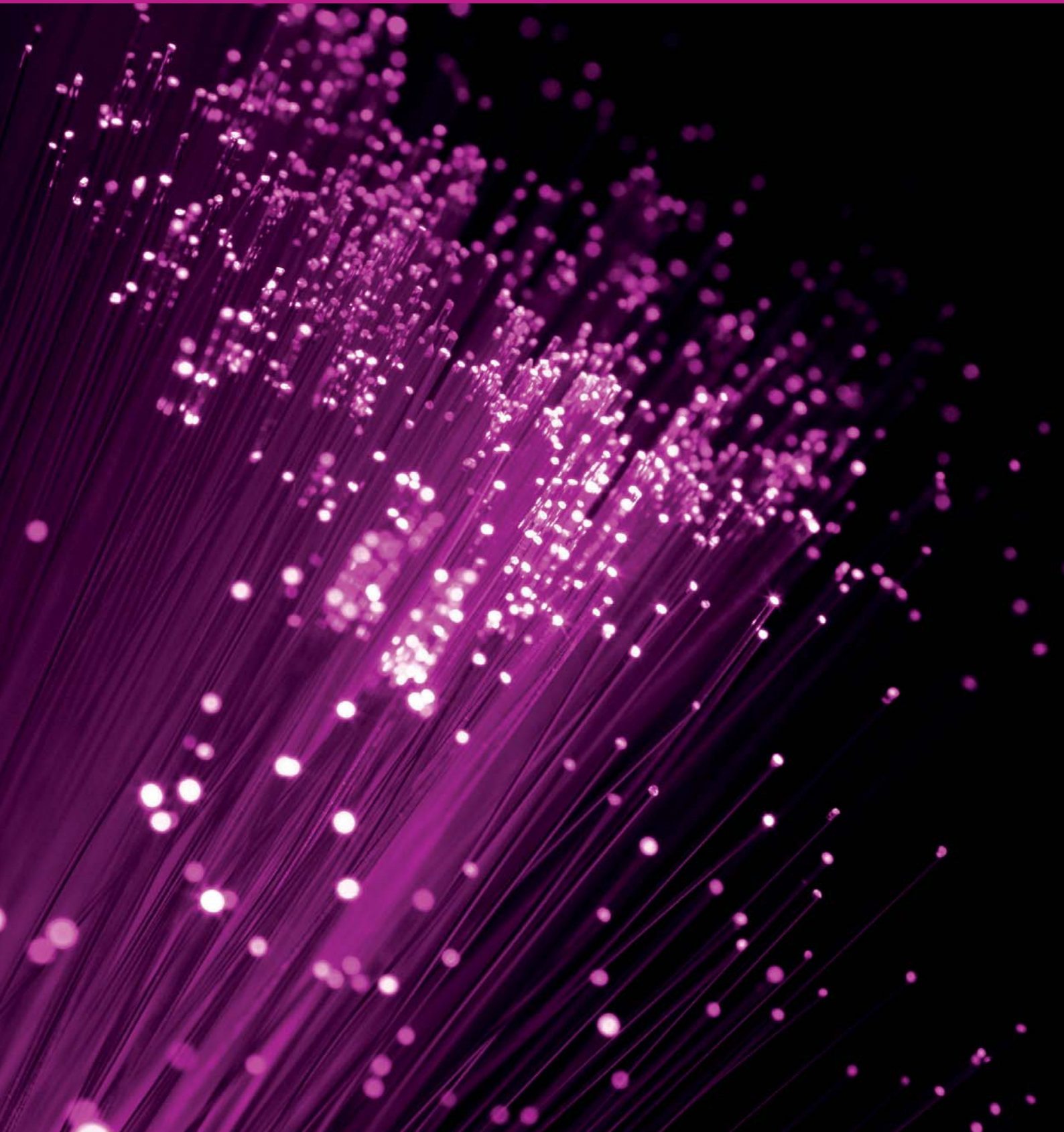
Adaptive optical systems for high-speed microscopy permitting relevant information to be extracted quickly from copious amounts of measurement data is one such example. The parallelization of computer operations is one way of processing such large volumes of data. The fast processors of the graphics 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.

