RESEARCH NEWS – SPECIAL ISSUE

05 | 2018 ||

Research awards in brief

Four science prizes will be presented at this year's annual conference of the Fraunhofer-Gesellschaft in Berlin. The first, the Stifterverband Science Prize, is awarded for scientific excellence in collaborative applied research projects. The Joseph von Fraunhofer Prize will be awarded to three teams of researchers in recognition of outstanding scientific work leading to the solution of application-oriented problems.

1 Free-form: quality leap in optical systems

Radiation therapy is one of the most essential elements in cancer treatment. But properly planning radiation therapy is a highly complex task. Fraunhofer mathematicians have joined an alliance with medical physicists and physicians to improve the therapy planning process. In doing so they have helped improve patient's chances of recovery.

2 XXL computed tomography

Researchers at the Fraunhofer-Gesellschaft have achieved decisive progress in computed tomography. For the first time, it is now possible to analyze even very large objects with X-ray technology. XXL computed tomography produces high-resolution, high-contrast images in 3D. The technology enables, for example, the analysis of electric cars after a crash test. Historical relics can also be examined – and even a dinosaur skull.

3 Improved efficiency of aircraft engines

The Fraunhofer Institute for Material and Beam Technology IWS has succeeded in increasing the stability of those aircraft engine parts which are subject to stress due to temperature. The IWS process helps to reduce kerosene consumption as well as CO_2 emissions. In combination with further measures, significant cost savings result during flight operations. The research project was developed in close cooperation with the engine specialist Rolls-Royce. The first engines with the new technology are already in use.

4 Algorithms for liver surgery

Four complex, interwoven vascular systems pass through the liver. Surgically removing tumors is therefore often a great challenge. The Fraunhofer Institute for Medical Image Computing MEVIS has developed algorithms that analyze patients' imaging data and calculate surgical risks. This makes liver cancer surgery safer and easier to plan.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000, who work with an annual research budget totaling 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. 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.

Research awards in brief

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Stifterverband Science Prize

The Stifterverband is a consortium of approximately 3,000 companies, corporate associations, foundations and private individuals formed to jointly support progress in science and education. The Stifterverband uses subsidy programs, analyses and recommendations for action to ensure the proper infrastructure for innovation: high-performance universities, strong research institutes and productive exchange between business and science. The Stifterverband is a visionary body and an initiator of reforms - the model projects it supports drive changes in the system of innovation. The Stifterverband is a renowned voice in economics and in science and is an important partner to politics in matters concerning science and education.

For more than ten years, Stifterverband has supported the Fraunhofer-Gesellschaft through its Science Prize, endowed with prize money of 50,000 euros. This prize is awarded for scientific excellence in applied research projects conducted by Fraunhofer Institutes in collaboration with industry and/or other research organizations (topic 1).

Joseph von Fraunhofer Prize

Since 1978, the Fraunhofer-Gesellschaft has awarded prizes every year in recognition of outstanding scientific work by members of its staff that solve application-oriented problems. To date, over 300 researchers have seen their work honored in this way. This year, three of these prizes will be awarded, each worth 50,000 euros (topics 2 through 4).

The prizewinners also receive a silver lapel pin bearing the face of the man for whom the award was named, as illustrated in the logo of the topics.

Juries for the Stifterverband Science Prize and the Joseph von Fraunhofer Prize in 2018

Prof. Dr.-Ing. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft (chair)
Dr. Reinhold E. Achatz, ThyssenKrupp AG
Prof. Dr. Karsten Buse, Fraunhofer Institute for Physical Measurement Techniques IPM
Prof. Dr. Michael Dröscher, Gesellschaft Deutscher Naturforscher und Ärzte e.V.
Prof. Dr. Jörg Eberspächer, Technical University of Munich
Dr. Alexandra Goll, TVM Capital GmbH
Prof. Dr. Horst Hahn, Fraunhofer Institute for Medical Image Computing MEVIS
Prof. Dr. Jürgen Hesselbach, TU Braunschweig
Prof. Dr. Hartmut Hoffmann, Technical University of Munich
Dr. Monika Kursawe, Merck KGaA
Dr. Gyula Meleghy, Meleghy Automotive GmbH & Co. KG
Prof. Dr. Thorsten Posselt, Fraunhofer-Zentrum für internationales Management und Wissensökonomie IMW
Prof. Dr. Erich R. Reinhardt, Medical Valley Europäische Metropolregion Nürnberg e.V.
Prof. Dr. Paul Schönsleben, ETH Zürich

Free-form: quality leap in optical systems

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Light is a universally employed energy source. Technologies and solutions that work with light are present in almost all industries and markets. Even science and research are unthinkable without optical systems. Spherical or aspherical optics have been predominant for many decades. In the age of digitization, short product cycles and miniaturization, though, optics also demand new functions and features. A particularly promising technology consists of so-called free-form optics. The optionally shapeable surface profiles enable new functions with significantly improved image quality. Another advantage is the particularly compact design.

