RESEARCH NEWS

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1 A mobile guide for buses and trains

If people had access to a fully-fledged system to help them navigate public transport, it could persuade many drivers to switch to their local trains, buses and trams. Researchers are busy developing an application that will enable passengers to use a cell phone to navigate their way through the public transport network.

2 Robotics: Safety without Protective Barriers

The modern working world is no longer conceivable without robots. They assist humans in manufacturing, laboratories or medicine. In the future, a new projection and camera-based system will prevent collisions between robots and humans working together.

3 The perfect connection between guitar and computer

Guitar virtuosos have to master all kinds of playing techniques. But how can the intricate process of playing the instrument be captured digitally? A special thin film on the tailpiece has the answer. Functioning as a sensor, it converts the tension on the string into digital control signals.

4 Expert help from a distance

When electronic devices refuse to work, you rarely find the solution in the manual. Technicians often face similar problems with industrial machines, and companies end up flying in experts from the manufacturer to get things running again. A new system aims to help manufacturers lend a hand regardless of how far away they are located.

5 Saving fuel while plowing

Less friction, less power, less fuel – plowshares coated with diamond-like carbon (DLC) slide through the soil like a hot knife through butter. As a result, the tractors pulling them need less power and fuel. In some tests the power required has been reduced by more than 30 percent.

6 Accident protection in the windshield

Driver-assistance systems help prevent accidents. Quite simply, the more a car knows about its surroundings, the more intelligently it can respond to them. Researchers have now developed an optical sensor for the windshield that can even tell the difference between fog and darkness. The system will also be available for small cars.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 60 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 18,000, who work with an annual research budget totaling 1,66 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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A mobile guide for buses and trains

Research News
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Drivers were freed from their dependence on maps a long time ago – nowadays they rely on their navigation device to get them to destinations in unfamiliar areas. But this luxury has so far remained elusive for users of local public transport systems. A personal guide – similar to a car's navigation system – designed to show them the way to their destination and help avoid hold-ups and out-of-service lines would be a tremendous help. Commuters and locals could switch to alternative routes if their bus or train was late and tourists would be able to find the quickest route to their hotel or to the main city sights. Now it seems there is a glimmer of hope on the horizon for public transport users: Researchers from the Fraunhofer Institute for Transportation and Infrastructure Systems IVI in Dresden are working with eight partners from industry and the research community on the "SMART-WAY" project, which aims to develop a personal guide which would offer a whole lot more than just timetable information.

This mobile guide is being developed in the form of a navigation application for cell phones and smartphones. The goal is to make the app available from 2012 to help people find their way through the labyrinths of trains, buses and trams that criss-cross Europe's cities. "All you will need to do is to launch our SMART-WAY app on your cell phone and enter your destination. SMART-WAY will then guide you to the nearest station or bus stop and tell you where you need to change and what lines you need to take to get there," explains Andreas Küster, the researcher responsible for coordinating the project at the IVI. The application displays multiple alternative routes on a map which shows all the stops, connections, modes of transport, directions, arrival and departure times. Users also have the option of breaking off their journey, switching to different forms of transport or entering a new destination at any point they wish: By constantly tracking the user's current location, SMART-WAY is able to respond in real-time by simply re-calculating the route. The same applies in the event of traffic jams, delays or early arrivals – whenever new developments affect your chosen route, the app immediately suggests alternatives. A useful touch is the vibration alert that tells you when you have reached your destination or missed a stop.

But how exactly does the SMART-WAY app calculate a user's current position and respond in real time? "As well as providing support for satellite navigation with GPS and – in the future – Galileo, our navigation system also dovetails with the location-finding systems the public transport companies use to keep track of their vehicles," says Küster. "These positioning systems are supplemented by inertial sensors which register whether a vehicle is accelerating or braking in order to decide whether it is in motion or waiting at a stop. All the information on timetables, connections and hold-ups in the network are supplied by the transport companies in real time and imported into the app." A prototype of SMART-WAY has already been completed and the researchers hope to have a final version of the application ready to roll out across Europe by 2012. The first field tests are scheduled to be run in September 2011 in Dresden and Turin in cooperation with the local public transport operators.

