tomorrow

Signposts to tomorrow's markets

Researching with Fraunhofer today
for market success tomorrow

Fraunhofer Gesellschaft

Signposts to tomorrow's markets
Succeeding through innovation on international markets

Global competition has increased in both scope and intensity over the past few years. Knowledge and markets have become international; everyone in the "global village" is everyone else's neighbor, rival – and customer, too. Risks and opportunities have grown in equal measure, and the time that elapses between an entrepreneurial initiative and its consequences has grown shorter.

In economic terms, this means that a company's business results will immediately reveal how well it has adjusted to the changes in the market. Companies that fail to adapt quickly enough will be left behind. Only those who are significantly faster or better than all the others can achieve real growth; only companies that have created a vital culture of innovation can hold out against the unceasing challenge.

The Fraunhofer-Gesellschaft undertakes applied research aimed at promoting the innovative capacity of German industry and thus strengthening Germany's status as an industrial location. Our work involves analyzing markets, developing new products, processes and services, and enhancing existing production plant and organizational structures. We play our part in ensuring that German companies are able to gain a competitive edge in the face of international competition, and can maintain and expand that edge.

To help us find our bearings in the fast-moving current of technological trends around the world, our experts have evaluated numerous foresight studies conducted by other industrial nations and roadmaps drawn up by international corporations, and have discussed and further evolved the results with internal and external experts. A comparison of national and international research trends with the present competencies and strengths of the Fraunhofer-Gesellschaft has revealed twelve areas of technology in which we particularly expect to see market-relevant innovations.

These twelve thematic areas have now been collected under the title of "Signposts to tomorrow's markets". They are characterized by their outstanding potential for innovation and their remarkable relevance to the market. The Fraunhofer-Gesellschaft is particularly well equipped to meet the great need for research and development in these areas. The Fraunhofer Institutes have therefore joined forces with partners from industry and are vigorously pressing ahead with the corresponding activities.

By purposefully concentrating our research and development activities in this way, we will be strengthening German industry as a provider of innovative products, processes and services that are successful all over the world. We will be tapping new markets and achieving sustainable growth, and ultimately only this can generate revenues that will fill our coffers once more.

If we manage to secure a share in the growth markets, we will be making an important contribution to Germany's future as an industrial location. The "Signposts to tomorrow's markets" will give us our bearings on the way to this important goal.

Sincerely,

Hans-Jörg Bullinger
President of the Fraunhofer-Gesellschaft

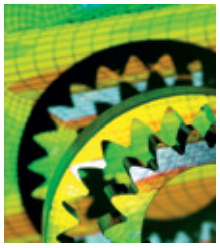
Fraunhofer thematic innovation areas

The Internet is a self-organizing distribution system. If the same principles are applied to real merchandise, each parcel can find its own way to the customer.

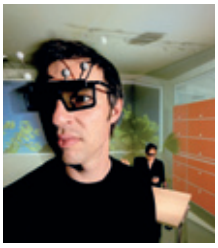
Electronics create a helping environment: Sensors and microchips locate devices, control service robots, remind us of important things to do and relieve us of burdensome tasks.

Mobile electronic devices such as cell phones and digital cameras have become an essential ingredient in our lives: Miniaturized fuel cells will keep them powered up for longer.

Adaptronic systems actively dampen vibrations: Machines and cars run quietly when noise is cut down or shut out.



The gap is closing between ideas and reality: Modern simulation methods allow the properties of components and other products to be tested as early as the design stage.



Interaction between people and machines is growing easier and more intuitive. Design engineers and planners can move around in virtual reality systems without the distraction of complicated input devices.

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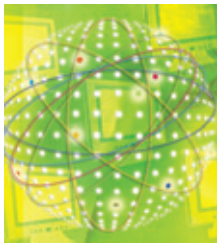
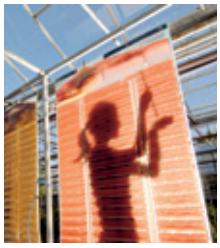
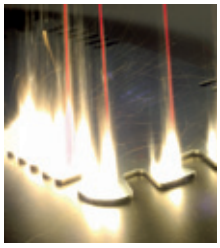


People are more productive when they cooperate – and the same applies to computers. Standard PCs linked together to form a grid are even capable of outperforming supercomputers.

Lightweight construction methods bring immense benefits to vehicle manufacturing: When less mass needs to be moved, energy consumption is reduced accordingly.

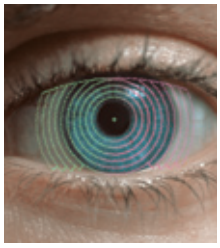


Plants produce useful raw materials: Through genetic engineering, algae and higher forms of plant life can be encouraged to manufacture valuable drugs and chemicals of remarkably high quality.



