RESEARCH NEWS

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1 Training to promote health

Many people use fitness studios to get back into shape after an injury. Fraunhofer researchers are now developing a system that will provide doctors with data on the exercises people do on the various machines. This should help them plan better training programs.

2 Finding reserves on the electrical grid

The weather determines how much energy wind turbine systems provide. The same applies to power line capacity. On cold and stormy days, this capacity is higher than on days with no wind and high mid-summer temperatures. An autonomously powered sensor network monitors power lines to find the reserves in the lines.

3 Water for Mongolia

Clean water is a rare commodity in many countries of the world and governments often face problems ensuring its reliable supply. In Mongolia, an interdisciplinary research team is demonstrating how this vital resource can be efficiently managed and used. Specially developed software help to detect weak points in the supply system.

4 Perfect welds for car bodies

Surface welding instead of penetration welding, allows a laser to produce a weld that is only visible on one side. But how do you control the laser power to prevent it burning a hole through the sheets of metal? A new camera system analyzes thermal images in real time – and ensures a perfect weld.

5 Microscope – handy, quick and flat

Suspicion of melanoma: In the future, doctors can pull out a new type of microscope to get to the bottom of suspicious changes in the skin. It provides a high-resolution image of skin areas of any size – and so quickly that you can hold it in your hand without blurring the resulting picture.

6 Wireless sensor network monitors microclimate in the forest

During a forest monitoring operation, forestry scientists measure various environmental values. This is how they obtain indications about how the forests are changing and what can be done to preserve them. However, installing and maintaining the wired measuring stations is complex: Researchers developed a wireless alternative.

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 1,65 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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Training to promote health

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Marianne has constant pain in her right knee at the moment – she hurt it when she took a tumble skiing in the Swiss Alps. Everything happened so quickly: The searing pain, the helicopter ride to hospital, the operation the following day, and then a week later the return home with crutches to rest in a reclining chair. Her aim now is to mobilize the operated knee and regain full mobility of the joint – something she'll achieve by following a targeted machine-based training plan drawn up by a physiotherapist.

In order to be able to devise training programs properly, physiotherapists and medical experts require detailed information on the progress of muscle build-up, the degree of mobility and the overall physical condition of the patient. Marianne's general physician, in particular, needs to know how well her knee is recovering. But that's not easy, because qualified data from the training machines she uses is not automatically made available to him. There is no direct connection between the software systems used by physiotherapists or rehabilitation specialists and general medical practices, and as a result, a great deal of potential is wasted. "The quality of treatment can be greatly improved if medical experts are able to assess training data," explains Sven Meister, project manager at the Fraunhofer Institute for Software and Systems Engineering ISST in Dortmund. He and his team of co-workers have developed an interface that is able to transfer patient fitness training data to a medical practice computer system or hospital information system.

By developing their 'eTraining' system, the ISST scientists are seeking to promote a better flow of information between doctors, health insurance companies and training specialists when it comes to the personal efforts made by so many individuals to promote their own health. For the Fraunhofer IT experts, the basic imperative was to create a standardized information platform that would allow personal measurement data such as pulse, weight used, speed, duration and 'range of motion' of orthopedic rehabilitation measures to be sent to medical information systems. "eTraining combines a patient's training plan with their current training data and makes the information available to authorized viewers," says Meister. The scientists are counting on specific standards to render their solution compatible with all IT systems used by healthcare providers. Their chosen model for linking external training data into a hospital network is U.S. standard Health Level Seven (HL7). In cooperation with fitness equipment manufacturer Ergo-Fit, they have created a data model that amalgamates training-related data with medical treatment data using the HL7 Clinical Document

Architecture (CDA). And together, the partners have developed a CDA-based training plan that specialists can use to assess how successful any given fitness training plan is from the medical point of view.

But exactly what information is needed if medical experts are to be able to assess physical training? “We’re currently holding discussions with various bodies of experts in order to reach agreement on an industry-wide standard that also takes into account the needs of health insurance companies,” reports IT expert Meister. If this exchange of information is developed further, it could potentially give rise to new business models, for example by transferring a greater proportion of rehabilitation work to fitness studios. Ergo-Fit and the ISST are convinced that “networking the health markets will improve the quality of machine-based training efforts in both rehabilitation and preventive medicine,” says Meister.