**GAINING ADDITIONAL INFORMATION BY PARALLEL  
COMPUTER OPERATIONS FOR DATA ANALYSIS**

# CONNECTING TECHNOLOGY KNOW-HOW AND PROCESS KNOWLEDGE



# 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. However the ability to spot and trace the right information at the right time usually requires a trained eye and considerable practical knowledge. Networked, community-based approaches can be extremely useful in such cases by involving network partners and experts outside the organization in the search for the appropriate technology and the best way to manage it.

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. A systematic approach to the identification of custom-fit

technologies within the scope of Industry 4.0 has been applied by the Fraunhofer IPT in the fields of transport and medical engineering among others. This enables specific economic potentials of digital manufacturing for companies in this sector to be derived.

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





# 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. Classical goal criteria used in production planning such as machine utilization or throughput times are accompanied in the age of Industry 4.0 by further information relating to factors such as time-related risks or energy consumption. New production planning and control concepts which take account of these data can make a major contribution towards lowering production costs.

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.

TAKING ACCOUNT OF NEW VARIABLES SUCH AS  
TIME UNCERTAINTIES AND ENERGY COSTS

# ONLINE/OFFLINE PROCESS AND PROCESS CHAIN ADAPTIVITY



# 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.

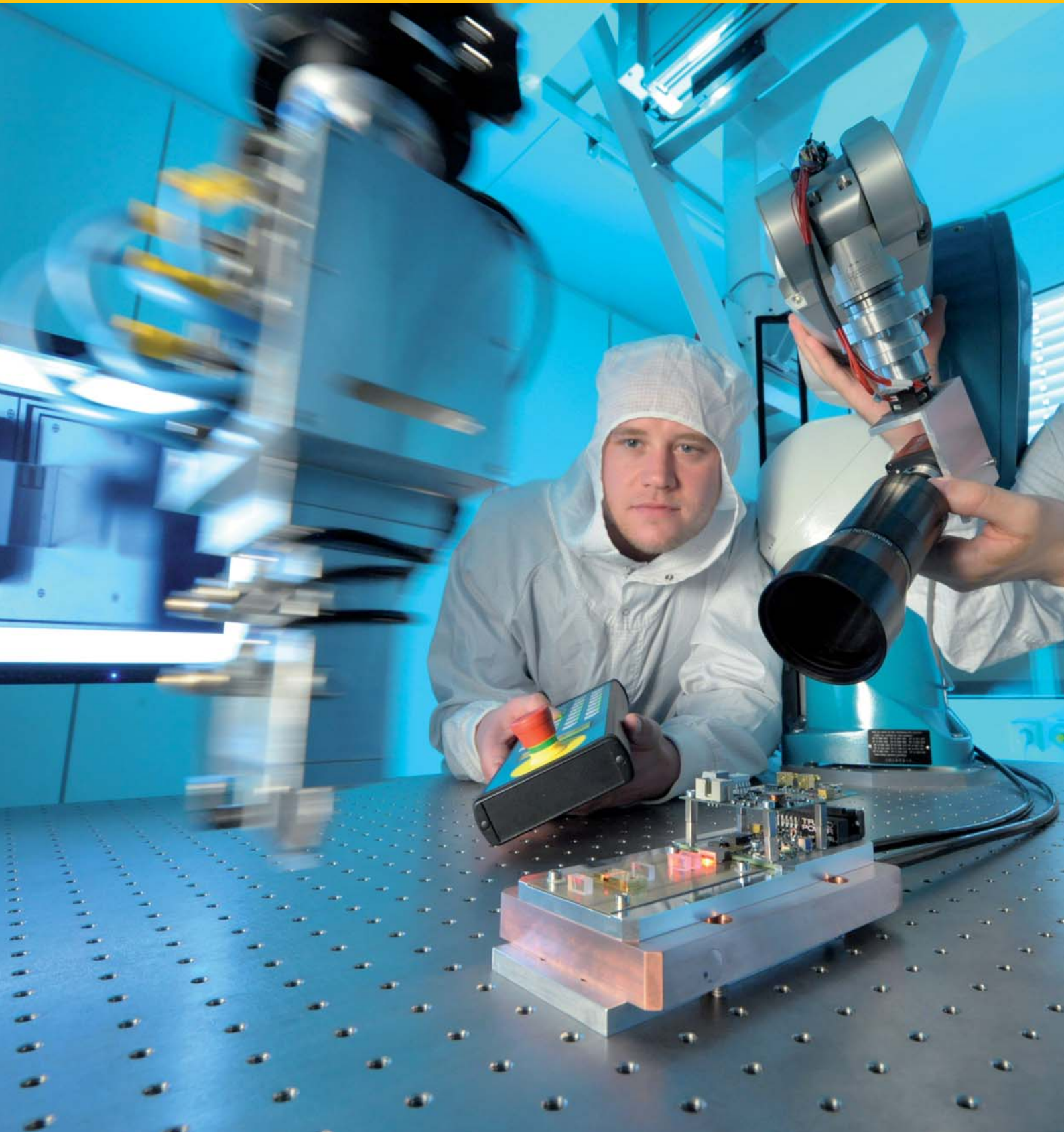
The Fraunhofer IPT is working on production systems which will be capable of manufacturing medical, personalized disposables cost-efficiently. The Fraunhofer IPT in conjunction with eight project partners is developing a pilot production system within the publicly funded OPENMIND project, which will 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”.



