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RESEARCH NEWS

10 | 2014 ||

1 Combatting periodontal pathogens

A total 12 million Germans suffer from periodontitis. If the inflammation remains untreated, this could lead to tooth loss. However, it is also suspected of triggering many other diseases, like cardiopulmonary diseases. Researchers are studying the interactions, and developing compounds to combat the causative agents.

2 Engineering new vehicle powertrains

Car engines – whether driven by gasoline, diesel, or electricity – waste an abundance of energy. Researchers are working on ways to stem this wastefulness. Ultramodern test facilities are helping them to optimize the entire development process of the engine. In the laboratory, they have already raised the degree of efficiency by up to ten percent.

3 Miniature camera may lead to fewer accidents

Measuring only a few cubic millimeters, a new type of camera module might soon be integrated into future driver assistance systems to help car drivers facing critical situations. The little gadget can be built into the vehicle without taking up space. The way it works is particularly reliable, thanks to its special encapsulation.

4 Analyzing gold and steel – rapidly and precisely

Optical emission spectrometers are widely used in the steel industry but the instruments currently employed are relatively large and bulky. A novel sensor makes it possible to significantly reduce their size and, moreover, enables a more precise analysis in half the time previously required.

5 Minimally invasive surgery with hydraulic assistance

Endoscopic surgery requires great manual dexterity on the part of the operating surgeon. Future endoscopic instruments equipped with a hydraulic control system will provide added support during minimally invasive procedures. Their outstanding sensitivity simplifies the biopsy procedure.

6 More efficient transformer materials

Almost every electronic device contains a transformer. An important material used in their construction is electrical steel. Researchers have found a way to improve the performance of electrical steel and manufacture it more efficiently, using an optimized laser process.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 67 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 23,000, who work with an annual research budget totaling 2 billion euros. About 70 percent of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the Americas and Asia serve to promote international cooperation.

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Combatting periodontal pathogens

If the gums bleed when brushing one's teeth or biting into an apple, this condition could be pointing to periodontitis – an inflammatory disease of the periodontal apparatus. Bacterial plaque attacks the bones; over time, the tooth could loosen. Leaving the disease untreated could lead to tooth loss. Periodontitis, also known as periodontal disease or "shrinking gums," is also a source of disease for the entire body: If the to some extent highly aggressive bacteria make their way into the blood circulation, they could cause additional damage. Medical studies highlight the interaction between periodontal disease triggers and various diseases like cardiopulmonary disease, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD). Evidence shows that the affected patient has an elevated risk of cardiovascular constriction, as well as Alzheimer's.

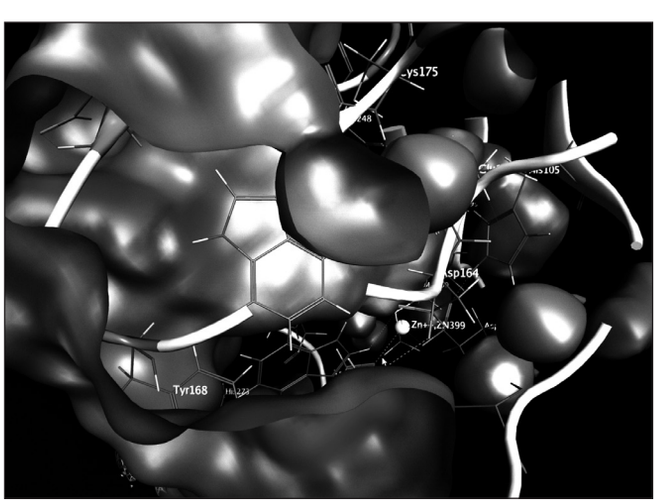
According to the World Health Organization, around 60 percent of all adults suffer from gum inflammation and are in need of treatment – which is a rather high figure. In the EU project known as "TRIGGER," eleven European research institutions from nine countries are dedicated to the study of the widespread disease. They investigate the influence of periodontitis pathogens on the aforementioned diseases. The goal is to explain and prove the connections between periodontitis and other inflammatory diseases, and that effective oral hygiene and treatment of the periodontal disease can improve the status of one's general health. One particular task of the joint project was taken over by the Department of Drug Design and Target Validation of the Fraunhofer Institute for Cell Therapy and Immunology IZI: the researchers for the satellite office of the IZI in Halle/Saale aim to develop substances that can be used to treat pathogenic oral germs effectively. To support their efforts, the Halle-based team is entitled to one-tenth of the total research grant of EUR 7.8 million. The Group's expertise lies in identifying pathological mechanisms at the protein level and optimizing substances based on these insights.