Targeted machine-based training helps patients recover more quickly after accidents. A new information platform facilitates the exchange of fitness data between doctors and trainers. (© Ergo-Fit)

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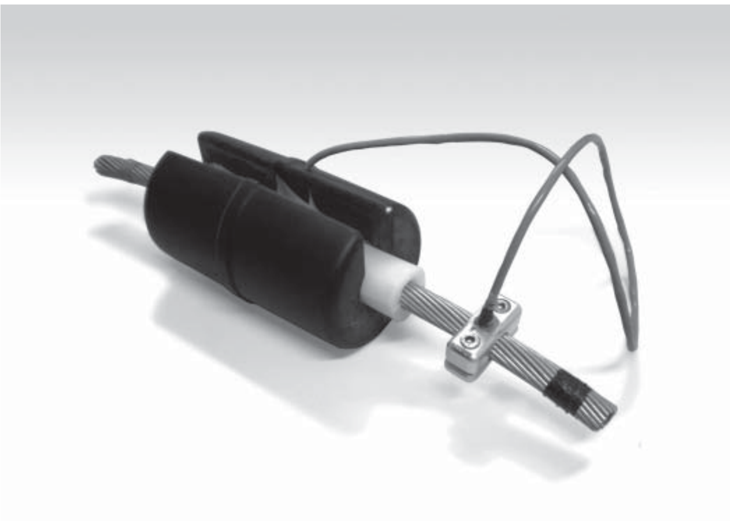
Finding reserves on the electrical grid

When storms lash northern and eastern Germany, it regularly gets tight in the high-voltage and highest-voltage electrical grids. Electricity from renewable resources has priority on the grid. But, on stormy days in particular, wind turbine systems must be taken offline, because the gird capacities are insufficient. "Currently we are in a situation where we have high inflows from renewable energies into our high voltage line system and are expecting large increases in the future. However, the grid is not designed for this level of energy feed," reports Hanjo During of envia Verteilnetz GmbH in Halle, Germany, Additional power lines are being planned. But the authorization processes could take years and very often fail due to the resistance of the people living near the projected path of the lines.

For this reason, the grid operators are already utilizing various line-monitoring procedures to increase the grid capacity over the short term: They utilize reserves that are the result of a standardized assumption regarding the worst weather conditions for operating the line and the actual state of the line. In favorable weather conditions, they were therefore able to increase the transmission capacities by 20 percent or more. Currently, Amprion and envia Verteilnetz are testing a new type of autonomously powered sensor network to monitor 110 kV and 380 kV lines. It is being developed jointly with the Fraunhofer Institutes for Reliability and Microintegration IZM in Berlin and Electronic Nanosystems ENAS in Chemnitz, Germany as well as other research and industrial partners in the "ASTROSE" project. "Our autonomously powered sensor network can be retrofitted easily and does not require additional infrastructure," says Dr. -Ing. Volker Großer from the IZM. In contrast to the current monitoring systems it supplies measurement data from a tight-knit sensor network directly attached to the conductor wires.

How much current can be transmitted by a power line depends very much on temperature. If the conductor wires heat up as a result of flowing current or the sun, they expand and sag. If the sagging conductor wire gets too close to the ground, buildings, vehicles or humans, there is a risk of electrocution. To rule this out, prescribed safety clearances are mandatory. At the same time, the permitted current flow is calculated under the assumption that the ambient temperature is 35 °C and that the wind's velocity will not exceed 0.6 m/s. However, high midsummer temperatures often bring with them a lull in the wind. Most wind turbine systems will only start to operate once wind velocity has reached 3 m/s. They deliver high amounts of electricity during fall and in winter when the power lines are effectively cooled by the weather.

