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# RESEARCH NEWS

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## 1 To understand every word

Hearing-impaired people face a challenge at the theater or cinema. Fraunhofer technology promises a remedy integrated into two apps made by Sennheiser Streaming Technologies GmbH. They allow the hearing impaired to adjust the sound to match their individual needs – allowing them to follow the story through their headphones.

## 2 Fast charging electric bus does overtime

Electric buses are an eco-friendly alternative to diesel. With several project partners, Fraunhofer researchers have developed a concept to swiftly recharge buses while they operate routes. System testing in Dresden has been underway since November last year.

## 3 Banknote check with ultra-fast line scan sensor

Speed and accurate image reproduction are the alpha and omega of quality inspection in security printing. Conventional image sensors are limited in this regard. Fraunhofer researchers have developed an ultrafast line scan sensor that delivers high-quality images and identifies banknotes with faulty safety features.

## 4 Small and discreet data glasses for everyday use

Data glasses tend to be chunky, unstylish objects, so it's no wonder they haven't caught on among general consumers. Fraunhofer researchers have now developed a technology that allows the "specs" to be made in small, unobtrusive designs. The new glasses also correct for farsightedness.

## 5 Precisely simulating the production of ceramic tape

Manufacturers of ceramic tape currently have to rely on their own experience when it comes to configuring the tape properties. But now a new combination of macroscopic and microscopic simulation is facilitating this process by predicting how the slurry will flow through the machine and determining the alignment of the ceramic particles.

## 6 Mini laser for real-time quality control

Good quality and precision are essential – a dictum that also applies to products from the pharmaceutical and chemical industry. While the quality of chemical products is often still being monitored manually during the production process, a laser-based system could take over this task in future, allowing for a continuous monitoring in real time.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 66 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 24,000, 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.

**Editorial Notes:**

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# To understand every word

An insanely comical play is on stage, and the audience is roaring with laughter. Yet all too often, guests with limited hearing abilities feel left out – they miss out on just too many details. For this reason, countless hearing impaired prefer the reassuring comforts of the living room chair instead of going to the theater or cinema. The number of affected people is vast: Acccording to recent studies, one out of every six people in Germany is hard-of-hearing, and eligible for hearing aids, and could get them financed through Germany's health insurance fund. As a matter of fact, however, not even 25 percent of eligible patients take advantage of this option. Because, unlike eyeglasses, many people still see a stigma tied to hearing aids.

## Optimizing sound individually

The "Cinema Connect" and "MobileConnect" apps from Sennheiser Streaming Technologies GmbH aim to ensure that soon, the hearing-impaired audience members at a play or a movie are once again able to perceive and understand every single word, even if they are wearing no hearing aid. This assisted hearing technology is the brainchild of the researchers at the Oldenburg-based Project Group Hearing, Speech and Audio Technology of the Fraunhofer Institute for Digital Media Technolgy IDMT.

The basic principle of the Sennheiser technology is for a streaming server to transmit audio signal from the stage or screen directly to the viewer's smartphone. The phone reproduces the data directly, via the headphones as they are being loaded through the secured network. Alternatively, if the viewer wears a hearing aid adapted to his or her smartphone, the app is also able to send the sound signal to the hearing aid directly via Bluetooth instead. "Our technology, which is integrated into the apps, does not just enhance the sound volume, rather it lets the theater attendee individually adjust the sound," affirms Dr. Jan Rennies, Head of group at IDMT. Because the range of optimal sound adjustments is narrow: loud noises swiftly appear to be too loud, and therefore have to be reduced. By contrast, soft speech components require substantially greater amplification. And depending on the type of hearing loss, the affected individual is unable to perceive each frequency with equal intensity: many people can still detect lower sounds quite well, but when sound reaches a higher pitch, it gets difficult.