"We are searching for the active ingredients to battle the highly toxic bacteria known as Porphyromonas gingivalis. This aggressive lead pathogen resides in the gingival pockets of the gums. It is responsible for gingivitis – the gum disease of the mouth that can lead to the development of periodontitis," explains Dr. Hans-Ulrich Demuth, head and initiator of the project group in Halle. The expert in proteins headed up an "active ingredient research" work group for a long time at the Martin-Luther-Universität Halle, and later at the Leibnitz Institute for Natural Substances Research in Jena. During his tenure as managing director of Probiodrug AG, the biotechnology company, his team designed a treatment plan for age-related diabetes that is currently on the market today.

Porphyromonas gingivalis lives off of the breakdown of collagen in the oral cavity. The bacteria destroys the gum's connective tissue by activating a protein-degrading enzyme

– and specifically before it is released into the oral cavity. In order to trigger this mechanism, Porphyromonas gingivalis uses a special enzyme: the bacterial glutaminyl-cyclase, which is involved with protein maturation. The Halle-based researchers characterized this enzyme years ago in mammals, and discovered new traits. "It plays an essential role in the immune-overreaction to disease patterns, and is involved in inflammatory diseases, such as rheumatoid arthritis, COPD, and Alzheimer's disease, for instance. There is obviously a fundamental connection between certain bacterial infections and various inflammatory diseases that has yet to be explained. We presume that human glutaminyl-cyclase, for instance, forms a variant of the amyloid-beta peptide in Alzheimer's patients that is especially deleterious to nerve cells. A treatment principle based on this to combat Alzheimer's meanwhile is in clinical trials. With gingivitis, the blocking of the bacterial key enzyme could cause starvation of the Porphyromonas gingivalis pathogen," explains Professor Demuth. The biochemist and his team are therefore searching for an inhibitor substance that minimizes the enzyme's action.

The Halle-based group has already seen initial successes. From a package of 20 substances, they could filter out a few highly effective substances, which have inhibited growth of the germ Porphyromonas gingivalis in the cell culture model by 95 percent. Animal-based experiments commence next. Yet before a compound against periodontal disease hits the markets, a series of measures must transpire first. The first manner of business is optimizing the substances before they can be put to clinical trials, in which form and quantity the active ingredient can be administered. "This is a protracted process. But in order to combat periodontitis, an adequately good oral hygiene by itself is not enough. Here, one additionally must resort to medicinal interventions and thus also prevent Porphyromonas gingivalis from triggering other inflammatory diseases," Demuth states.



Sideways view of the active center of a bacterial glutaminyl-cyclase. (© Fraunhofer IZI) | Picture in color and printing quality: www.fraunhofer.de/press

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Engineering new vehicle powertrains

Trucks, cars and motorcycles are energy-guzzlers: over 60 percent of the energy generated in their engines by fuel is lost through the exhaust gas and the coolant. The biggest part of this simply slips off into the environment as heat. Beneath our engine hoods, gasoline, diesel and electricity are wasted and unnecessarily pumped into the air through the exhaust system as CO_2," says Dr. Hans-Peter Kollmeier, from the Fraunhofer Institute for Chemical Technology ICT in Karlsruhe. The "new drive systems" project group is probing the causes for this kind of waste. Together with other researchers, it is developing efficient drive concepts for vehicles. In the laboratory, they have already succeeded in increasing the degree of efficiency of car engines by five percent, and up to ten percent for commercial vehicle powertrains.