To better utilize these reserves in the grid without compromising safety, the ASTROSE project partners equip the 110 kV and 380 kV lines with „eGrains." Cylindrical sensor nodes are wrapped around the conductor wire approximately every 500 meters. „They consist of two half cups that are clamped on and attached to each other. The ASTROSE-eGrains measure the cable's angle of inclination, the current flow, the temperature as well as wind movement. All measurement values are relayed from eGrain to eGrain to the next transformer station and there they are fed into the central monitoring and control system or rather made available to the internet-based remote maintenance systems of the grid operators," explains Großer. The ASTROSE eGrains pull the energy they require from the electrical field that surrounds the conductor wires. However, the ASTROSE sensor network does not only help utilize the capacities of the power lines better. It also reports dangerous line sags, such as can occur in winter as a result of ice build-up on the lines. The sensor node can be seen at the „Sensor + Test" tradeshow from June 7 – 9 in Nuremberg, Germany, in Hall 12, Booth 231.



Autonomously powered sensor nodes can detect reserves in the electrical grid. Thus enabling significant transmission capacity increases. (© Fraunhofer IZM)

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Water for Mongolia

Mongolia is a country of contrasts – in summer boiling hot, in winter freezing cold; in the north damp, in the south bone dry. One million of its three million inhabitants live tightly packed together in the capital Ulaanbaatar, while the rest of the huge country is largely populated by nomads and their cattle. Providing a clean supply of drinking water across the entire country is a difficult challenge – beginning with the need to lay freeze-proof water pipes over an area of 1.5 million square kilometers. The people in the countryside therefore use water from rivers, or from wells that they dig themselves. But these traditional ways of obtaining water are reaching the limits of their capacity. In recent decades the periods of rain during the summer months which replenish the reserves of groundwater have become infrequent. They have been replaced by heavy storms unleashing torrents of rain that runs off rapidly without soaking into the ground. At the same time, demand for water has risen with the rapid growth in the country's population. "Providing a supply of drinking water is becoming more and more difficult. To create a reliable supply in the long term you have to take many different factors into account and find out how they influence each other," explains Dr. Buren Scharaw from the Fraunhofer Application Center System Technology AST in Ilmenau. Born in Mongolia, he has been working for many years on the a project entitled "Integrated Water Resources Management for Central Asia: Model Region Mongolia", known also as MoMo. Project partners include the universities of Heidelberg and Kassel, Bauhaus University Weimar, the Helmholtz Center for Environmental Research, the Leibniz Institute for Freshwater Ecology and Inland Fisheries and various private-sector enterprises. The model region under study by the research scientists is the catchment area for the Kharaa River and Darkhan, a city of 100,000 inhabitants.

Since the start of the project, in 2006, Scharaw has traveled back to his homeland several times. He has examined the quality of the water from public and private wells along with the distribution network, measured the energy consumption of pumps, and investigated the effectiveness of the sewage system. All of the data he has meanwhile collected has been fed into the computer models developed at Fraunhofer AST. "Our HydroDyn water management solution makes it possible for the first time to visualize the quality as well as the quantity of water resources and to model their future development," the scientist explains. There is plenty of scope for improvement: the water pumps consume lots of energy, the water pipes are in need of repair and nearly half of the drinking water is lost on its way to the consumer because of leaks. Many yurts have their own wells, but the water is often contaminated with bacteria from latrines. What can be done? "Having collected data and produced models we are now preparing proposals that make sense in economical and ecological terms", says Scharaw. His team has developed a software program for the purpose which can determine how the water supply can be sustainably secured using less energy.

To minimize the losses in the drinking water distribution network, the Fraunhofer research scientists have also developed a measuring system for locating leaks. Small sensors detect any drop in pressure in the pipes, enabling leakes to be localized with relatively high precision. Once the leak has been found, that section of the pipe can be repaired. To reduce contamination in the water supply, and to increase the efficiency of the sewage system, the MoMo scientists are now building a test sewage plant which contains microorganisms in high concentration: "We expect this test facility to deliver good results also during the cold season when the microorganisms are less active. The findings can then be transferred to a future full-scale plant." In three years' time, when the MoMo project has been completed, the experts intend to present the government administration in Darkhan with a catalogue of measures which will show how the water supply and sewage system can be efficiently and cost-effectively secured. Scharaw regards it as one of his major successes that he prompted the Mongolian authorities to discontinue mining operations in some regions of the Kharaa catchment area – an achievement that extends far beyond improving the drinking water supply in Darkhan.