# ONLINE/OFFLINE PROCESS AND PROCESS CHAIN ADAPTIVITY





# 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.

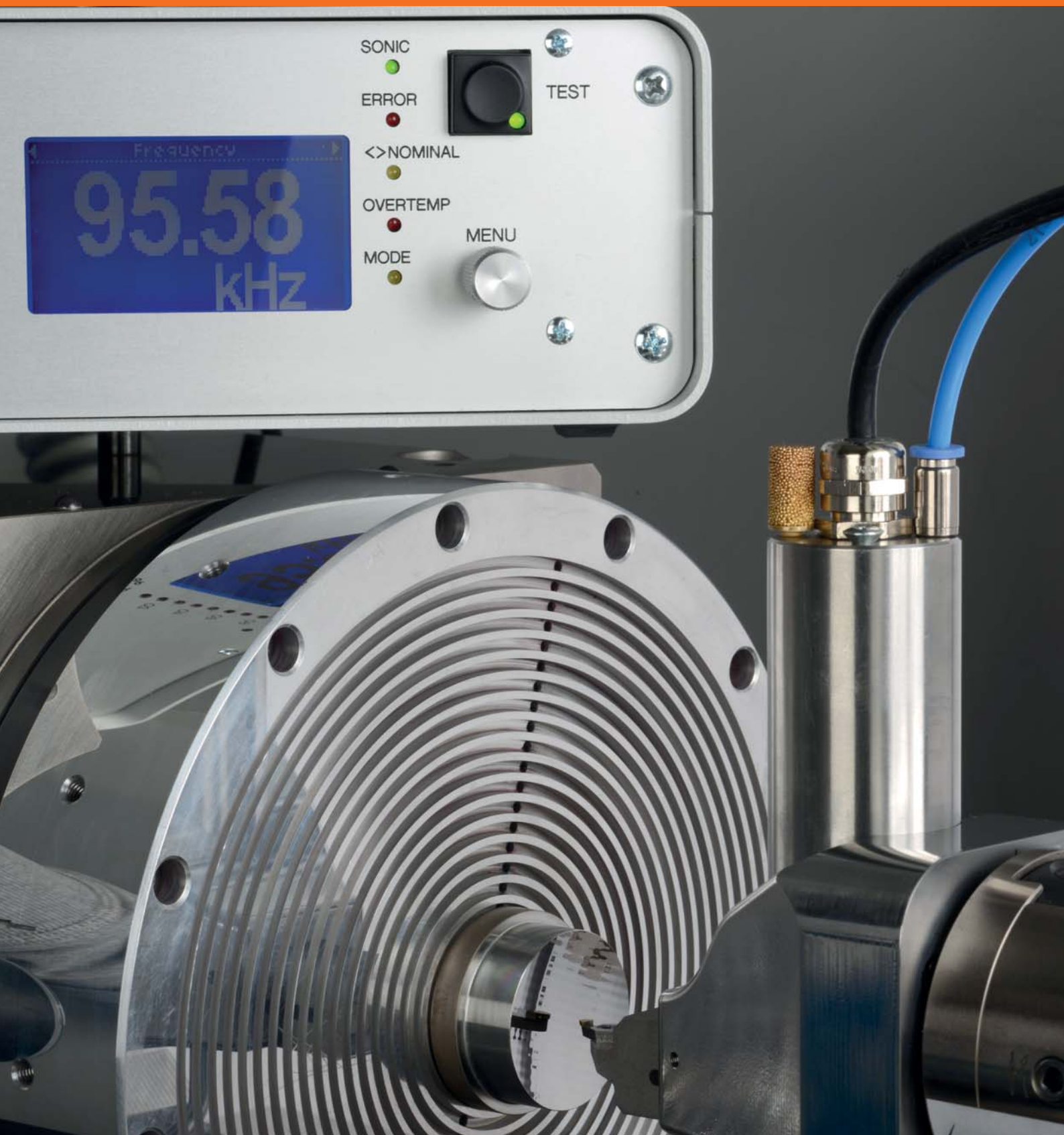
In the “Integrative Production Technology for High-Wage Countries”, the Fraunhofer IPT along with institutes and facilities affiliated with the RWTH Aachen University is investigating new means of applying the principles of artificial intelligence to expand significantly the range of applications and 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.