The scientists have new test facilities available since this summer. "At the Karlsruhe location, we were able to map the entire process of powertrain development: from design to simulation and to testing," says Kollmeier. The researcher's goal is to optimize the technologies of the drivetrain being utilized, so that the fuel savings is optimal. For this purpose, you must know how the individual components interact with each other in reality. "With the new testing options, we have come one huge step closer to this goal. Through this effort, we have the opportunity to test the drivetrain as a whole, and validate our simulations," says Kollmeier.

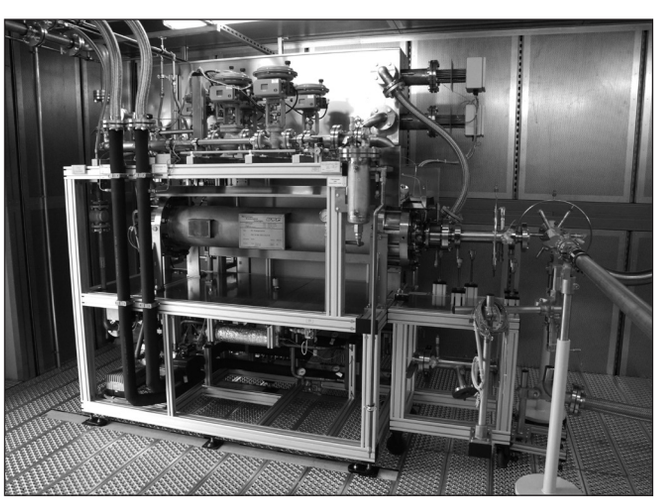
The linchpin of this new test infrastructure is an engine and hot gas test stand. There, researchers can analyze engines and their components both mechanically and thermodynamically. A computer controls the systems and simulates realistic application scenarios. For example, the computer can additionally switch on virtual hybrid drives (like electric motors) or systems that use waste heat. The scientists analyze how the vehicle drive acts with regard to fuel consumption and CO_2 emissions. For this purpose, Kollmeier's team simulated vehicle in terms of type, route, or driver methods accordingly. Once sufficient data are gathered, the researchers build prototypes and then gradually substitute the simulation models through real components in the test facility. Step by step, they are thus arriving at the optimal powertrain. In the process, lightweight materials become increasingly important.

If it is about making car engines more efficient, then the term "downsizing" comes into play. Generally speaking, it is minimizing the displacement of the engine, without reducing its performance capacity. Through the diminished friction resistance and the improved thermodynamic process, we can reduce fuel consumption and CO_2 emissions. As a rule, turbo-chargers are used in downsizing concepts, which are integrated into the suction and exhaust tract. These screw-shaped components – about 15 centimeters in cars – suck up air and push it into the internal combustion engine. Thus, more fresh air is conducted to the engine, which allows for a greater quantity of fuel to be consumed. Due to the higher cylinder pressure that this reaches, higher engine power is

also achieved for the same engine displacement. The turbocharger is driven by the exhaust gas of the vehicle. At the hot gas test facility, the scientists are testing their turbo-chargers. At this facility, a certain exhaust gas mass power is generated by a natural gas burner which corresponds to that of an internal combustion engine. The burner can be set very precisely, in order to analyze how the most miniscule changes to peripheral conditions affect the turbo chargers.

"The turbo charger is the classic approach to improving the degree of efficiency of an engine. You use a portion of the energy that is deflagrated through the exhaust. But it is also subject to limits. Steam power cycles can be helpful here for example," says Kollmeier's colleague Dr. Sascha Merkel. In doing so, a fluid working medium (e.g., water or ethanol) is heated by the waste heat. It evaporates and drives small turbines that will, in turn, generate mechanical energy. The gain can then be transferred directly to the crankshaft or converted by a generator into electrical energy, in order to supply them into the new power circuit, e.g. in the vehicle's electrical system. At the hot gas test facility, scientists are studying how individual components of a mini-power plant behave under various framework conditions.