The wells in Darkhan are often contaminated with bacteria. (© Fraunhofer AST)

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Perfect welds for car bodies

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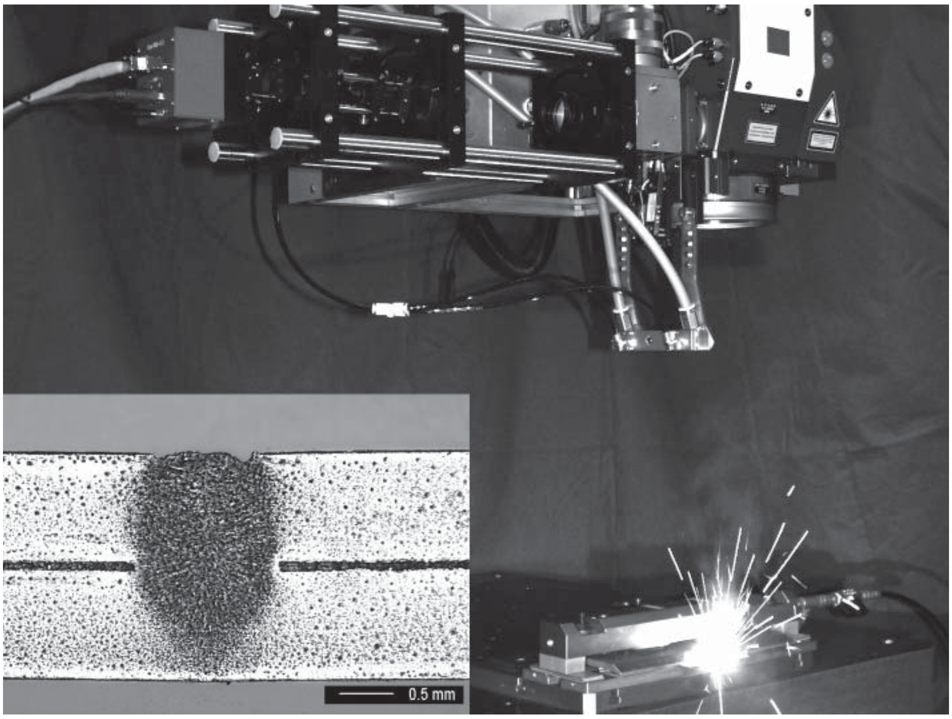
As if controlled by an invisible hand, the welding head on the robot's arm races along the sheet metal parts. Where the laser hits, sparks fly and the metal glows red hot. The process lasts just a few seconds. The outer door panel and the door frame are now welded together perfectly. A thin weld seam extends along the join, but it can only be seen on one side. From the other side of the welded car door the join is invisible. This is a perfect weld – the kind every car manufacturer dreams of, because it could be used anywhere on the car body. Expensive work to hide the seam, such as folding the sheet metal or covering with trim would no longer be necessary.

Research scientists at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg have turned this car makers' dream into reality. 'Controlled partial penetration welding' is how experts refer to the process in which the laser does not burn right through all the sheets of metal – in contrast to full penetration welding, where a hole briefly forms in the melt pool. Instead, the weld seam is controlled to penetrate the lower sheet without damaging the bottom surface. Up to now, however, it was not possible to precisely control this type of welding and produce a seam that meets the requirements in respect of strength.

"As we do not weld through the sheet, basically we cannot see what we are doing," states Andreas Blug, project manager at Fraunhofer IPM, outlining the problem. But they found the solution using an innovative camera that generates temperature images. This enables the system to recognize how deep the laser has penetrated into the sheets. Where it burns into the metal, causing it to melt, the images show a hot region. If the bottom of the melt pool reaches the gap between the upper and lower sheets, the conduction of heat is interrupted and a cooler point can be seen. This is referred to as the full penetration hole. From the relative frequency of this full penetration hole the system calculates the penetration depth into the lower sheet. A software program then adapts the output of the laser to the specific requirements. "The process is closed loop controlled in real time," Blug explains. An extremely rapid camera system is needed for this – which is the key to Fraunhofer IPM's innovation. The system is based on cellular neural networks (CNN). A tiny processor is integrated in each pixel. They all work simultaneously and speed up the analysis of the individual images enormously, whereas in conventional image processing systems a few processors process the data consecutively. "In this way the system analyzes up to 14,000 images per second," says Blug. This compares with the usual rate of only 1,000 to 2,000 images per second.