When engineering the individually adaptable hearing support, the challenge was primarily in designing intuitive functionality. Ideally, each person should be able to improve the sound at any time autonomously – without having to consult an acoustics expert, as is the case with hearing aids. That is precisely what these apps accomplish: by driving with a finger across the touchscreen of his or her smartphone, the user "guides" a small dot across the screen. Volume rises or falls by drawing the dot upward or downward. Shifting the tone horizontally makes the sound softer to deeper.

**Integrated into current Sennheiser apps**

The integration of the "Personal Hearing" function into two apps offered by Sennheiser is scheduled to arrive this summer, and at no charge. Users can go to the "Culture Inclusive" culture portal (www.culture-inclusive.com) to find out which cinemas and theaters offer the technology.

Fraunhofer's assisted hearing function is also being used in other applications; IDMT scientists are currently developing another app that turns an iPhone into a microphone, and features customized amplification. At the beginning of this year, Sennheiser electronic GmbH & Co. KG unveiled its cordless headphones, featuring customized sound adjustment from Fraunhofer. Another area of research and application is hearing assisted telephony. "Our user studies indicated that the technology for the hearing-impaired is immensely helpful in various applications scenarios, such as headphones or telephones, and frequently those with normal hearing also consider it beneficial," says Dr. Jens Appell, division head of the Hearing, Speech, and Audio Technology project group. "So far, the majority of test subjects are enthusiastic – whether they had a hearing aid or not."

**Now people with hearing loss can adjust the sound with a smartphone app to match their individual hearing ability. (© Sennheiser Streaming Technologies GmbH) | Picture in color and printing quality: www.fraunhofer.de/press**

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# Fast charging electric bus does overtime

Electric vehicles are supposed to make urban transport more environmentally friendly in the future. Using buses for short-range public transportation is a good way of helping to implement this vision: fixed routes and stops make it easier to plan and provide the requisite infrastructure. In addition, public transport sets an example to the wider public. "However, electric buses will only gain acceptance if they adapt to established operational practices and do not create a need for additional vehicles or personnel," says Dr. Thoralf Knote from the Fraunhofer Institute for Transportation and Infrastructure Systems IVI. This poses some challenges: regular urban public transport buses travel up to 400 kilometers a day without returning to the depot. To supply the electric energy this requires, huge batteries would be needed, for which there is not enough space available in a bus. The alternative is to quickly recharge the vehicle's battery while it is serving its route – for example, while the bus is waiting at the terminus. This requires high charging capacity.

## Contact system for recharging fitted to roof of bus

Working with several partners in the EDDA Bus project, Fraunhofer scientists have developed a solution that permits fast, uncomplicated recharging. EDDA Bus is part of the Fast Charging Systems for Electric Buses in Public Transport joint research project funded by the German Federal Ministry of Education and Research (BMBF). The solution is based on four core technologies: the Dresden-based company M&P GmbH designed a charging station with very high charging capacities; HOPPECKE Advanced Battery Technology GmbH supplied special batteries designed for such high power capacities; Vossloh Kiepe GmbH was responsible for adapting the power electronics; and finally, the heart of the development work is the contact system located on the roof of the bus, which was realized by Fraunhofer IVI together with Schunk Bahn- und Industrietechnik GmbH.

For the contact head, six powerful contacts were housed in a small installation space. There are two contact poles – one positive, one negative – on each side. Fitted to the top, there is an earth contact and a control pilot, which monitors the earthing. "This means our system meets the most stringent safety requirements," explains Knote. Schunk Bahn- und Industrietechnik GmbH developed heat-stable components for the contact system. This was necessary because, in contrast to streetcars for instance, where energy is transferred while the vehicle is moving, transferring power to a stationary vehicle generates high local temperatures that would damage conventional components.

The charging process is very straightforward: "We don't want to burden drivers with extra tasks," emphasizes Knote. All drivers have to do is position the bus beneath the contact hood at the charging station. While doing so, they can use a marker at the

edge of the curbstone for orientation. An acoustic signal assists drivers when positioning the bus at the stop. To ensure some leeway, the contact head adjusts itself on a slide rail and then docks with the contact hood. The charging process begins automatically. During charging, drivers can follow the battery's charge status on a display. If required, the charging process can also be interrupted.