To demonstrate how SMART-WAY works, researchers from the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern developed a software program which simulates a virtual city and a virtual public transport operator including all the timetable information. "The software gives us a real feel for how the application would work in real life. It even lets us play around with situations that only occur sporadically, such as traffic hold-ups and similar problems. And we can also use it to demonstrate our real-time navigation system at trade fairs and conferences and to show public transport operators how the system works," says Dr. Michael Schröder from the ITWM. SMART-WAY has been developed for Android smartphones. The question of whether versions will also be made available for other mobile platforms depends on the public transport companies who choose to offer users the application. "We hope to see as many public transport operators as possible offering this application to their customers from 2012 onwards," Küster says.

The SMART-WAY navigation application guides users through the labyrinths of local public transport networks in real time. (© Fraunhofer IVI)
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Robotics: Safety without Protective Barriers

Research News
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A robot carefully lifts and positions a heavy component while a worker welds lightweight aluminum components to a machine right next to it. Although such scenarios are visions of the future at present, they will soon be part of the everyday work routine if industry has its way. Humans and robots will team up, especially on assembly jobs, and collaboratively employ their particular capabilities: Steel assistants could bring their power, durability and speed to bear and humans their dexterity and motor skills. At present, automated helpers are usually enclosed by protective barriers. Industrial safety regulations permit contact between people and robots only under certain conditions since the risk of injury to humans is too great. In order to allow their collaboration after all, new technologies will have to define workplaces and safe zones, which humans may not enter. A robot will stop or slow down whenever a safe zone is entered. In the ViERforES project supported by the Federal Ministry of Education and Research, researchers at the Fraunhofer Institute for Factory Operation and Automation IFF have developed a novel solution that monitors workplaces highly flexibly.

This safety system employs conventional projectors and cameras, which are normally mounted on the ceiling. One distinctive feature of the system is its projection of monitored safe zones directly onto a floor or wall. Projected beams produce visible lines in the work area. Thus, humans recognize the safe zone right away and know how close they may get to a robot. The camera immediately detects any intrusion in the safe zone by an individual – the projected lines are disrupted. The robot decelerates at once. Optical and acoustic warning signals can additionally be generated. Another distinctive feature is the variability of marked areas' position and size and the capability to give them any shape – for instance, a circle, a rectangle or any freeform. "Since we employ common standard components, our system can be installed cost effectively. The projector and camera are calibrated and synchronized to one another," says Dr. Norbert Elkmann, Robotic Systems Business Unit Manager at the Fraunhofer IFF. When a larger area needs to be monitored, the system can be extended as desired by additional projectors and cameras.

The monitoring system operates with modulated light. "The advantage of this is its reliability even under the effects of external light, e.g. sunlight and shadow. Present purely camera-based space monitoring systems operate independently of external light only to a limited extent," explains Elkmann. In addition, the experts can combine this system with robot controls and thus dynamically modify danger and safe zones.

If, for example, a robot only works to the left of its workspace at times, the maximum robot workspace would not have to be monitored.

Elkmann and his team have filed a patent for their system. A prototype already exists. The potential applications of the projection and camera-based system are not merely limited to safe human-robot interaction. Other spaces in which safety is relevant, e.g. public buildings, can be monitored. The system can also be used wherever safe zones ought not to be perceptible – by projecting invisible light.

Visible lines denote the safe zone. Should a person enters the zone, a robot will stop its work and a warning may be signaled. (© Fraunhofer IFF)

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The perfect connection between guitar and computer