Together with colleagues from the IFSW Institut für Strahlwerkzeuge at Stuttgart University and the Institut für Grundlagen der Elektrotechnik und Elektronik (IEE) at Dresden University of Technology, the Fraunhofer IPM research scientists have now developed a prototype which perfectly controls the surface welding process, offering car makers a further great benefit in comparison with full penetration welding: zinc does not vaporize on the bottom side of the weld. The corrosion problems encountered on galvanized car bodies are therefore a thing of the past.



In the new surface welding process the laser produces a perfect seam. Bottom left:
Weld seam profile – the penetration depth is controlled without damaging the bottom surface.
(© Fraunhofer IPM)

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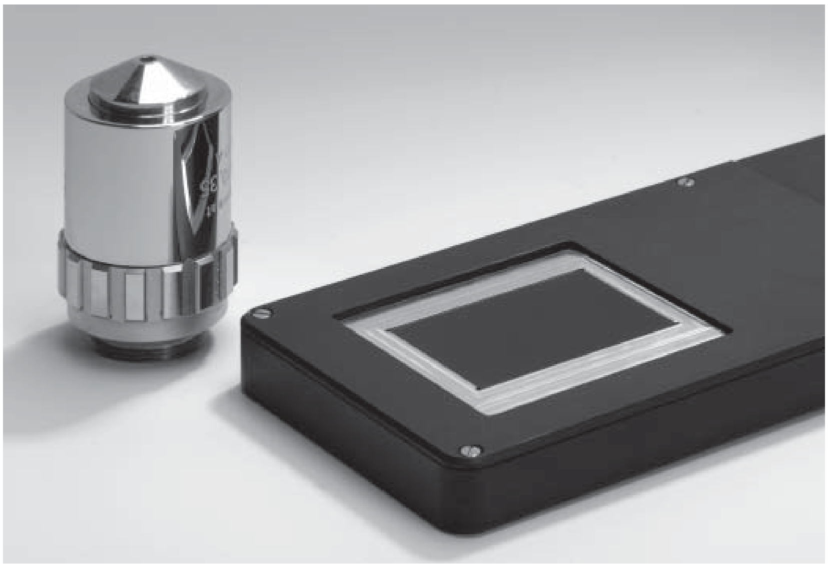
Microscope – handy, quick and flat

Are the dark spots on a patient's skin malignant? In the future, doctors will be able to take a closer look at suspicious blemishes using a new microscope – with results in just a few fractions of a second. It examines to a resolution of five micrometers; it's also flat and lightweight, and it records images so quickly that the results are not blurred even if the doctor is holding the microscope in his or her hand. For results with comparable resolution values, a conventional microscope would either be restricted to a tiny field forced to scan the surface: conventional equipment slowly sweeps the surface, point by point, recording countless images before combining them to create a complete picture. The drawback: it takes quite a while before the image is complete. The new microscope designed by researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena, combines the best of both types of microscope: because it foregoes the grid, it needs to make just a single measurement, and that's what makes it very fast. Still, it records across a broad imaging area. "Essentially, we can examine a field as large as we want," remarks IOF group manager Dr. Frank Wippermann. "At five micrometers, the resolution is similar to that of a scanner." There is also another benefit to the new system: With an optical length of just 5.3 millimeters, the microscope is extremely flat.

But how did researchers accomplish this feat? "Our ultrathin microscope consists of not just one but a multitude of tiny imaging channels, with lots of tiny lenses arrayed alongside one another. Each channel records a tiny segment of the object at the same size for a 1:1 image," Wippermann explains. Each slice is roughly 300 x 300 μm^2 in size and fits seamlessly alongside the neighboring slice; a computer program then assembles these to generate the overall picture. The difference between this technology and a scanner microscope: all of the image slices are recorded simultaneously.