EDDA Bus passed its first practice assignments in regular service in Dresden with flying colors. Following the test phase, the vehicle served a more challenging route of around 20 kilometers in length and containing several hills. "Once again in this second phase, the results have exceeded our expectations," says a delighted Knote. The average energy consumption is 1.19 kWh per kilometer – it should be noted here, however, that the bus is not heated electrically, but using engine-independent diesel heating. Recharging takes less than 6.5 minutes.


**Since February of this year, EDDA Bus serves a new 20-kilometer route. (© Fraunhofer IVI) | Picture in color and printing quality: www.fraunhofer.de/press**

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# Banknote check with ultra-fast line scan sensor



In the first half 2014 alone, nearly 25,000 counterfeit euro notes worth EUR 1.5 million were registered, according to information by the Deutsche Bundesbank. In order to make the criminal work of counterfeiters more difficult, banknotes are equipped with special security features. These include tiny structures that are not visible to the naked eye, such as holograms with a tilt effect. This results in the subject changing when it is looked at from different perspectives. Through the use of special cameras, quality checks during printing are intended to ensure that these features are free of errors on each banknote.

The AIT Austrian Institute of Technology is a leader in the international market in the production of such test systems for security printing. For the development of a new sensor, the Austrian research institution has brought the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg on board. This is because the sensors which are currently available have meanwhile reached their limits: their speed is often not enough to check quality in real-time during the production process.

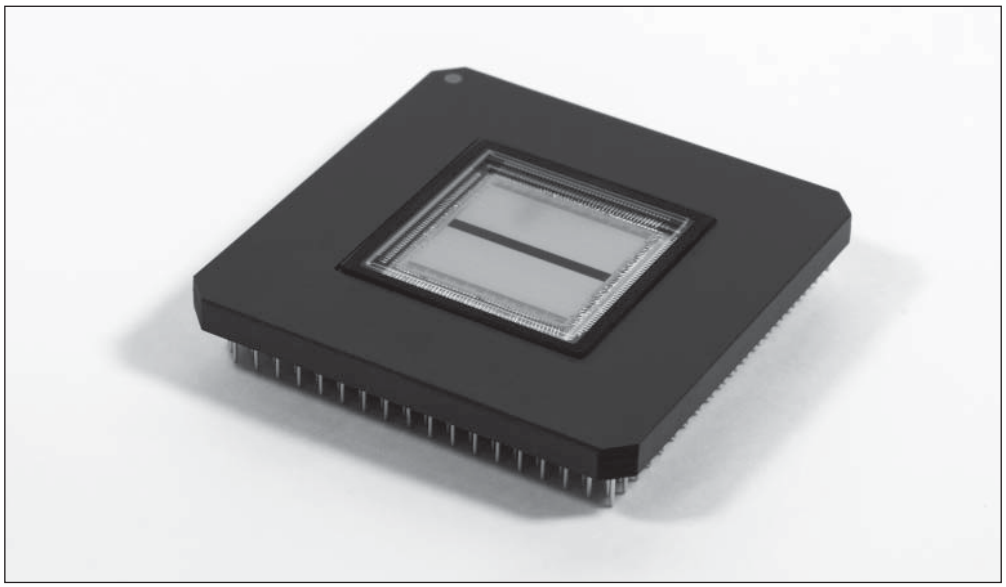
**Camera takes 200,000 color images per second**

With the 60-line sensor that the Duisburg experts have developed, these drawbacks are now a thing of the past: "Our sensor is twice as fast as currently available solutions, while providing high-quality images in very high resolution," explains Werner Brockherde from the IMS. The sensor detects the bills – like a scanner does – line by line when they come off the press. The camera takes up to 200,000 color images per second, with exposures of millionths of a second. Software compares the recorded images to a desired image and identifies banknotes with faulty safety features. In order to achieve the high speed, the IMS researchers have integrated an individual readout chain on the chip for each pixel column. In addition, they have developed special photo pixels, thanks to which conventional optics can be used, despite the short exposure times. In each pixel column, the three colors red, green and blue are recorded at the same time and over the entire pixel area. This allows high-quality color reproduction. Another special feature of the sensor is that the high number of lines makes it possible to detect objects from different perspectives. "As a result, surface structures in 3D, such as the tilt effects of holograms, can also be checked for the first time," says Brockherde.