A research team at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena has made decisive progress in this regard. Together with industry partners and the University of Jena, the IOF experts have explored the potential of free-form optical systems, presented innovative solutions and developed the manufacturing methods. From the high precision grinding of the lenses as well as the coating and finishing of the complex surfaces to the polishing of the lenses, the researchers had to solve a number of technical challenges.

Demonstrators verify the potential of the new technology: for example, as infrared optics for rescue teams, as special optics for space telescopes or as a driver assistance system. In addition, the free-form optical systems make new application scenarios feasible, such as in earth observation and weather monitoring, in environmental technology, as well as in the automotive and public safety sectors. Project leader and IOF researcher Dr. Ramona Eberhardt mentions a current example – night vision technology in cars: "Conventional technology would require a large number of cameras to record all the angles. Free-form optics enable the construction of cameras that combine different focal lengths and functions in a compact housing." The free-form optics are also ideal for the micro and nano-satellites of the future. They enable a folded beam path with fewer lenses, therefore saving weight and space.

A holistic technology platform

Although the idea of free-form optics is not new, it has so far not been widely accepted, since there have not been any coherent process chains for the economic production. This was therefore a central concern of the Fraunhofer project. Under the leadership of Eberhardt and her team, a holistic technology platform has been created in which numerous industrial partners, including companies such as Jenoptik and Asphericon, contribute their expertise. The manifold capabilities of the group cover the entire process chain – from development and design to production and system integration. The initiative received 14.4 million euro from the German Federal Ministry of Education and Research (BMBF) as part of the "Innovative Regional Growth Core" program.

The collaboration of the IOF team with its industrial partners was crucial for the success of the project. "For a functioning free-form optic, all of the partners have to work together and contribute their different skills," says Eberhardt. In addition, the consortium actively contributed to the design of the corresponding DIN standard "General description of surfaces and free-form surfaces".

The subject of free-form is also good news for the traditional optical industry in Thuringia. The project funded by the BMBF contributes significantly to strengthening the industry in Thuringia and the Jena region.

The „Research in the Group" science award of the Stifterverband für die Deutsche Wissenschaft

For the advancement of the technology, Dr. rer. nat. Ramona Eberhardt of the Fraunhofer IOF has received the "Research in the Group" science award of the Stifterverband für die Deutsche Wissenschaft. Among other things, the jury praises the economic impact as well as the novelty of the scientific-methodological approach and the progress in knowledge.

Team around Dr. Ramona Eberhardt (third from left), who, together with industrial partners and the University of Jena, researched the potential of optical free-form systems, presented innovative solutions and further developed production methods.
© Fraunhofer / Walter Oppel

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XXL computed tomography: a new dimension in X-ray analysis

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Computed tomography with X-rays is nowadays playing an important role even outside of medicine. For example, for product development for industrial applications. However, computed tomography has so far been limited to smaller and simpler objects, especially in the field of high energy, due to unavailable suitable reconstruction and correction algorithms and sensors. The existing large CT systems are severely limited in their scope of functions for large objects.

Researchers from the Fraunhofer Institute for Integrated Circuits IIS have now made significant progress in this regard. Michael Salamon, Nils Reims and Dr. Michael Böhnel have developed a technology that also illuminates very large objects and generates high-resolution 3D images.

As an X-ray source, the researchers use a linear accelerator with nine mega-electron volts (MeV) and combine it with an X-ray camera that works with a sensitive length of four meters and 10,000 pixels. For the first time, objects with a diameter of 3.20 meters and a height of five meters can be recorded with three-dimensional X-rays – special technology in which a large object is recorded in parts also allows the scanning of even larger objects. This makes the system the currently largest CT system in the world.

The objects are rotated on a heavy duty turntable. The camera and the radiation source scan the object synchronously in vertical motion, line by line. Due to the rotation of the turntable, the camera records many viewing angles, thereby creating the basis for the three-dimensional representation.

Crash tests in X-ray images

With the XXL-CT, electric cars, for example, can be analyzed after a crash test. Previously, the objects had to be disassembled in a time-consuming process in order to analyze the structure and inner workings. Non-destructive X-ray inspection now makes it possible to perform a detailed analysis of the structure and materials of the object that were previously inaccessible, such as entire battery modules. The strong X-rays even make structures in densely packed batteries visible.