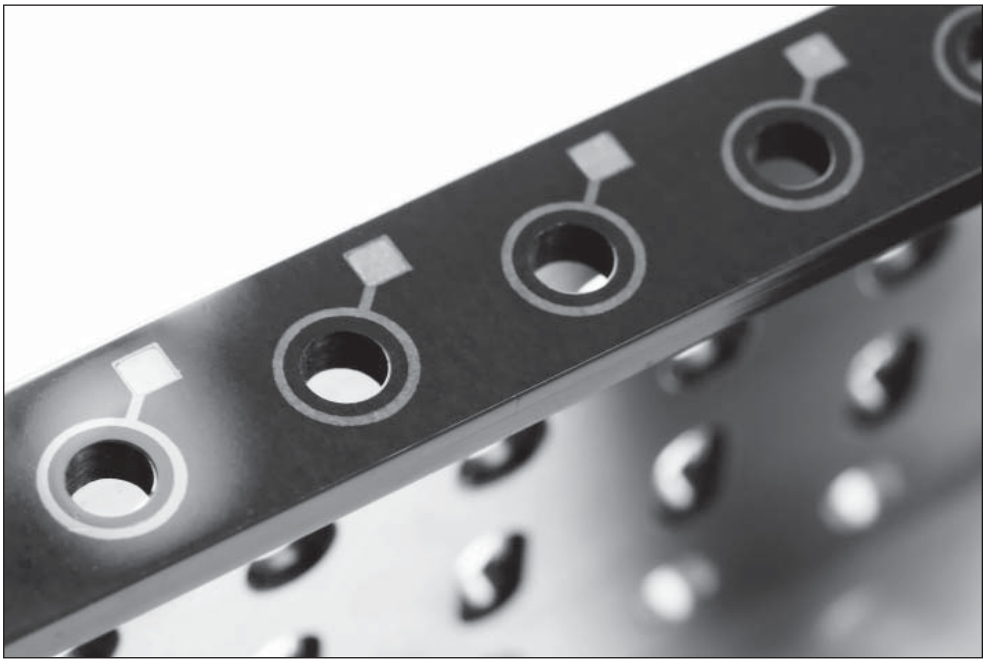
Rapidly, but expressively and with amazing ease, the guitarist's fingers move over the strings on the neck of the instrument. His fingertips move up and down and a vibrato resonates. From the guitar a cable leads to a laptop, which records the virtuoso performance in minute detail. The computer registers each vibrato, each bend precisely and almost instantaneously. Afterwards the guitarist can play back the digital recording and process it on a computer.

The guitar incorporates a piece of Fraunhofer technology. Engineers at the Fraunhofer Institute for Surface Engineering and Thin Films IST have developed a sensor which translates complex guitar-playing movements into digital control signals. "This enables the different techniques such as vibrato and bending to be precisely captured," explains Saskia Biehl, head of the micro and sensor technology group. The key element is a thin film bearing the name DiaForce®, which coats the tailpiece, the part of the instrument anchoring the guitar strings to the body.

DiaForce® is based on amorphous carbon and is piezoresistive. Biehl explains what this means: "When the player changes the string tension, the pressure on the film changes. This in turn leads to a change in resistance, which is measured by electrodes on the film." To be able to record the string tension forces and therefore the various playing techniques accurately and with as little delay as possible, Biehl and her group have tested various coating parameters and contact materials. They achieved good results with a tailpiece coated with a ten-micrometer DiaForce® film. The intention is also to measure the strength of the string vibration, which would make it additionally possible to digitally represent the stroke strength and fading – regardless of whether the player plucks the strings with their fingers or a plectrum.

The development partner for this Fraunhofer technology is M3i Technologies GmbH. The company has already developed a laser-based sensor system which captures the pitch of chords and individual notes. A software program converts this data into digital control signals. DiaForce® supplements this development and makes it the perfect sensor system for guitar playing. The Fraunhofer research engineers now aim to develop suitable processes for mass producing the DiaForce® coating as a low-cost tension sensor for guitars. "We also want to extend its application to other musical instruments," says Biehl. "After all, force is exerted at various points on many string instruments, and so the possible applications are numerous."

In the future, coated tailpieces could replace the pickups on electric guitars which convert the string vibration into an electrical signal to create the sound from an electric guitar. "The DiaForce® film will need to be particularly sensitive for this, which is what we are working on right now," concludes Biehl.