The special architecture of the sensor opens up room for further applications. Thanks to the large number of lines, its wavelength spectrum can still be expanded – up to the UV or infrared light range. That would be interesting for the recycling of plastics, as well, where the sensor could identify shredded materials according to their color information, thereby facilitating separation. With the ability to analyze 3D surfaces, it is also suitable for the quality control of different materials in industrial production.

Another field of application is the study of the rails or contact wires of trains: Even at a speed of around 300 km/h, the sensor could provide razor-sharp images with a resolution of up to 0.4 mm and, thus, detect the tiniest hairline cracks. Near-Earth satellites, which are equipped with such a sensor and which orbit the Earth at a speed of 26,000 kilometers per hour, could take color photographs of the earth's surface with a resolution of 3 centimeters.

The market launch of the new sensor which is at the heart of the AIT test camera is scheduled for the end of 2015.



**This 60-line sensor is twice as fast as previous systems. (© Fraunhofer IMS) | Picture in color and printing quality: www.fraunhofer.de/press**

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# Small and discreet data glasses for everyday use



Picturesque streets and winding lanes of one village enthrall tourists. They would love to have a little historical background on the buildings they are watching at. But unless they get out a guidebook and read up on them there, they remain in the dark. In future, tourists will be able to see all important information instantly as it flashes up on their data glasses. As they admire a building, they will also see useful facts displayed alongside it – similar to the speech bubbles used in comic books. And if they were trying to find their way around in unfamiliar surroundings, these glasses will be able to display navigation data taken from their smartphone directly in their field of view. This is known as "see-through data glasses."

**Small and elegant**

Moreover, the data glasses developed by researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena fulfill even more product functionality. In fact, it solves a problem that has plagued the manufacturers of such eyewear in the past: cumbersome frames. The awkward design means that few private users have been keen to wear them. "We designed our glasses to be small and discreet," says Dr. Peter Schreiber, group manager in the Microoptical Systems department at Fraunhofer IOF.

Models usual consist of two parts: a micro-display that generates the image and optics that project the image on the desired position. Both units are attached to the temple (earpiece). Although the micro-display of the new glasses measures 8 x 15 millimeters, making it a similar size to conventional models, the optics are only 5 millimeters long, almost one-fifth the length of previous designs. Instead of having single long optics, the scientists have placed many small optics alongside each other in an array. "This allows us to obtain the same results with a much shorter structure," explains Schreiber.

While commercially available data glasses often project the image on the edge of the field of view – for example, users have to look up and to the right – users of the new model see the information precisely where the context dictates it should be – in our example from earlier, right next to the monument our tourist is looking at. For this purpose, the researchers apply a nanoscale lattice structure – invisible to the human eye – to a glass plate, purposing it as light guide. In short: the optical image is coupled into the light guide through a lattice, guided to the required position, coupled back out through a lattice there, and reflected into the wearer's field of view. "The manufacturing methods are suitable for large-scale production and are already used in the industry, so making the glasses is easy and cost-effective," says Schreiber.

**Glasses compensate for defects in vision**

People who need glasses to read usually also have difficulties reading the information displayed in data glasses. However, Fraunhofer IOF's new glasses correct for farsightedness. "Our multi-channel approach compensates for farsightedness without any moving mechanical parts, such as the adjustable eyepiece in binoculars, and to set the focus for each wearer by purely electronic means," explains Schreiber. For users, this means entering their vision defect data in the corresponding app on their smartphone, which sends the relevant content and information to the glasses via Bluetooth. Everything else takes place automatically: the glasses adjust the display images in such a way that they appear sharp to users. The glasses are also able to partly compensate for other vision problems, such as astigmatism and shortsightedness.