The quality of the 3D images has impressed even skeptics. Group Manager Salamon explains: "Previously, it was thought that high-energy structures would no longer be recognizable, since low-absorption materials tend to be overshadowed by high-absorption ones. The common opinion was that a lot of KV turns everything gray. With our development, we've proven the opposite."

In order to maintain the required quality of the 3D X-ray image, the researchers had to work on further innovations in addition to the linear accelerator and the large line X-ray camera. Together with their industrial partner MT Mechatronics, they have developed a design that enables extremely precise positioning even with objects weighing several tons. The processing of the X-ray data has also been optimized such that it can be automated with as little user interaction as possible, thereby enabling future use in the industrial environment.

Inspection of freight containers

Another application example is the inspection of sea freight containers. Many freight containers are already X-rayed in ports, but only in two dimensions. Thanks to 3D X-ray technology, even small objects inside the containers become clearly visible. Especially for security agencies which inspect freight containers for explosives or weapons, as well as for customs authorities that are looking for contraband, the IIS technology provides a decisive added value.

In addition to its use in industry, XXL computed tomography opens up many more applications. As a result, historical objects such as musical instruments for which cutting open and disassembling is out of the question can be X-rayed. In a particularly spectacular action, the Fraunhofer specialists scanned a 65-million-year-old dinosaur skull. The skull of the Tyrannosaurus Rex remained in a box during the X-ray procedure, together with the surrounding soil in which the paleontologists had found it.

The Fraunhofer research team is already planning the next step: in a gantry CT, linear accelerator and camera are to circle around the object. The object itself remains still and does not have to be positioned vertically. A prototype is currently being developed in cooperation with MT Mechatronics.

With the XXL computed tomography developed by Dr. Michael Böhnel, Nils Reims, Michael Salamon (from the left), it is now possible to analyze even very large objects with X-ray technology. © Kurt Fuchs / Fraunhofer

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Fraunhofer

Improved efficiency of aircraft engines

RESEARCH NEWS
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Combustion chambers of modern aircraft engines produce temperatures of over 2,000 Kelvin during combustion. This value is several hundred degrees above the melting temperatures of the materials used so that components must be cooled and provided with special thermal barrier coatings, both internally and externally. After landing, the engines cool down again quickly. The constant change of heating and cooling places enormous stress on the components in the engines. Therefore they have to be checked and serviced regularly.

After years of research, Professor Frank Brückner and Mirko Riede of the Fraunhofer Institute for Material and Beam Technology IWS have developed laser-fabricated microstructures that extend the life of the thermal barrier coatings and contribute to a significant reduction in kerosene consumption and pollutant emissions.The research project was performed in close cooperation with the renowned engine manufacturer Rolls-Royce.

At its core, the IWS technology bases on filigree, additively manufactured microstructures. These are used to build innovative Thermal Barrier Coatings (TBCs) on the turbine components and ensure that a metallic, oxidation-resistant adhesion promoter layer and a ceramic insulating layer are clamped together.

The Fraunhofer researchers have solved a further issue that occurs during the rapid expansion and contraction of the components. The expansion creates mechanical stresses in the insulation layer, which are caused by different expansion degrees of the materials. This can lead to horizontal cracks in the ceramic layer, which could subsequently flake off. The microstructures therefore specifically initiate vertical segmentation cracks in the ceramic layer. These reduce tensile stresses in the material and thus prevent the formation of the dreaded horizontal cracks.

Additive manufacturing technology using single-mode fiber laser

To generate filigree microstructures, the researchers had to further develop existing production techniques. A high-precision single-mode fiber laser generates microstructures down to the order of 30 microns. The columnar arrangement of the microstructures increases the expansion tolerance of the insulating layer.

The knowledge needed to design the structures for the TBCs and for the sophisticated manufacturing processes have not only been gained in practical experiments. “The simulations and the theoretical modeling with which we have worked in addition to the experiments also play a major role in the success,” explains Brückner.

Kerosene consumption drops by 10 percent

The many years of work on the joint research project has paid off. The new technology can further improve the efficiency of the jet engines, along with increasing the combustion temperature. The more efficient combustion results in decreasing fuel consumption by ten percent and reduces greenhouse gas emissions. In conjunction with other measures, there are significant cost savings per year and aircraft amounting to approximately USD 2.9 million.