The laser is steadily being adopted for many new industrial applications. The use of special mirrors to guide the beam with great precision speeds up the welding of complex parts and optimizes the manufacturing process.

Conductive and luminescent polymers are creating new perspectives for the design of innovative products such as low-cost electronic labels, roll-up displays and smart clothing with integrated sensors.



Many security technologies are based on unique attributes that allow a person to be identified. Biometric methods have proven to be a highly reliable solution.

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Internet of things
Parcels that deliver themselves

Taking a lead from the Internet and the way in which data packets find the optimum route from one network node to another and onward to the addressee, the "Internet of things" foresees that physical packages should organize their own route to the customer: With a final mouse click, goods ordered online set off on their way to the recipient, requesting the necessary transport services and deciding at each node which is the quickest route forward.
Having objects of all types monitor and control themselves over the Internet is an enticing proposition. All too often the advantages of electronic ordering are squandered because the goods do not reach their destination fast enough. Consequently the success of e-business and e-commerce hinges more on logistics than on information technology. However, the successful principle of transporting data is difficult to apply to transporting physical items that are heavy, bulky or fragile.

Logistics as an economic factor

The vision of the "Internet of things" is now within our grasp. The Fraunhofer-Gesellschaft intends to leverage these wide-ranging opportunities for Germany as a logistics location. Largely unnoticed by the general public, Germany has turned into an international frontrunner in the field of logistics.
Over the past five years the sector has seen 8 percent annual growth and, if the forecasts prove right, the logistics market will continue to grow. Professor Michael ten Hompel from the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund has therefore brought together the expertise of numerous Fraunhofer Institutes in the disciplines of the emerging field of the "Internet of things", and brought in partners from commerce and industry.
To realize this vision, logistics objects – products, crates, packages, palettes, containers – will need to become independent "subjects". They receive an electronic identity and are networked wirelessly with their environment. RFID technology provides the key to giving what have tended to be dumb items the freedom to choose, making them "smart" and giving them the "ability to communicate".
RFID tags or labels are attached to packaging, boxes or containers. They include a chip on which considerably more information can be stored than in a barcode. Information on batches and serial numbers can be included as well as details of the manufacturer, country and item number. The contact with the environment is established using a transmitting and receiving antenna that allows data to be read out wirelessly over a certain distance any number of times. This technology provides seamless goods tracking throughout the entire product cycle. New generations of RFID tags and labels will be so efficient and cost-effective that you will be able to attach them to virtually anything.

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Each package finds its own way to the customer on the "Internet of things".

The Internet will become an information and switching hub for physical material flows. Communications will be based on standardized protocols such as EPC global. Increasing volumes of data demand entirely new control concepts: Packages, containers and pallets will need to know their destination and also be able to get there on their own. In other words: material flow will not control the consignments but vice versa, enabling in-house and external logistics systems to respond automatically and adjust flexibly to changing requirements. All of which opens up the possibility of self-organizing, autonomous logistics networks. The current centralized logistics concepts would not be able to meet these growing requirements.

Highly complex networks and increasing process speed mean transparency alone is no longer sufficient. Information must be processed and interpreted in real time to identify where things go wrong and respond quickly. And ultimately this decentralized control philosophy finds its logical extension in agent-based communications. These mobile software agents ensure that vehicles and conveyor technology kick in exactly as the consignments demand – without any central computer, autonomously, wirelessly, under their own control.

Fraunhofer researchers have already tested such a solution as part of an in-house material flow system: The package fitted with a tag receives the destination information including all possible routes in the goods-in department. The remote control unit reads out this information at all decision-making points and autonomously guides the package. Products find their own way from production through to the customer – and back again to recycling – on the "Internet of things".

Internet of things at the Fraunhofer-Gesellschaft

The "Internet of things" links ICT with microsystems engineering and logistics.

Principal applications

– Hardware and IT: Aware objects
– Material flow systems: Adaptive baggage handling systems
– Management: The logistics network assistant

Key R&D areas

– Chip technology
– Network technology
– Software technology
– Material flow technology
– Logistics

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Smart products and environments
Invisible helpers at the ready

Electronics have found their way into many everyday appliances: digital alarm clocks, coffeemakers, the computer, or the car. Yet whatever all these appliances have in common, the user needs to work out how each device works. The vision of "ambient intelligence" provides a better solution: The devices are networked to form a "ubiquitous computing environment" and automatically adapt to the user depending on specific circumstances – thus adding value for the individual. The ubiquitous computing environment waits unobtrusively in the background ready to help, responding only when needed.
Relentless electronic miniaturization coupled with wireless communications technology create the conditions for ubiquitous computing environments: Tiny electronic components contain microchips, sensors and radio transmitters. Consequently they transform objects and infrastructure in the human environment from passive into active objects. The embedded electronics not only connect electrical appliances. They provide the individual's entire environment – e.g. clothing, tables, windows, blinds, carpets – with additional functions and integrate these functions into communication networks. These may be local networks in the home or office, or even the Internet.