The researchers have already laid the groundwork for the data glasses. At the World of Photonics laser trade show, which will take place in Munich from June 22 to 25, they will present a demonstrator model (Hall B3, Booth 341). The applications for the data glasses are by no means limited to tourism. Wearers could view their personal intensity levels and heart rate while exercising or playing sports, to give an example. And the glasses could also help people in their everyday working lives: for instance, mechanics responsible for maintaining and repairing big machines would no longer have to lug around hefty manuals; instead, the work steps could be displayed directly in their field of vision.

**The near-to-eye display with see-through functionality facilitates a small, unobtrusive design. (© Fraunhofer IOF) | Picture in color and printing quality: www.fraunhofer.de/press**

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## Precisely simulating the production of ceramic tape



Mention "ceramic" and people typically think of products such as cups, dental implants and washbasins. Few people know that this material is also used in automotive exhaust and temperature sensors, where it is installed in the form of ceramic tape. In this case, the ceramic material serves as a substrate for electrical circuits which are exposed to extremely high temperatures. Porous ceramic tapes are also used in filter systems, for example to strain water, milk, beer and wine in the food industry. The key to the success of these applications is making sure that the tape has exactly the right properties when it is produced. Currently, however, manufacturers can learn how to get the properties they want only by experience, because their costly production facilities typically run around the clock. There's simply no time to run comprehensive test batches through the machine, and the results from small lab trials cannot be scaled up without uncertainties creeping in. Adjusting ceramic tape properties is therefore a matter of trial and error with many unknown factors.

Researchers at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg have now come up with a new combination of simulation methods that significantly reduces the number of unknown factors in this process. Using computer simulations, they can now determine what happens in ceramic tape casting processes on both a macroscopic and microscopic level. From the macroscopic perspective, the researchers can calculate how the liquid ceramic, or slurry, moves through the machine. On a microscopic level, they can analyze how the micrometer-scale ceramic particles are aligned in the slurry and, subsequently, in the tape itself. No other simulation method in Europe uses this unique combination of techniques. "Our SimPARTIX® software allows us to take a multi-scale approach to simulating the tape casting process and shows us exactly what effect individual parameters have on the properties of the tape," says Pit Polfer, a scientist at IWM. Manufacturers can use this information to optimize process control, minimize waste and improve the quality of their products.

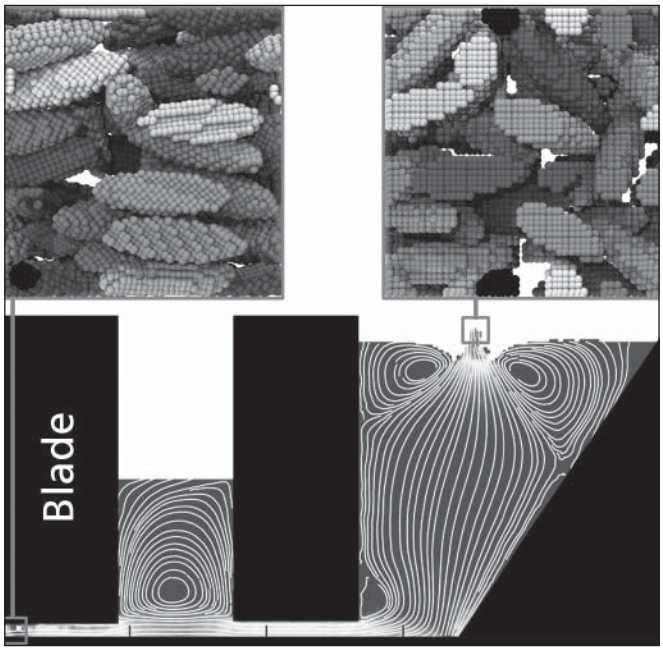
So how is ceramic tape actually produced? A ceramic powder with a range of particle sizes and shapes is mixed with solvents and additives to form a free-flowing casting slurry. This is then poured into the slurry chamber. The slurry exits the bottom of the chamber and flows onto a conveyor belt that runs underneath. A doctor blade – a kind of scraper positioned at the gap between the blade and the belt – ensures that the ceramic slurry forms a flat layer of the required thickness. The result is a smooth layer of slurry which is then dried.