The joint team of Fraunhofer researchers and engineers from Rolls-Royce has succeeded in transferring the research work into production-ready manufacturing that meets the stringent safety standards of the aviation industry. After first successful test flights of the engines with Fraunhofer IWS technology in November 2015, the official aviation approval of the European Aviation Safety Agency (EASA) was issued. Since February 2018, the engines have been used in long-haul aircraft for the Airbus A350-1000. The Trent XWB-97 is the exclusive propulsion of this aircraft model and the most efficient large-capacity engine in the world today. The Fraunhofer experts expect that other jet engines will also be equipped with the innovative IWS technologies in the future.

For their scientific achievements, Frank Brückner and Mirko Riede as well as Dr. Dan Roth-Fagaraseanu from the industrial partner Rolls-Royce received the 2018 Joseph von Fraunhofer Prize of the Year 2018.

Professor Frank Brückner and Mirko Riede (from the left) have developed microstructures that, among other things, extend the life of the thermal barrier coatings. © Fraunhofer / Juergen Loesel

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Fraunhofer

Algorithms for liver surgery – performing operations more safely worldwide

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Every year, 750,000 people worldwide develop liver cancer, and many more develop liver metastases caused by other cancers. Surgery still offers the best chance of recovery. However, even minor changes in the surgical resection can have a dramatic impact on the surgical outcome: One wrong cut can interfere with the inflow or outflow of blood in the liver and impair organ function. The complex, entangled vascular anatomy is difficult to reconstruct mentally based on CT or MRI images alone.

Researchers at the Fraunhofer Institute for Medical Image Computing MEVIS in Bremen have developed software that analyzes a patient's radiological images. It generates a detailed three-dimensional model of the liver and its vascular systems. Supply and drainage areas of the blood vessels are calculated and help determine the risks of possible tumors resection strategies.

Surgeons can use this information to prepare their surgery accurately by planning the optimal resection virtually. The analysis of vascular anatomy in the vicinity of the tumor also helps locate critical sections of the planned procedure. The surgeon receives a risk map of the resection path and knows where there is little room for deviations from the optimal cutting plane, such as where the planned resection corridor is particularly narrow.

The software generates suggestions for performing resections. "However, these are only proposals. Ultimately, the decision has to be made by the surgeon," says Dr. Andrea Schenk, Head of Liver Research at the Fraunhofer MEVIS. Studies have shown that liver surgery is more efficient and safer with the MEVIS analysis. In addition, blood loss can be reduced. In individual cases, the analysis algorithms allow safely performing even delicate operations which would have been considered too risky without the software.

Breakthrough innovation in living donor liver transplantation

In living donor liver transplantation, the organ is divided in the donor, and a part is transplanted into the recipient. After the surgery, the two parts in the recipient and donor have to work and grow again. The MEVIS analysis of the liver shows physicians the functional limitations that may result from the unavoidable transection of large vessels following the division, thereby enabling predictions of postoperative liver function in the donor and recipient. The surgical procedure can thus be optimized to minimize the risk of post-operative organ failure.

However, it is not only algorithms and computer science expertise that are decisive for the quality of the MEVIS analysis. Intensive exchange with surgeons and other clinical experts is also very important. “Only through this exchange did we learn what software featured are needed in practice and how we can improve our system,” explains Alexander Köhn.

The researchers from Bremen use hospital visits to investigate doctors’ practical problems . They are faced with the challenge of bringing the planning data from the MEVIS analysis to the operating theater. MEVIS expert Köhn has developed an iPad app in close collaboration with doctors from Yokohama University in Japan. The surgeon can wrap the tablet in a sterile sheet and take it into the operating room to view all planning data during the operation.

The app even goes one step further by combining the planning data with augmented reality. To do so, the doctor turns on the iPad camera and directs it at the patient’s liver. The three-dimensional image of the patient’s liver, previously generated using the algorithms, is superimposed onto the image of the camera and shows the position of the blood vessels and tumors beneath the liver surface.

2018 Joseph von Fraunhofer Award

Since 1998, the Fraunhofer researchers have been working on image-processing algorithms for use in medicine as part of a long series of projects. The method is now widely known by physicians as MEVIS analysis and has become established in practice. Together with her colleagues Zidowitz and Köhn, team leader Andrea Schenk has received the 2018 Joseph von Fraunhofer Award. In addition to scientific excellence, the award also acknowledges the practical effectiveness of surgical support, the many years of expertise on the part of the MEVIS team in liver surgery, as well as the character of the research project as a role model in society.

Dr. Stephan Zidowitz, Alexander Köhn and Dr. Andrea Schenk have developed algorithms that analyze patient image data and calculate surgical risks. Liver cancer surgery is thus easier to plan and safer. © Kay Michalak

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