This tailpiece is coated with a thin-film sensor system. It converts the tension on the string into digital control signals. (© Fraunhofer IST)

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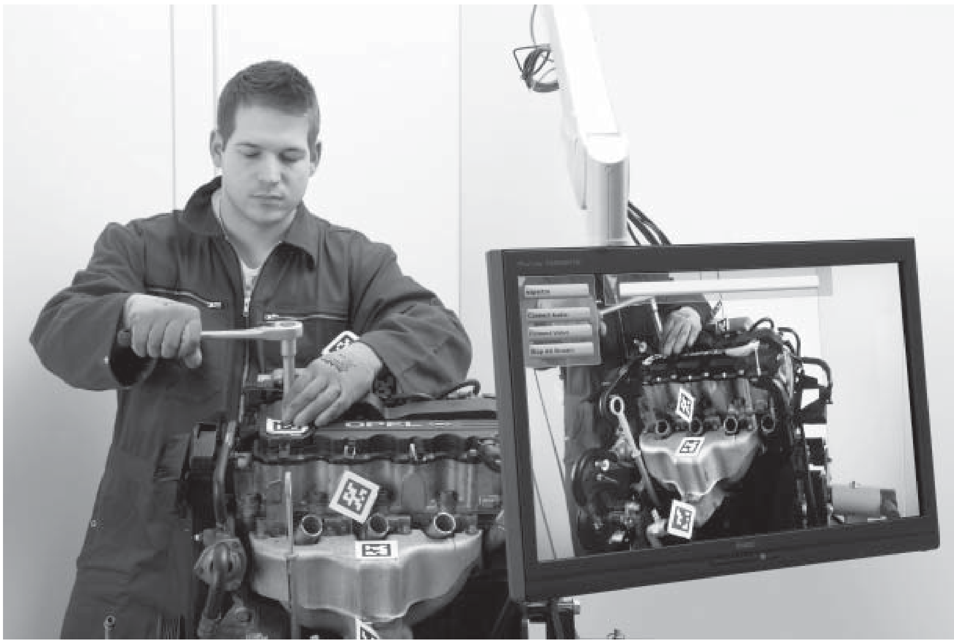
Expert help from a distance

Machines stretch from one end of the production hall to another, each of them an important part of the manufacturing process. When one of these complex pieces of machinery stops working, the on-site technicians grab their tools and the manual and try to fix it – but sometimes the only solution is to call the manufacturer for tips on how to get it working again. The problem is that giving advice over the telephone is never easy: Do they mean the screw on the right or the screw on the left? Well, that depends on which side of the machine you are standing on! Even putting things down in writing can only get you so far. Often the only choice left is to fly experts in, sometimes from the other side of the world. But until they arrive, the machine stays stubbornly offline, perhaps bringing the entire production process to a halt.

Soon experts will have an easier and quicker method of supporting the on-site technicians without having to set foot outside their office: the augmented reality system developed by researchers from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE in Wachtberg. This allows technicians to record the malfunctioning machine with a camera fixed to the back of their laptop monitor. The computer is mounted on a swivel arm so that the technicians can view the screen while carrying out repairs. An image processing program calculates the camera's position and direction of view and sends this information to the manufacturer over standard telecommunications networks. This enables the experts to view the machine on their monitor from the same perspective as the technicians. They can even use the software to write instructions on specific parts of the machine such as 'Remove this screw'. These instructions then pop up on the technicians' screen on exactly the same part of the machine. And if a technician walks around the machine with the laptop, the image moves accordingly – and the written information stays where it was intended to be, for example hovering over a specific screw. Once the technicians have carried out the experts' instructions, the pop-up information can be deleted by simply clicking on it. The system is based on a chat protocol, which means everyone involved can communicate either through the chat function or by telephone.

The researchers managed to minimize the quantity of data transmitted to allow the system to function over a cellphone network. That means there is no need for a broadband connection, so technicians can call on experts even from remote locations such as wind turbines in the middle of a field or machines in newly industrialized and developing countries. "We only transmit location data, not pictures," says Dr. Thomas Alexander, who heads up the research team at the FKIE. "At the moment we do that by attaching 2D barcodes to various parts of the machine. When the repair technician takes a picture of the malfunctioning machine, the software on the laptop reads those markings and links them to information in the database – for example the machine's identification code and the position and location of the barcodes that appear in the picture. And this is the only information that actually gets transmitted." Once the data reaches the manufacturer, another software program links it to the machine's CAD data to enable the experts to view the machine from the same angle as the on-site technician. The researchers have already developed a prototype of the system, and the next step is to carry out a study in which users will put the system through its paces. The results should help the scientists to optimize the system and tailor it more closely to user requirements.