### Macroscopic and microscopic simulation

Researchers use macroscopic simulation to determine how the ceramic slurry flows through the system. This is important because the geometry of the system is one of the factors that affects the properties of the finished tape. If the slurry spends too long in

"dead spaces" within the casting chamber, it begins to degrade. If this slurry does eventually end up in the tape, it can compromise quality – which ultimately means more waste. The simulation shows manufacturers how the casting chamber's geometry affects the slurry flow. Where does the liquid ceramic get stuck? How does the flow pattern change when you change the geometry of the doctor blade? Simulating these changes allows ceramic manufacturers to try out promising casting chamber geometries in a virtual environment first, thus sidestepping the high cost of testing experimental doctor blades on real production lines.

Along with this macroscopic simulation, the researchers also determine the slurry's properties on a microscopic level – and it's this approach that makes the combination so unique. For example, they investigate what impact individual ceramic particles have on each other and how they are aligned in space. Running the calculations for all the slurry in this way would be far too complex, so instead the researchers pick out different drops of liquid in the material. How do these droplets make their way through the system? And how are the ceramic particles aligned in these droplets? "We can then extrapolate these calculations to infer the behavior of the ceramic slurry as a whole," says Polfer. That makes it possible to adjust the particle alignment and size gradients in the tape, offering a more targeted way of producing ceramic tape for specific applications.




**Bottom – macroscopic simulation: flow lines during the casting process. The ceramic slurry enters the system on the right and exits the casting chamber on the left as a tape. Top – microscopic simulation: alignment of the ceramic particles at two points in the process. (© Fraunhofer IWM) | Picture in color and printing quality: www.fraunhofer.de/press**

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# Mini laser for real-time quality control



Pharmaceutical industry, food production or industrial manufacturing: new products are constantly being brought to market, with improved active ingredients or less negative side-effects. One important point in the development of material compositions, such as pills or capsules: their quality has to be impeccable. To verify if the chemical reaction proceeded as desired, samples are taken from the reaction vessels and examined in the laboratory, applying chromatography or spectroscopy. A costly and tedious endeavor that however only allows an investigation based on random samples.

## Continuous analysis in real time

This process might soon be simplified with the help of a novel infrared laser developed by researchers at the Fraunhofer Institutes for Applied Solid State Physics IAF in Freiburg and for Photonic Microsystems IPMS in Dresden. "Our quantum cascade lasers facilitate a new kind of spectroscopy," explains Dr. Ralf Ostendorf, project manager at Fraunhofer IAF. "The process of chemical reactions – as, for example, in the development of new pharmaceuticals – could soon be continuously monitored in real time, rather than analyzing random samples, as done in current monitoring processes." The key principle is as follows: The laser sends infrared light into the reaction vessel. The substances it contains absorb a portion of the light; the rest is scattered back and analyzed by a detector. Each substance "swallows" the light at different specific wavelengths. The result is an absorption spectrum which allows to precisely identify each substance – similar to the identification of a human being based on his finger print. With this kind of spectrometer, it will soon be possible to precisely determine the concentration of the reactant materials in the reaction vessel as well as the quantities already transformed into the end product – at any point of time during the reaction process.