Ubiquitous electronic assistants

Networked, integrated systems – for the home, car, machine tool, clothing – form a ubiquitous electronic assistant around the individual. The electronic assistants work away in the background single-mindedly helping the individual. Data tends to be transferred via wireless *ad-hoc* networks: If the user comes into the office, the PDA synchronizes any data automatically with the PC, unbeknownst to the user.
In the home the ubiquitous computing environment provides added security and convenience; it regulates heating and lighting and connects the occupant to other people via various communication channels. "But the human individual is not the only player in ambient intelligence," says Prof. Dr. José L. Encarnação, director of the Fraunhofer Institute for Computer Graphics Research IGD. "Machines, vehicles or other objects, what we term smart players, can assume this role too. The principle is that their environment provides support services depending on the environmental context and their needs." On the road, vehicles could communicate with one other, share data about traffic jams, speed or state of the road surface. Ambient intelligence can even help look after pets, with sensors that recognize signs of illness and automatically notify the vet.

Interface between hardware and software

Microelectronics, nanotechnology and communications systems form the technical basis for ambient intelligence. Strategies are now being developed to help devices organize themselves. Assistance is provided through middleware technologies that facilitate data exchange between the various applications. One such example is the universal Plug and Play standard, which allows computers, televisions, multimedia devices and household appliances to automatically recognize and communicate with each other or share data.

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Smart products and environments at the Fraunhofer-Gesellschaft
Ambient intelligence is the vision of a world where environments respond independently, proactively, intelligently to the needs of the various players in line with given circumstances.

Principal applications
– Work and home
– Shopping, leisure and events
– Emergency assistance
– Personal medical assistance
– Logistics, transportation and traffic
– Production and maintenance

Key R&D areas
– Novel sensors
– Open communications and interaction platforms
– Middleware for *ad-hoc* networked systems
– Information management, context, situation and objective identification
– Architecture and engineering standards

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Microchips under the carpet locate devices or control service robots.

The communication process among the component devices is not static or fixed – in other words they are not preprogrammed. Instead, communication is geared to available communication channels. Methods for context and situation identification are crucial in this respect. Here sensor and tracking systems play just as important a role as technologies that semantically map characteristics or interfaces for voice and gesture identification. "Knowledge-based systems are also required to enable software systems to interpret the information provided by the context," explains Professor Heinz Gerhäuser, director of the Fraunhofer Institute for Integrated Circuits IIS. "In this way the environment can identify the players' possible intentions and needs and, where necessary, develop and apply strategies to respond to the environment. Our consistent aim has been to create humanized technology that assists the individual."

Markets

Miniaturized fuel cells improve the power supply options for mobile electronic devices.

Micro power engineering
Mobile power supplies

Laptops, camcorders, cell phones, PDAs, digital cameras or MP3 players – portable electronic devices are becoming more sophisticated with each new generation of products. A notebook lets you process text, images and graphics, play DVDs or access Web sites. Apart from making calls, a cell phone will now let you take photos or navigate the Web.

All these additional functions require power of course. Yet while microprocessors have become around thirty times faster over the past ten years, the energy density of batteries has barely doubled. Battery times suffer as a result, with laptop batteries providing as little as two to three hours of power. Meantime power-hungry UMTS handsets will need to be charged at least once a day during normal use.

New energy technologies are thus needed to support potentially higher energy densities or for use in conjunction with batteries to create hybrid energy systems that significantly extend the battery life of each device. Researchers from numerous Fraunhofer Institutes are working on micro power engineering solutions.

Power from ethanol

"Micro power engineering is playing a key role in a large number of fast-growing markets such as microelectronics, actuator technology and microsystems engineering," stresses Prof. Dr. Joachim Luther, who supervises research in this area at the Fraunhofer-Gesellschaft. Today batteries, accumulators or supercaps dominate micro-energy technology.

One of the most promising candidates among emerging technologies in micro power engineering is the miniaturized fuel cell. By comparison with rechargeable batteries, fuel cell systems have a far higher specific energy density. Pure methanol contains 5,500 watt-hours of energy per kilogram (Wh/kg), while the corresponding figure for ethanol is an astounding 7,800 Wh/kg. This technology makes way for much longer battery life. Experts predict that fuel cell systems will make the breakthrough to the mass market by the end of the decade.