The scientists are closely networked with other powertrain experts from research institutions and the development departments of automakers. "Of course, contact with the automotive industry in particular is immense. This development of the powertrain concepts runs in close coordination with carmakers. The direct application of the research findings in the practice is at the forefront," explains Kollmeier.



Researchers at a new hot gas test facility are testing the waste heat use systems and turbo-chargers. Their goal is to develop more efficient powertrain concepts for passenger vehicles and trucks. (© Fraunhofer ICT) | Picture in color and printing quality: www.fraunhofer.de/press

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Miniature camera may lead to fewer accidents

All too often, a driver has only fractions of a second to decide when facing a potential car accident: A brief moment of distraction, overtiredness or inattention – there are several reasons why the number of accidents in Germany is high, on the autobahns most of all. According to data from the Federal Statistical Office, the number of deadly casualties on German autobahns in 2013 rose by more than eight percent when compared to the prior year. Driver assistance systems could help prevent these unfortunate incidents - or at least help reduce them. Microcameras are indispensable helpers: They register potential risks even when the driver has not yet even noticed them - and could warn him or her just in time.

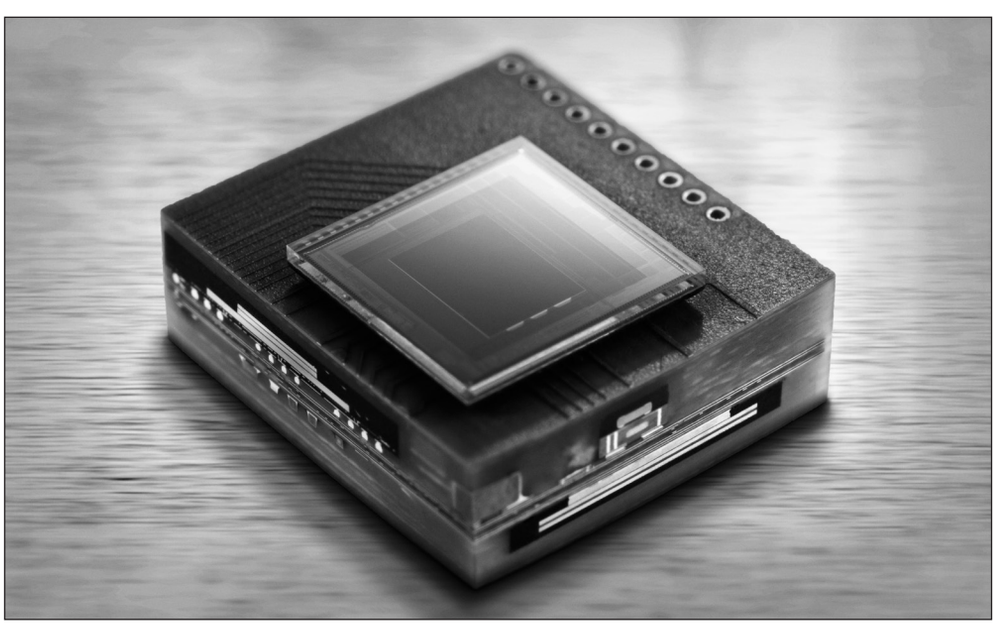
Researchers at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin developed a microcamera module that aims to achieve this. The camera detects, for instance, traffic signs that could easily be overlooked on the autobahn, and thus could lead to serious or fatal accidents. One particular feature of the system: in contrast to the conventional driver assistance systems on the market, the image material is processed – and thus, the traffic signage interpreted – directly inside the camera, since it is equipped with an integrated processor for image processing. After the integrated image sensor has recorded the images, the processor evaluates the frames. "The video itself no longer has to – as previously the case – be sorted and analyzed by an interposing system. Instead, only the relevant signals are transmitted," says Andreas Ostmann, a graduate of physics and the group manager at IZM. The advantage for traffic signal detection: The data volumes to be transmitted and processed turn out to be much less – by many times over. Since the detection of all signals can be adapted to all traffic signs that are typical of the country, there are no kinds of restrictions with regard to their areas of use: the microcamera detects stop signs just like speed limits, no-passing zones or one-way street signs. For example: through a signal in the dashboard, they could advise the driver and thus improve both driving comfort and safety.