The imaging system consists of three glass plates with the tiny lenses applied to them, both on top and beneath. These three glass plates are then stacked on top of one another. Each channel also contains two achromatic lenses, so the light passes through a total of eight lenses. Several steps are involved in applying the lenses to glass substrates: first, the scientists coat a glass plate with photoresistant emulsion and expose this to UV light through a mask. The portions exposed to the light become hardened. If the plate is then placed in a special solution, all that remains on the surface are lots of tiny cylinders of photoresist; the rest of the coating dissolves away. Now, the researchers heat the glass plate: the cylinders melt down, leaving spherical lenses. Working from this master tool, the researchers then generate an inverse tool that they use as a die. A die like this can then be used to launch mass production of the lenses: simply take a glass substrate, apply liquid polymer, press the die down into it and expose the polymer layer to UV light. In a process similar to the dentist's method of using UV light to harden fillings, here, too, the polymer hardens in the shape the die has printed into it. What remains are tiny lenses on the glass substrate. "Because we can mass-produce the lenses, they're really pretty low-cost," Wippermann adds.

Researchers have already produced a first prototype and will be showcasing it at the LASER World of PHOTONICS trade fair in Munich, from May 23-26. Boasting an image size of 36 x 24 mm², this microscope can capture matchbox-sized objects in a single pass. It will be at least another one to two years before the device can go into series production, according to the researcher. The spectrum of applications is diverse: with this technology, even documents can be examined for authenticity.



In a single pass, the ultrathin microscope can deliver high-resolution images of objects the size of a matchbox. (© Fraunhofer IOF)

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Wireless sensor network monitors microclimate in the forest

What effect does climate change have on our local forests? What types of trees will be suitable for which geographic location? And how great is the pollution level here? Forestry scientists are conducting „forest monitoring" procedures: They continuously record parameters such as soil humidity or pollutant penetration at permanently installed monitoring stations. The results of such examinations contribute to maintaining the ecological stability of the forests over the long term. The problem: Not only are the wired measuring devices complex to install and maintain, they also hinder silvicultural work in the forest.

In the future, technologies from the Fraunhofer Institute for Microelectronic Circuits and Systems IMS could enable differentiated analysis without any bothersome cables. Scientist from the institute in Duisburg installed a new type of system for microclimatic monitoring on the grounds of the Northwest German Forestry Testing Facility in Göttingen, Germany. "We are using a wireless sensor network so we can measure relevant parameters within an area at many sites simultaneously," explains Hans-Christian Müller, group manager at the IMS. This way, we receive a very detailed picture about the environmental conditions on site, without much installation effort. Depending on which values they are to measure – for example, soil moisture content, air temperature or the moisture in the leaves – different sensor nodes are inserted into the soil or affixed to branches. If required, the measuring positions can be changed without much effort. The intelligent mini-computers automatically form a network and control the transmission of measurement data within this network. The results are transmitted by cellular radio to a central tree stock database. To facilitate this, a mobile cellular modem is connected directly to the sensor network.

Providing power to the sensor nodes poses a particular challenge. Mounting solar cells to the sensors – a favored solution in other agrarian and forestry applications – is not an option due to the low penetration of sunlight under the leafy canopy of the trees. That's why, to date, there has been no alternative to batteries that have to be replaced regularly. Researchers, however, managed to significantly increase battery life, keeping maintenance requirements within reasonable limits: "We adapted the software design accordingly and now have operating times of 12 months," says Müller. A software solution integrated into the sensors ensures that the radio nodes are for the most part in an energy-saving sleep mode. They are active only during the measurement and data transmission process. The measurement intervals can be set to be variable. Parameters that change slowly such assoil moisture need not be measured as often as air temperature, for example, which is subject to larger variations. Since data transmission requires the most energy, the measurement values are calculated as early as the sensor node. This reduces the data volume.

The new technology is already in use in Göttingen as part of the joint project „Smart Forest." The project aims to optimize forestry processes with the aid of microelectronic components. The researchers from IZM will be introducing their results on the "Smart Forests" as well as other developments on the industrial application of wireless sensor networks at the „Messe Sensor + Test" tradeshow from June 7 – 9 in Nuremberg, Germany, in Hall 12, Booth 231.

A wireless sensor network records data such as soil and leaf humidity, as well as air temperature. (© Fraunhofer IMS)

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