The direct ethanol fuel cell is one highly promising solution. It offers several advantages over other low-temperature fuel cells: Ethanol is a high-energy, non-toxic product that can be stored and transported more easily than hydrogen. Added to which, a universal supply infrastructure is already in place.

Alongside fuel cells, solar cells, piezoelectric converters, microturbines and micromotors as well as thermoelectric converters, dry-cell and rechargeable batteries are another option for micro-energy technology. Depending upon requirements, individual components can be combined with batteries to produce hybrid systems. Thus a tailor-made energy supply can be developed for any application covering an output range from a few milliwatts to several hundred watts.

Thanks to the high energy and power density of these highly efficient energy converters, a hybrid energy supply system easily outperforms conventional rechargeable batteries.

Mobile sensor systems

Hybrid solutions are also a compelling option for sensors or transponder systems such as RFIDs used for environmental monitoring, goods logistics or security applications, for instance. These applications often require a power supply that can power a device for a long time with minimal maintenance and yet also needs to be small and light. Maintenance-free mount-and-forget applications are just one area where such requirements exist.

Micro power engineering at the Fraunhofer-Gesellschaft

Development of efficient energy converters and energy storage devices, customized energy management systems, and suitable assembly and interconnection technologies.

Principal applications

– Medical engineering
– Environmental sensors
– Consumer electronics
– Security systems
– Smart cards

Key R&D areas

– Fuel cell systems
– Batteries, accumulators, supercaps
– Solar cells
– Thermoelectric devices
– Piezoelectric converters
– Microturbines and micromotors

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Adaptronics
Self-regulating structures

Nature provides the models for the young branch of research known as adaptronics, in which the perfect interplay of the brain, nervous system and muscles is applied in a comparable way to mechanical structures. With active material systems and control signal processing they can adapt to changing operational conditions. Active structures suppress vibrations, reduce noise, control deformation and recognize component damage.
The term adaptronics is coined from "adaptation through electronics". Adaptive structures consist of sensors, actuators, control-system and electronic components which are a constituent part of the structure itself. They are based on active function-integrated materials such as shape-memory alloys, piezoelectric and electrostrictive ceramics, magnetostrictive alloys and electroactive polymers, which function both as sensors and as actuators. Adaptive structural systems adapt themselves to changing operational conditions.

Vibration suppression and noise protection

Vibration and noise are closely linked. If a structure vibrates, it usually also emits noise which places a critical load on components and reduces their service life. Suppressing vibration and noise is a typical task for engineers. Modern structures, particularly in vehicle manufacture and mechanical engineering, are being made lighter, which means they are more susceptible to vibration. Adaptronics offers solutions to this problem. Fraunhofer research scientists are developing techniques for fusing active materials with the structure. For instance, piezoelectric fibers are introduced into metallic components by means of composite materials to create an active material system.
Such components have local or distributed sensor and actuator capabilities. They can measure mechanical vibrations in car body parts, engines and wheel suspensions, convert them into electrical energy and use them for charging a battery, or they can actively control the propagation of vibration by introducing counter-movements.

Active protection

In the EU project APROSYS (Advanced Protection Systems), Fraunhofer research scientists are developing systems which can recognize when a vehicle is entering a potential accident situation and intervene in the properties of the structure before a possible collision occurs: Sensors monitor the vehicle environment and e.g. activate a bolt mechanism to strengthen the car's doors before it crashes. If no collision occurs, the bolt mechanism is immediately released. This process is based on shape-memory alloys, i.e. metals which "remember" their original shape and can return to it.

Adaptronics at the Fraunhofer-Gesellschaft
We understand adaptronics to mean the development of structures which permit the direct, actively controllable, purpose-optimized adaptation of mechanical properties to changing operational conditions through function integration in structures.

Principal applications
– Active chassis, active engine suspension
– Vibration reduction on machine tools
– Safety technologies in the transport sector

Key R&D areas
– Materials and components, intelligent material systems with sensor/actuator function properties
– Numeric and experimental methods, system analysis and evaluation
– Electronics and control technology, controller and circuit design
– System applications and technology transfer

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Adaptronic systems actively suppress vibrations in machinery and vehicles.

Applications
Adaptronics offers solutions for optimizing products across different sectors and technologies. Areas of application exist e.g. in machine tool manufacture, automobile and transport technology, aerospace, optical systems, medical engineering and in the consumer goods industry.
Low-vibration sports equipment such as skis and tennis rackets represent initial commercial applications. Stronger aircraft, automobiles which are both more comfortable and safer, higher-precision tools, quieter machinery and lighter components are just some examples from the broad spectrum of other possible applications.