The system uses the 2D barcodes attached to various parts of the malfunctioning machine to determine the camera's position and direction of view and then sends this data to the experts. (© Fraunhofer FKIE)

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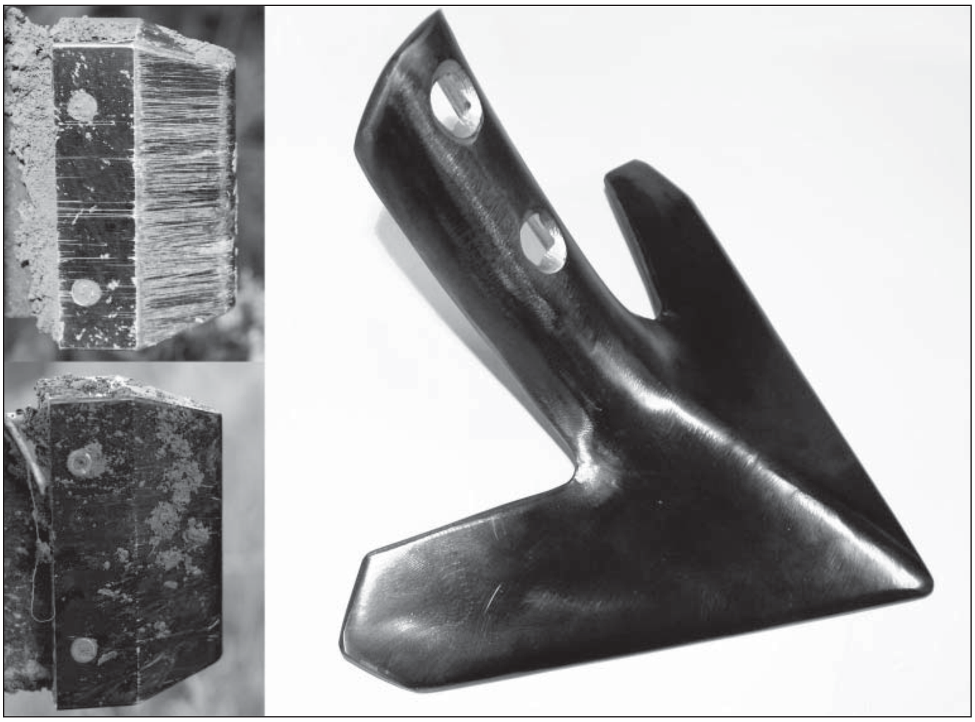
Saving fuel while plowing

Extremely hard, diamond-like carbon coatings are used to protect hard disks in computers and ensure that sliding bearings remain smooth. In the future they could help farmers to save fuel while plowing and make it easier to till the ground. Farmers in Germany consume nearly a billion liters of fuel every year to work their land. Around 50 per cent of the energy used when plowing or harrowing is lost as a result of friction between the plowshare and the soil. To change this, scientists at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg and their partners in the RemBob project are working on DLC-coated plowshares. They have already been able to reduce friction by half. The power required by the tractor has also been reduced, by more than 30 per cent in some tests.

For farmers, the smoothly cutting plowshares mean either a time gain because they can use wider equipment or lower costs for fuel, machinery and maintenance. The tractors can be smaller or can operate in partial load, with longer repair and maintenance intervals. “From the environmental point of view it would be better for the tractors to be smaller,” says physicist and trained fruit farmer Martin Hörner from Fraunhofer IWM. They would not only need less fuel but would also be lighter. Lighter machines mean less soil compaction, and the looser the soil, the less power is needed to work it. The quality of the soil would also be better. In highly compacted ground there are hardly any worms and other small creatures which help to turn the soil and enrich it with nutrients. Compacted soils are less able to absorb water and dry out more quickly. “In Germany we are relatively advanced as far as protecting soil resources is concerned, but even in this country more soil is lost by compaction and erosion than is created by natural processes,” explains Hörner.