Assembly is a classical field of application. Principles of self-optimization for the assembly of high-performance laser systems are developed and applied at the Fraunhofer IPT. High-precision orientation of optical components is one of the crucial quality criteria for the assembly of such laser systems. It is vital to meet the most exacting demands in terms of manufacturing and process tolerances. Self-optimizing assembly systems can rise to the challenge by using models to interpret

the sensor data. This is achieved by drawing on the optical characteristics such as beam profile, optical power or imaging quality, evaluating them and using the results in a closed control loop in order to correct the position of individual optics. In a self-optimizing system, tolerance minimization is replaced by function-oriented assembly process management. As a result, the planning effort required for complex assembly processes can be greatly simplified whilst maintaining a robust production system.

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.

# ONLINE/OFFLINE PROCESS AND PROCESS CHAIN ADAPTIVITY



# 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. The use of sensors is usually limited to the most important safety functions or to automatic calibration of tool and workpiece. There is usually a centralized information processing unit which collects all of the signals in one operation and analyzes them.

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





# 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.

Process automation and control in cell technology is a critical venture: influencing factors such as cell density, temperature, humidity and gas concentration as well as the very marked genetic individuality of cell products, imposes exacting demands on the process control operation. A high degree of networking among individual devices and seamless integration of metrology within process control, are major prerequisites.

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. Each cell colony is measured continuously and the process parameters are repeatedly adapted automatically on the basis of the measuring results. The