Coordinated research
Twelve Fraunhofer Institutes are conducting work in the field of adaptive structural systems in the Adaptronics Alliance. The Fraunhofer Project Group FASPAS (function-consolidated adaptive structures combining piezo and software technologies for autonomous systems) is engaged in market-oriented, strategic pre-competitive research. They are all pursuing the goal of developing prototypes and demonstrators through to products and processes which are ready for commercial application.

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Simulated reality: Materials, products, processes
Future worlds inside a computer

Anyone involved in planning or design engineering would like to take a look into the future: How will the product really look? Will the processes function as intended? What would happen if I changed the design?
This wish can be fulfilled by simulating reality as realistically as possible. High-performance computers and software tools have enabled simulated reality to develop into an important instrument for planning and design engineering – one which still holds great potential for further enhancement and application.

Model, tool, test instrument

Simulation programs describe and compute events and objects in digitized form. As a result, products, components, buildings, procedures and lots of other things can be viewed and studied on screen – and appropriately changed and adapted before realization. This helps to avoid the risk of design errors, saving time and money.
It is no longer possible, for example, to design highly specialized filters for industrial applications using the old approach of trial and error. What's more, simulation techniques reduce the time and money expended. The first step is to enter the component's data and all relevant parameters into the computer. These include the filter medium and the filtered particulate, the design and installation of the finished component, and the operating conditions, which can be extreme, e.g. in a sewage plant, an air conditioning system or an exhaust particulate filter.
The task of developing high-performance materials, e.g. electroceramics for use as switching elements in microelectronics or as piezoelectric sensors and actuators in motors, is equally demanding. The material properties in fringe or extreme areas are difficult to determine experimentally, so that simulated reality is becoming an essential tool for understanding the processes and developing the requisite materials.
New and efficient approaches are required in process development too. Engineers who design and build plants for the manufacture of high-quality fiber products and textiles need to further increase the pace of innovation in order to maintain their lead in international markets. New simulation tools from the Fraunhofer Institutes can provide the technological edge in process development to help such companies defend their market position.
Testing is an important part of new product development. In order to handle this on the computer, simulation techniques from a wide range of different disciplines, such as stress analysis, strength of materials, hydraulics and control technology have to be linked together – another challenge for the developers of new simulation tools.

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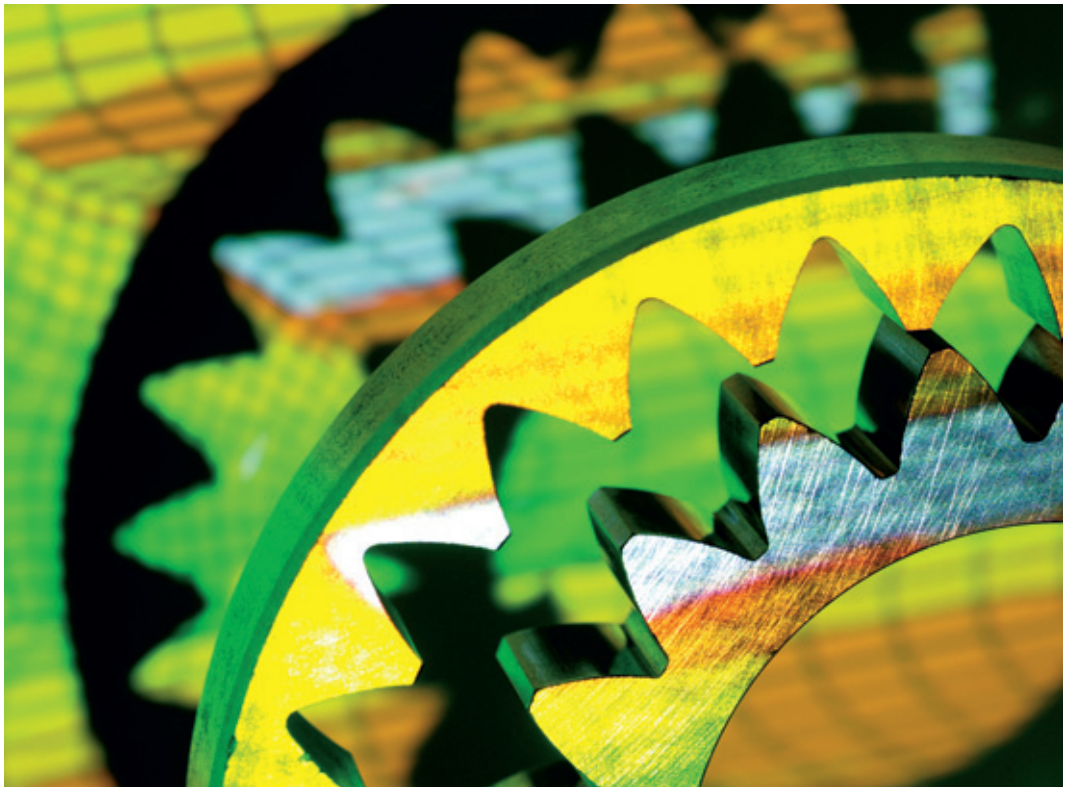

Modern simulation technology makes it possible to test components in the design phase.