A further advantage of DLC coatings on groundworking equipment is the protection they provide against corrosion and wear. Plowshares have to be hard and sturdy but also resilient, so that they do not break if they hit a rock. High-durability steels are used, but they suffer visibly if they are used for a prolonged length of time in the ground. “A tine on a circular harrow can lose 50 per cent of its mass through wear every season,” states Hörner. But soil, sand and stones wear down conventional coatings within a very short time. This is why plowshares have not been coated up to now. DLC coatings, however, can withstand the extreme stresses and strains. The problem is that the tough steel on the groundworking equipment deforms too easily and is therefore unsuitable as a substrate for the much more rigid diamond-like coating – it would quickly spall. The project partners are therefore testing plowshares made of different materials, including nitriding steel, glass-fiber-reinforced plastic and tungsten carbide, out in the field. The next project goal is to plow at least 20 kilometers of ground before the coating fails. "If we achieve that, the wear-free plowshare will be within touching distance," affirms Hörner.



Left: Experimental DLC-coated tools after use. Top: Initial test results; the improved coatings after the same plowing distance are shown in the bottom of the picture. Right: DLC-coated plowshare for test purposes. (© Felizitas Gemetz/Fraunhofer IWM; Martin Hörner/Fraunhofer IWM)

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Accident protection in the windshield

The number of traffic fatalities on Germany's roads has steadily fallen in recent years. As studies show, this also owes to the numerous new driver-assistance systems that react more quickly than a human being can. They identify risks, warn of hazards and assist the driver in critical situations. Radar sensors, for instance, scan surrounding traffic conditions, monitoring the vehicle's blind spot or maintaining a safe distance to the vehicle in front; infrared detectors improve night vision, and fatigue sensors sound an alarm if there is a risk of momentary driver drowsiness.

To monitor the surroundings during a journey, complex systems equipped not only with a camera but also with sensors are now in use. These systems can register difficult-visibility areas near the vehicle – such as when parking – and automatically analyze the camera pictures generated. These sensors are mounted between the windshield and the rear-view mirror. In addition to imaging data, they also deliver information about ambient light conditions; for instance, they can distinguish between darkness and fog. The sensors interpret the optical data and analyze weather conditions. Still, thus far such high-tech systems have found their way only onto high-priced vehicles. They have been too expensive for standard-size and small models. The reason: with conventional components, constant use results in imprecise measurements – the integrated LEDs become less powerful over time, and the needed light detectors lose some of their sensitivity. To date, only expensive components have proven able to offset these effects.

This is all about to change: in the EU-sponsored „ADOSE" project, researchers at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin, working with Centro Ricerche Fiat and the chip manufacturer STMicroelectronics, have developed a sensor system that can be inexpensively produced for medium-sized and small cars as well. „Our multifunctional system consists of an entire camera, two sensors equipped with Fresnel lenses to detect light signals, and an infrared LED. Because fog and darkness can exhibit optically identical spectra, it is difficult to distinguish between these two light phenomena. That's why the infrared LED emits light waves that are scattered back in fog but not in conditions of darkness," explains IZM group manager Dr.-Ing. Henning Schroeder. „It's particularly difficult to capture the light signal from a broad aperture angle, to bundle the signal and pass it along the circuit board to the four corners of the camera chip. Because the middle of the chip is reserved for recording the camera image," Schroeder notes. To make this possible, the researcher and his team have developed lightpipes in a hot stamping procedure. These are hollow, mirrored tubes that can deflect a light signal by as much as 90 degrees. Up until now, optical fibers have been used to transmit these signals. But these snap at even low bending radii, are expensive and must be painstakingly mounted in place manually. „With the lightpipes, we have succeeded in making the optical signal transmission more efficient, making the entire system smaller and reducing costs as a result," the researcher points out. The hot stamping method involves several optical channels being produced in a single pass, simplifying assembly considerably. The trick: the IZM scientists' system is scalable and can be expanded through the addition of additional lightpipes – to record solar radiation, for instance.

The experts at IZM developed not only the lightpipes but also the Fresnel lenses for these sensors. They are also responsible for the design of the sensor module, which was carried out via Rapid Prototyping. A prototype of the sensor module is already in hand. Centro Ricerche Fiat is currently putting it through the paces in an initial field test.

The multifunctional system distinguishes between darkness and fog. It consists of an infrared LED, two sensors (right and left in the front) and a camera. (© Fraunhofer IZM)

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