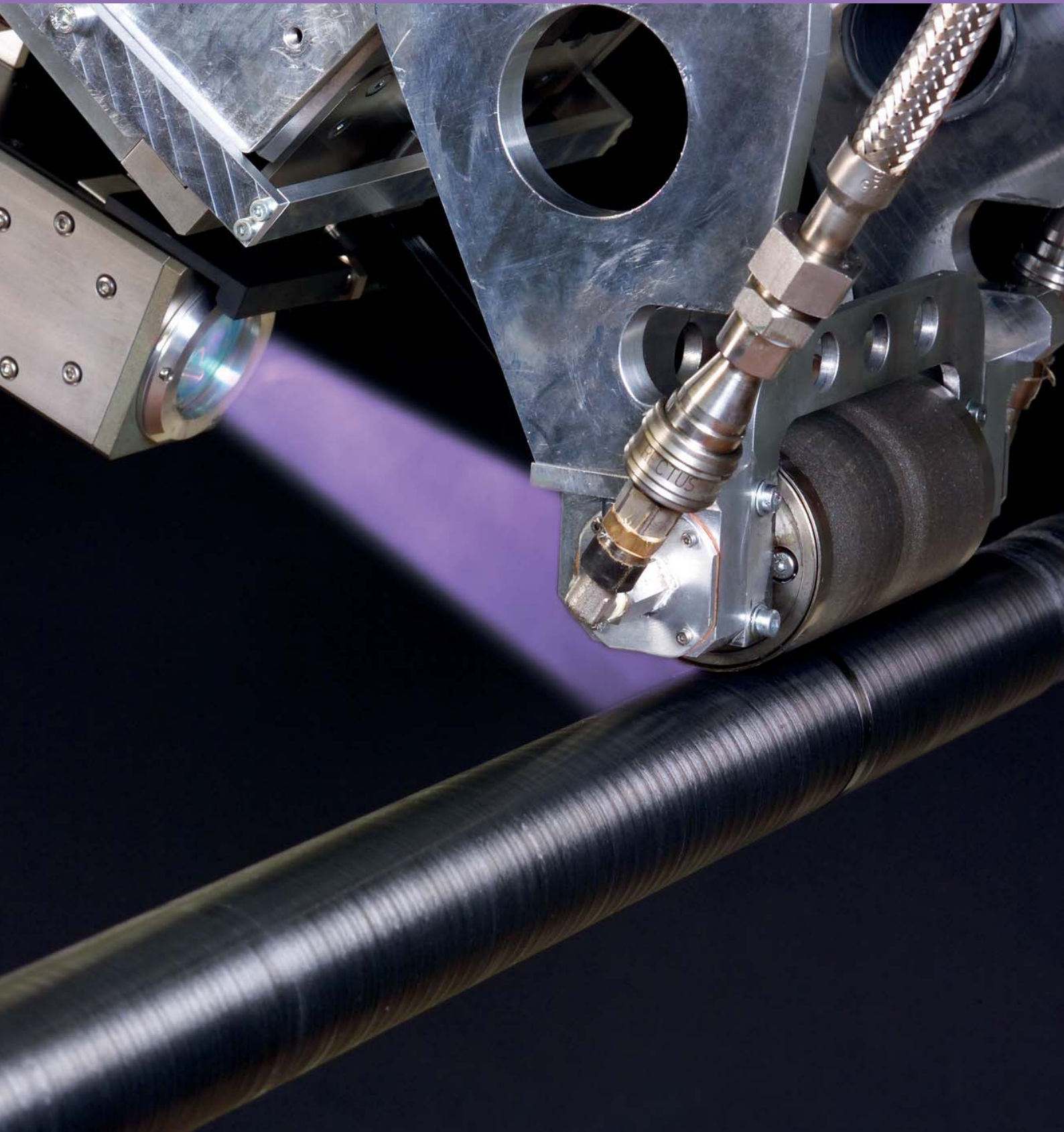
control station developed specially for this purpose controls the entire process and monitors the devices and material used throughout the entire production process. The user is informed automatically by the system if the volume of resources – the fill level of process media, for example – falls below a specified level. The device resource management system automatically applies an automatic scheduling algorithm.

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.