Research into computer simulation

A large part of the work conducted by the Fraunhofer Institutes consists of planning, development and design engineering. Simulation technology is therefore one of the standard tools employed by Fraunhofer scientists. The systems themselves, their further development and adaptation to new areas of application also represent an important area of business for the Fraunhofer-Gesellschaft. Fraunhofer Institutes conducting work in the fields of information and communication technology, materials/components and production are pooling their information technology and application-specific capabilities in order to create new practical, high-performance simulated reality methods and software tools.

Simulated reality at the Fraunhofer-Gesellschaft

We define simulated reality as an approach that combines scientific/technical simulation and optimization techniques with modern visualization and interaction methods.

Principal applications

– Complex functional materials
– Product design (filters, fuel cells)
– Process design (textile spinning, surface coating)
– Virtual testing and monitoring

Key R&D areas

– Multiscale material modeling
– Computational and reverse engineering
– VR-based interactive tools

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Markets

Human-machine interaction
An end to button-pushing

Manufacturing equipment, consumer appliances in the home, electronic devices, service terminals – all good ideas meant to simplify our lives. In many cases however, the result is confusion. People struggle with a myriad of machines: the VCR at home, the automated ticket dispenser at the train station, the new computer system at work.
Teaming up to bring relief are thirteen Fraunhofer Institutes from the fields of information and communications, microelectronics and production. By improving human-machine interfaces, their aim is to make it easier to manage technology. People will no longer need to undergo tedious learning processes – instead, our electronic assistants simply react to speech, gestures and mimicry.

Virtual reality systems give designers the freedom to move around without the distraction of complicated input devices.

Human-machine interaction at the Fraunhofer-Gesellschaft
Human-machine interaction involves the user-oriented design of interactive systems. Knowledge from diverse disciplines flows into this work including computer science, microelectronics, surface technologies, production and industrial engineering.

Principal applications
– Interactive automotive systems
– Intelligent operation concepts for the home of the future
– Interaction with mobile systems: Applications for communication and navigation, e.g. for mobile healthcare services or service robots in a domestic environment
– Virtual environments to support development, testing, training and maintenance: New forms of training systems and operating guides
– Intuitive and physical interaction in manufacturing

Key R&D areas
– Multimodal input/output interfaces
– Sensor technologies for context-sensitive human-machine interfaces
– Virtual technologies
– Integration of software engineering, product development and usability engineering

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Sensors: Intelligent and miniaturized

Fraunhofer researchers face several challenges in their quest. Sensors have to be developed that can process sensory input like sight, sound and touch. Using measurements such as pulse rate or the skin's resistance, these assistants will even comprehend the user's emotional state and react accordingly. Interaction systems based on physical contact are especially important where people and machines share the same space – manufacturing facilities and robotic workstations for instance. Furthermore, equipment and systems will adapt themselves according to how they are being utilized, to accommodate the user. What is the environment of the person operating the machine? What kind of task is he or she performing?
Miniaturized sensors are the technical prerequisite. They must be able to analyze environmental and vital physiological parameters, identify objects and people and, as in virtual reality, accurately determine their position relative to one another.
This is where microelectronics comes in. Sensors must operate self-sufficiently, be able to handle signal processing tasks and be equipped with wireless communication interfaces.

Better operability: Opportunities for people and markets

The benefits of improved interaction between humans and machines can be seen in the example of driver assistance systems. When a driver brings a car too close to a pedestrian or other object, the system intervenes and maintains the required safe distance. At production workstations, people and robots could physically work together in the future, eliminating the need to operate in separate, strictly supervised areas. Intelligent machines will learn from their users, able to be programmed through demonstration.
New opportunities abound, particularly for a society that is steadily growing older. One example is Care-O-Bot, a robot created by Fraunhofer researchers and designed to help elderly, ill or handicapped individuals lead independent lives in the comfort of their own environs. Another thriving Fraunhofer project is the intelligent house in the city of Duisburg. Here, researchers can run trials of alarm functions, resource-saving building technologies or the operation of household appliances in a real setting.
"Our aim is to make simple-to-use technologies a hallmark of the Fraunhofer-Gesellschaft's research work," explains Professor Dieter Spath, director of the Fraunhofer Institute for Industrial Engineering IAO who adds that "the intuitive operation of technology will create new markets."