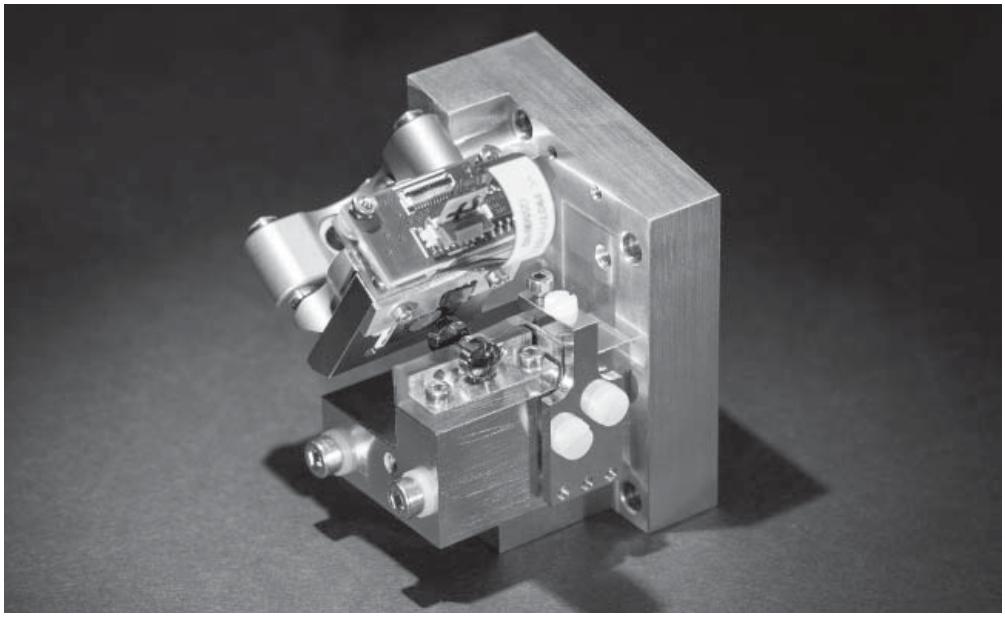
## Thousand spectra per second

For this, the laser needs to meet several requirements: the emitted laser light should consist of one specific wavelength only and, moreover, has to be constantly adjustable over a vast spectral range. Thus, the laser light initially has a short wavelength which is gradually increased up to a designated value – before the procedure restarts from the beginning. The detector then determines for each wavelength, how much light is scattered back by the respective sample. A further challenge: the process of switching the laser's emission wavelength has to be as fast as possible. Up to now, the laser needed a few seconds to tune through every wavelength and to determine the actual state of the chemical reaction being analyzed. Researchers from Fraunhofer IPMS were now able to increase this speed by a factor of 1,000 by applying a micromechanical scanning mirror. Instead of one spectrum per second, they now succeed in recording 1,000 spectra per second.

**Hardly any bigger than a matchbox**

The laser is just barely larger than a matchbox. Thus, it is not only suitable for the reaction vessels used in the pharmaceutical and chemical industry, it also facilitates other applications. Conceivable for the future, for instance, could be a hand-held device that would allow a police officer or customs officer to inspect suspicious substances both quickly and easily. Are we dealing with something insignificant, like flour or harmless powder – or illicit drugs? To answer this question, the agents merely would have to direct the laser beam at the substance. The detector analyzes the recorded spectrum, an underlying software compares it to numerous stored comparison spectra – and in a matter of seconds, the officers have clarity about the investigated substance.

A laboratory demonstrator model of the quantum cascade laser has already been realized. The researchers from the two Fraunhofer Institutes aim at developing a prototype of the laser by the end of 2015. On the trade fair 'Laser – World of Photonics' from June 22 – 25 in Munich, the scientists will present the novel infrared laser and will demonstrate its potential for spectroscopy applications. (Hall A3, Booth 121 and Hall B3, Booth 341).



**Scientists will soon be tracking the course of chemical reactions in real time. A quantum cascade laser, which records 1,000 spectra/second, makes it all possible. (© Fraunhofer IAF) | Picture in color and printing quality: www.fraunhofer.de/press**

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