**CONTROLLING HIGHLY INDIVIDUAL  
PRODUCTION PROCESSES**

# IN-DEPTH TECHNOLOGICAL UNDERSTANDING FOR HIGH-PERFORMANCE PRODUCTION



# 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

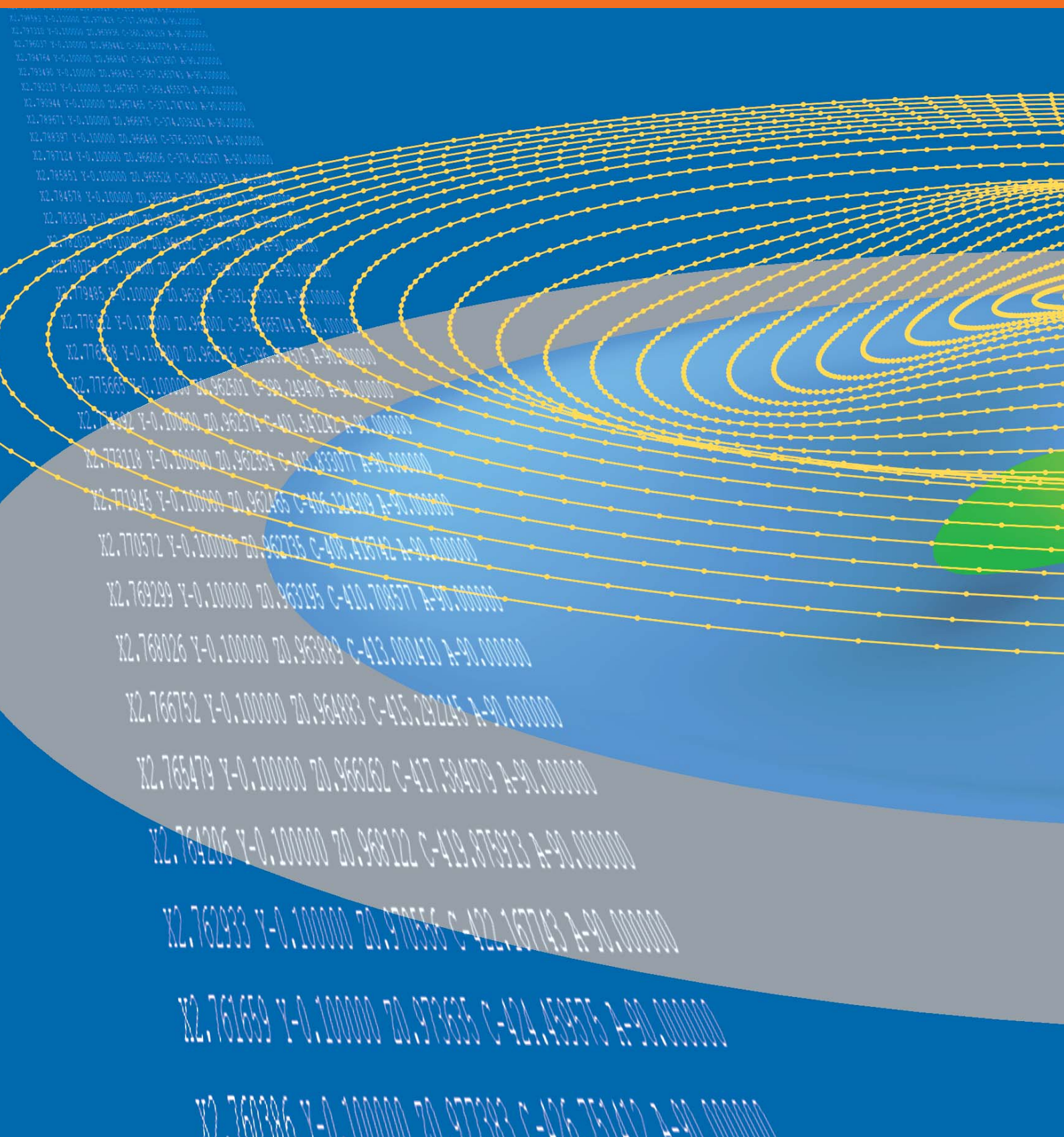
used to produce parts made of thermoplastic-based composite materials. It is intended that the facility will be just as suitable for use in the highly flexible production of products such as pipes for the oil and gas industries as for the pressure vessels used in the automotive sector.

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.



# IN-DEPTH TECHNOLOGICAL UNDERSTANDING FOR HIGH-PERFORMANCE PRODUCTION



# 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.

## ABOUT THE FRAUNHOFER IPT

The Fraunhofer IPT combines knowledge and experience in all fields of production technology. We offer partners and customers tailor made solutions and immediately actionable results for modern 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.

We develop and optimize new and existing methods, technologies and processes to create the production environment of the future. Using an integrated perspective, we always analyze the production technology challenges of our clients in the context of the process chains involved. This allows us to go beyond the development of individual technologies which are capable of performing highly specific tasks, designing customized system solutions for our clients' production requirements. This interdisciplinary view allows us to approach and develop solutions which require thinking beyond the narrow confines of any particular discipline.

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 3500 m<sup>2</sup>. The entire Fraunhofer IPT occupies an area of app. 6000 m<sup>2</sup>.



# COMPETENCES AND SERVICES FOR A CONNECTED, ADAPTIVE PRODUCTION

## Connecting technology know-how and process knowledge

- Data consistency in CAD/CAM and PDM systems
- Smart glasses and devices for increased production quality
- Selection and implementation of production and management software systems
- M2M und P2M communication strategies
- Scanning und monitoring of Industry 4.0 trend technologies

## Online/offline process and process chain adaptivity

- Self-optimizing production systems and control concepts
- Definition and implementation of data structures for adaptive production systems
- Measuring technology and sensor development
- Adaptive planning and control systems
- Development of modular software architectures for process chain related CAM programming
- Expanded goal systems for production planning and job scheduling (MES)

## In-depth technological understanding for high-performance production

- Data Mining & Predictive Analytics for production processes
- Big Data handling via GPU processing
- Planning, assessment and design of technology chains
- In-depth technological understanding of manufacturing processes in the following areas:
  - High performance cutting (turning, milling, drilling, grinding, polishing)
  - Manufacturing of glass- and plastic-based optics
  - Laser material processing
  - Lightweight technologies
  - Roll-to-roll processes
  - Automation technology
  - Life sciences and laboratory automation
  - Optical metrology
  - Structuring processes

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