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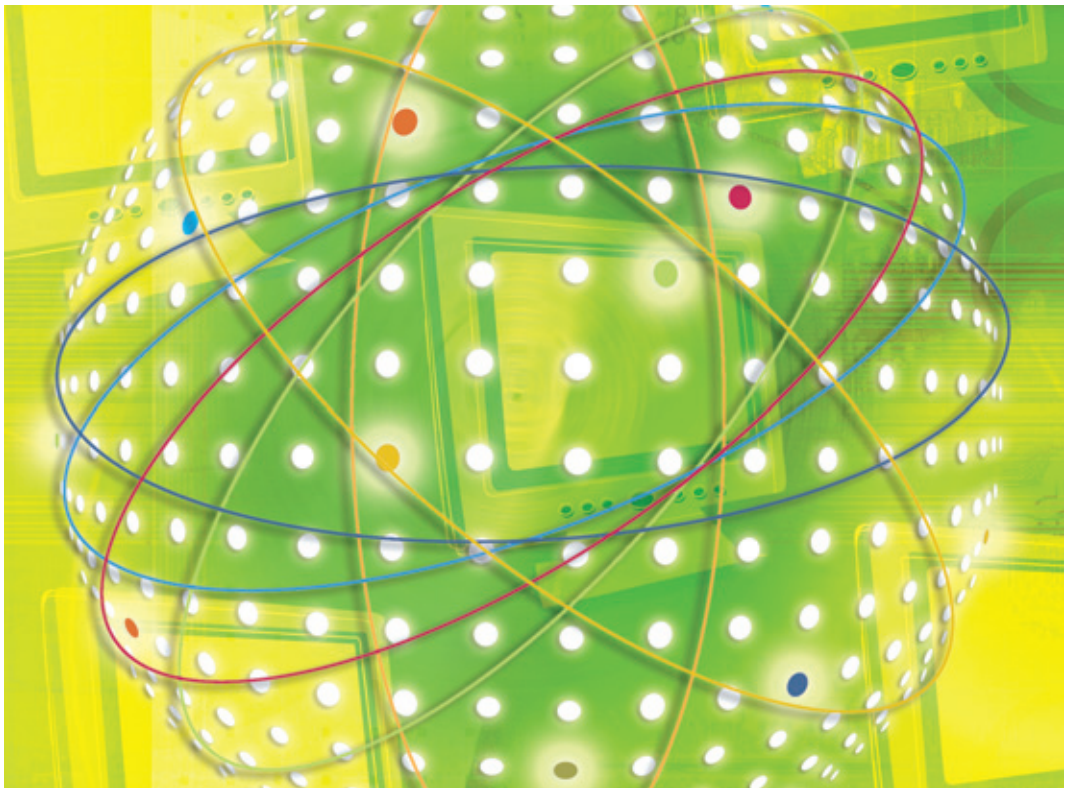

The World Wide Grid will revolutionize industrial work flows.

Grid computing
Link up wherever you like

markets

Humans need sleep to keep performing. Computers, on the other hand, operate around the clock provided they have a power source. And while their owners laze around in bed, they can use this time to take care of other jobs.
By linking scores of processors through a network and adding the appropriate software – or middleware – a grid is created. Grids made up of many networked components such as processors, databases, software libraries and archives can be used just like a large computer system. They are already being used today to connect numerous research institutes and computer centers, simplifying the work of scientific investigation and large-scale data analysis.

Grid computing for the enterprise

Grid technologies are blazing a trail from the lab to the real world. Industry has now discovered the numerous benefits these new computer networks offer: enormous processing power, access to costly hardware and software and streamlined cooperation between project partners, R&D departments, manufacturers and suppliers. "The vision is the creation of a virtual organization by networking all participants in the development of a product," explains Professor Ulrich Trottenberg, director of the Fraunhofer Institute for Algorithms and Scientific Computing SCAI. The strategic objective of the Fraunhofer-Gesellschaft is to tap the innovation potential of grid technologies for use in industrial applications.

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Grid computing at the Fraunhofer-Gesellschaft

Grid computing describes a means of utilizing distributed IT resources. It operates in a similar way to the public utilities supplying water, electricity or gas: The consumer (or user) has no need to worry about where the service comes from. They simply pay for the quantity consumed, with a guaranteed quality of service and built-in security. Access to the grid is just as simple as access to the Internet.

Principal applications

– Virtual workgroup cooperation
– Knowledge management services
– Decision support

Key R&D areas

– Establishment of common security standards
– Cost-effective industrial grid systems
– Software interoperability improvements
– Billing services for application grids
– Outsourcing of data-processing infrastructure

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Europe is catching up

Like the Internet, the idea of connecting computers into grids originated in the United States. But Europe is investing in this new technology as well. Brussels has earmarked 52 million euros over the next few years to promote the development of grid technologies to make Europe more competitive. 11 million euros alone have been set aside for the SIMDAT project (data grids for process and product development using numerical simulation and knowledge discovery). Besides the Fraunhofer Institutes for Autonomous Intelligent Systems AIS and for Algorithms and Scientific Computing SCAI, industry partners such as Audi and IBM are also participating in the project. The aim is to develop grid technologies for process planning in the automobile manufacturing, aerospace and pharmaceutical industries.