At a size of only 16x16x12 cubic millimeters, including optics and 16x16x4.6 cubic millimeters without the optics, the microcamera module is smaller than the driver assistance cameras currently installed with edge lengths of 20x20x20 cubic millimeters (without optics). This miniaturization was made possible by the expertise of the IZM researchers in the assembly and interconnection technology department. A total of 72 passive and 13 active components (such as LEDs, DC-to-DC converters, memory chip, image sensor and image processor) had to be positioned within the module in an especially space-saving manner. The research team succeeded with this: in just one attempt, the volume of the camera was reduced to 3 cubic centimeters with the optics, and 1.2 cubic centimeters without the optics.

Another advantage of the newly developed module: all components are integrated directly into the PC board from glass fiber and epoxy resin. Experts called this assembly

technology "embedding." By encapsulating the electronic components, the microcamera is now impervious to vibrations on uneven street surfaces.

"Our system can not only be used to detect traffic signs. If one programs the software accordingly, it is also possible to detect road markings. In this case, the camera is combined with a lane departure assistant. Since it also controls motion detection and detects objects such as animals, people, and their position, it can be readily coupled with a brake assistant or pedestrian safety system," Ostmann explains. Another scenario: mounted on the dashboard, the miniature system could monitor the cabin of vehicles and send an alarm for microsleep. If the camera detects that the driver's eyes are closed for somewhat longer than a second, an alarm is triggered. Other potential applications for the miniature camera could be anti-theft protection and quality control. For this purpose, only the image processing algorithms would have to be adjusted accordingly.



Cross-section of the microcamera module, with the image sensor mounted on the Printed Circuit board. (© Fraunhofer IZM) | Picture in color and printing quality: www.fraunhofer.de/press

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Analyzing gold and steel – rapidly and precisely

Gold is expensive, so it is only natural that jewelry buyers should want assurance that the precious ring or necklace they have set their heart on is really made of genuine gold. Jewelers in India are required by law to test the purity of gold using an optical emission spectrometer that analyzes the composition of the metal on the basis of the emitted light spectrum. But goldsmiths are not the only users of these instruments; the tools are more frequently found in steel foundries and car factories where they help engineers to determine the characteristics of steel materials, analyze their chemical composition, and assess their quality. Until now, this involved using very bulky equipment, at least in applications requiring a high resolution.

Researchers at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have developed a sensor that shrinks the size of the spectrometer optics. "Whereas earlier high-resolution spectrometers were the size of a washing machine, those built using our sensor will be no bigger than a microwave oven," says IMS department head Werner Brockherde. And this is not the only advantage of the new sensor: the delivered results are also more precise and available in half the time. This can be beneficial, for example, when performing quality assurance in the automotive industry.

The first sensor that combines time- and space-resolved measurements

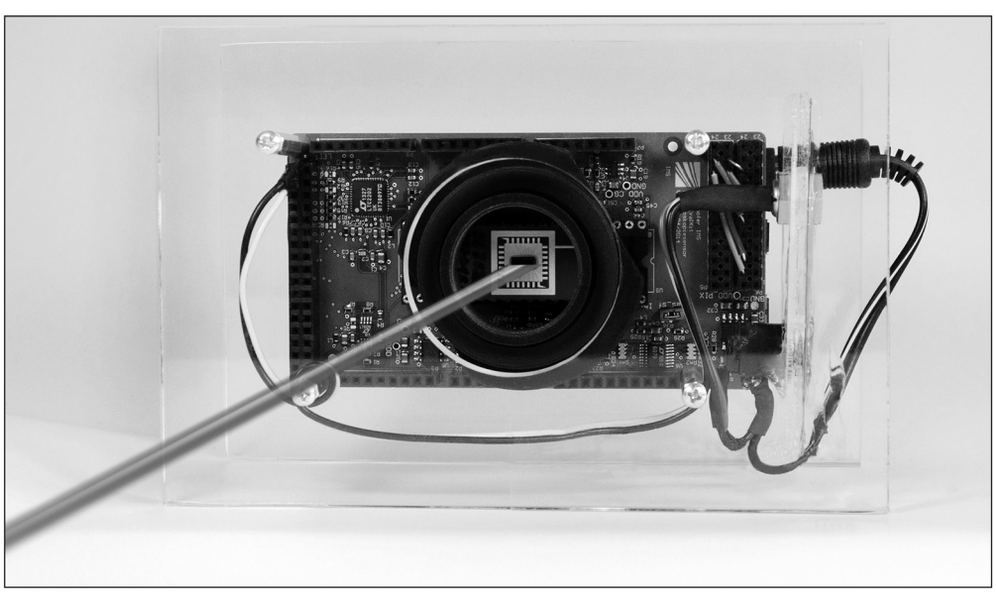
To understand how the scientists were able to miniaturize the instrument to this extent, we need to take a closer look at its inner workings. In order to analyze a piece of steel, for example, it has to generate sparks at regular intervals. These sparks knock atoms out of the material, resulting in a plasma that emits multicolored light. The plasma light is split into two beam channels and broken down into several wavebands, like the colors of a rainbow, which are then analyzed separately. In the first beam channel, light-sensitive electronic components known as CCD line sensors record the entire spectrum of the sample. This reveals the nature and concentration of particles suspended in the plasma, from which it is possible to derive information on the composition of the steel sample. Experts refer to this result as a space-resolved measurement. The second beam channel produces time-resolved measurements of individual spectral lines – adjusted so that the instrument can distinguish between light emitted by the plasma and that emitted by the sparks. All previous solutions were based on separate time-resolved and space-resolved measurements. "Our CMOS-based sensor enables these two sets of measurements to be conducted in parallel. As a result, we only require a single beam channel and thus a single optical unit," says Brockherde.

The new photo-detector multiplies the dynamic range by 100, resulting in a much faster spectrometer. It is capable of measuring signals in the microvolt range at the same time as signals measuring some 100 millivolts. Until now, this required several

measurement cycles. As well as increasing measurement speed, the high dynamic range also offers other advantages. "Because we can now measure the entire spectrum with a single series of pulses, the measurement accuracy is also higher," reports Brockherde.

Demonstrator at the Vision trade show

A demonstration version of the sensor will be presented at the Vision trade show in Stuttgart from November 4 to 6 (Booth 1H74). An evaluation kit for interested design engineers is also available. "The market for spectroscopy equipment is dominated by German manufacturers," says the scientist. "Our new sensor, which was developed in Germany and is not available anywhere else, will enable these manufacturers to secure a further competitive advantage."



Emission spectrometers analyze materials on the basis of their emitted light spectrum. Novel sensors permit the development of even smaller, faster and more precise test instruments. (© Fraunhofer IMS) | Picture in color and printing quality: www.fraunhofer.de/press

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Minimally invasive surgery with hydraulic assistance

Minimally invasive techniques, also known as "keyhole surgery," enable surgeons to operate on patients without requiring major incisions. This method causes much less trauma for the patient, and is commonly used when performing lung, esophageal and joint biopsies, and most especially when operating inside the abdominal cavity. An endoscope is inserted through one or two small incisions in the abdominal wall, allowing the internal organs to be visualized for surgery.

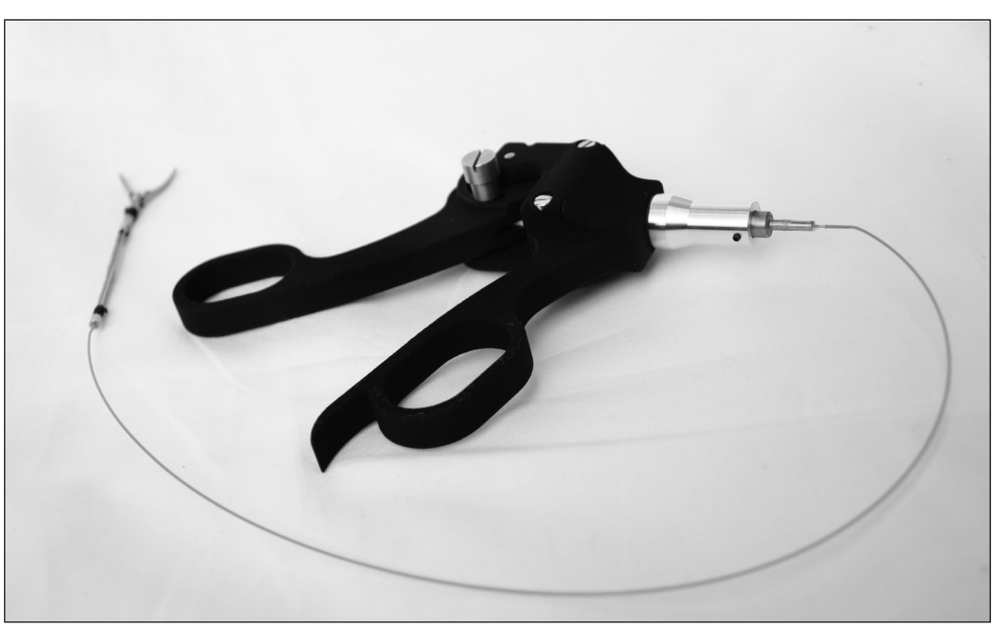
Surgical techniques have advanced by leaps and bounds in recent years. The same cannot be said for surgical instruments. In certain types of endoscope, the tip can be oriented at different angles. "This basic control mechanism, which demands great dexterity and even physical strength on the part of the surgeon, has barely changed since the earliest days of endoscopy," says Timo Cuntz, a member of the Project Group for Automation in Medicine and Biotechnology PAMB in Mannheim, a part of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The force required to deflect the tip is transmitted by a wire mechanism known as a Bowden cable (similar to a bicycle brake cable). Modern endoscopes are additionally equipped with tiny pincers, clamps or scissors for removing tissue samples, for example. These miniature instruments are controlled mechanically, too. The cable mechanism transmits the surgeon's hand movements at one end to the tiny instruments at the other extremity of the endoscope.

Using hydraulic fluid instead of wires

Cuntz adds: "The movement of the wires inside the Bowden cable generates friction and hence a loss of force. Only a small proportion of the force applied actually reaches the tip of the instrument, making it difficult for the surgeon to manipulate the tissue precisely." The surgeon's work would be made much easier if it were possible to reduce the friction and increase the power density. Hydraulic instruments are one of the alternatives being considered as a substitute for mechanical transmission based on Bowden cable. "Instruments with hydraulic force transmission have demonstrated promising results in our tests. They allow the surgeon to carry out much finer movements," says the engineer. A plastic tube filled with a sterile, biocompatible fluid based on medicinal white oil is used in place of the wire cable. To control the attached instruments and orient the tip of the endoscope, the surgeon manipulates a hydraulic cylinder or robotic muscle that exerts the required pressure to compress the fluid and push it through the hydraulic tube onto a second, spring-mounted cylinder. The advantage of this system is its lower frictional loss and higher gripping force – up to 50 newtons have been achieved in the laboratory. The system, which the researcher likes to compare with the hydraulic brakes on a mountain bike, also offers the option of connecting a pump to generate the pressure needed to dissect or remove precise areas of tissue.

The particular strength of hydraulically actuated instruments is the efficiency with which power is transmitted to the distal tip, especially in the case of meandering rather than straight insertion paths – for instance through the digestive tract. This also allows the use of more flexible feed lines, with very small diameters and a low bending radius. Cuntz and his fellow researchers at PAMB are currently building an endoscopic instrument with an outer diameter of no more than three millimeters. Such hydraulically actuated instruments are ideally suited for use in connection with a technique known as natural orifice transluminal endoscopic surgery (NOTES), in which the surgeon operates through natural body orifices in order to access internal organs; going through the stomach, for instance, when performing an appendectomy.

The reliability of the novel power transmission concept has been demonstrated in endurance tests, using both rigid endoscope tips and simple gripping tools. Laboratory prototypes with flexible tips have also been tested. Timo Cuntz and other members of the Mannheim project group will be present at the combined Compamed (Hall 08a, Booth K38) and Medica (Hall 10, Booth G05) trade shows in Düsseldorf from November 12 to 15. Exhibits include several hydraulic technology demonstrators, including an endoscopic instrument equipped with a gripper that can be oriented in any direction. The necessary force transmission is provided by six integrated hydraulic cylinders.



Hydraulic instruments support surgeons when working with endoscopes. The gripping force at their tip is greater. Medicines are able to operate more precisely. (© Fraunhofer IPA) | Picture in color and printing quality: www.fraunhofer.de/press

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More efficient transformer materials

Transformers convert the standard voltage from the wall outlet into the lower voltages required by electronic devices. Similar but more powerful transformers are used in electricity substations to convert the high voltages of the transmission grid into the standard AC power supply delivered to households. All transformers have the same basic structure: a pair of iron cores, around which wires of different lengths are wrapped. These are the transformer coils, one of which generates an oscillating magnetic field, while the other converts this magnetic field into a voltage. To minimize the energy loss associated with this process, special types of iron-silicon alloy known as electrical steel are used to make the core. In their native state, these alloys have a grainoriented structure which determines their magnetic properties.

Grain-oriented means that the material has a crystalline structure in which each crystal or grain is arranged in a regular periodic order. "By heating selected areas of the material, it is possible to reduce the size of the domains with the same magnetic orientation, which in turn alters the magnetic structure of the steel. This results in a lower heat development and thus reduces the material's hysteresis loss," says Dr. Andreas Wetzig, who heads the laser ablation and cutting department at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden, describing the complex changes that take place inside the material. Laser processing has long become established as the preferred method for this type of heat treatment. While the steel sheet, measuring around one meter in width, moves forward at a rate of more than 100 meters per minute, a focused laser beam travels at very high speed (approximately 200 meters per second) from side to side across the surface of the material along paths spaced a few millimeters apart.

Flexible control of the laser beam

The Dresden-based research team has optimized this process: "We have developed a means of deflecting the laser beam that allows the distance between the paths to be controlled flexibly and adapted to different parameters," reports Wetzig. To do so, the researchers make use of galvanometer scanners. These devices consist of galvanometer driven mirrors attached to one end, which is used to deflect the laser beam. This increases the flexibility of the machining process and allows it to be adapted to specific conditions, such as the quality of the raw material, and to different production rates. The main aim of this research is to facilitate the integration of laser processing in existing production environments, in order to save time and costs.

In a further effort to reduce hysteresis loss in electrical steel, the researchers have recently started working with a new type of solid-state laser: the fiber laser. "The results we have obtained so far are very promising. This type of laser offers better heat absorption characteristics than traditional CO2 lasers," says Wetzig. It cuts hysteresis

loss by up to 15 percent, compared with the 10 percent normally achieved until now. The optimized process is currently being implemented by the first commercial customer.

Possible energy savings of up to 25 percent

The IWS experts are currently working on the next important stage: that of expanding the applications of their technology to electrical steel for engine components. However, unlike transformer steel, these materials do not have a grain-oriented structure and therefore possess different magnetic properties. "This means that we cannot transfer our process one-to-one without modification," explains Wetzig. The benefits of laser processing in the case of non-grain-oriented electrical steel vary according to the working point of the specific engine or motor. The working point is the point of intersection between the torque curve and rotational speed curve of the drive system and the driven machine. In high-performance machines such as vehicle engines, which are designed to run at high rotational speeds, energy loss can be reduced by a few percentage points. In high-torque electric motors such as those used to operate pumps, the reduction in energy loss can be as high as twentyfive percent.

A scientist removing samples of electrical steel from the test facility at Fraunhofer IWS; this type of material is one of the main components of transformers. (© Fraunhofer IWS) | Picture in color and printing quality: www.fraunhofer.de/press

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