This is no easy task. Standards must first be developed to ensure component compatibility. Another key element is the creation of middleware to control the system and each of its parts. Add to that the issue of security. Confidential data must be protected from unauthorized access, a risk that calls for special attention when dealing with a large network.

The Fraunhofer researchers bring their own experience with the Fraunhofer Resource Grid to the project. Apart from connecting all members of the Fraunhofer Network for Grid Computing, the grid also permits access to other types of resources such as sensors, analysis equipment and simulation programs.

The World Wide Grid vision

Grid technologies offer the prospect of new applications in which numerous small computer elements – sensors, wireless communication modules and computer processors – can be integrated into devices at home, at work or in the car. This will result in the creation of a new dimension in ubiquitous computing – ambient intelligence.

"A World Wide Grid, with global reach, will revolutionize industrial work flows in research and development, product design, manufacturing, sales and marketing," predicts Professor Trottenberg. The only thing that will remain unchanged, even in the age of grid computing, is that people will still need their sleep.

Integrated lightweight construction systems
Weight-loss diet for four-wheel patients

Automobile and aircraft manufacturers impose the highest requirements: Vehicles have to be lightweight but strong and reliable while at the same time ensuring the safety of the occupants. New models have to lose weight because the heavier a car or an airplane is, the more fuel it consumes and the more emissions it discharges. At the same time, however, vehicles are increasing in size and are being equipped with more and more intelligence and comfort.

High-performance materials

New lightweight construction concepts are required. Various competing lightweight materials are being used in vehicle manufacturing, including aluminum and magnesium, as well as fiber-composite materials and thin-wall steels. Research scientists are developing new mixed materials comprising fibers of different materials such as ceramic, metallic foams, high-strength light-metal alloys, steel and titanium. "The future lies in the intelligent combination of different materials. Components are becoming more and more complex and incorporating additional functions," explains Dr. Thomas Hollstein from the Fraunhofer Institute for Mechanics of Materials IWM. The design of a suction tube for fuel injection pumps must, for example, incorporate interior flow characteristics as well as switching and measurement functions.

Heavy materials too can be used to make lightweight components. Here scientists were inspired by the biological principle of bone growth, where supporting tissue is thinned away at less stressed points and laid down thickly at the more heavily stressed points. By applying this principle, it is possible to strengthen the structure of a lighter metal support while maximizing the efficient use of materials.

Metal foams are proving to be extremely versatile. They can be pressed into any shape, cushion impact in an accident and serve as protection against heat and noise. Hollow spheres which are fused with each other represent one variant of these foams.

Magnesium alloys are lighter than aluminum but more difficult to process, and to exploit the high potential of this material a great deal of further research work is required. To this end, six Fraunhofer Institutes are pooling their resources in an industry-oriented strategic alliance devoted to magnesium lightweight construction.

Joining technologies

The future use of new materials or composites depends crucially on the joining technologies employed. They make it possible to connect different materials in order to create lightweight structures. Punch-rivets and clinches play an important role here, along with bonding, soldering, laser welding and laser hybrid welding.

An example of modern joining technology has been provided by the Fraunhofer research scientists in the form of a 16-meter-long laser welding facility for airplanes which combines high precision with rapid production. Pinpoint welding by laser is also suitable for lightweight construction materials, because the laser precisely melts only the actual contact point, which means that thermally induced stresses are lower than with other welding techniques.

The instrument panel of a luxury automobile: Top-quality lightweight construction.

Robust production

Engineers have an eye on the entire manufacturing process. They develop made-to-measure materials, harmonize production processes and analyze all the details in model tests and computer simulations. Lightweight construction does not just mean using lighter material. The scientists test the intricate interplay of ultra-light material and filigree structures in dry runs. On computer they analyze the static, dynamic and thermal properties of the dynamic component, simulate strength, thermal expansion, corrosion, crash behavior, durability and recycling, and develop high-precision production techniques. Will the lightweight structure withstand extreme conditions? Trials using full-scale models are the acid test.
Lightweight construction is more than just a means of saving energy and conserving resources. Small and lighter components reduce vibration, noise and wear on moving parts. The many different material variants make it possible to create innovative structures and production processes, through to self-optimizing production equipment.

Integrated lightweight construction systems at the Fraunhofer-Gesellschaft

The weight of components is reduced by using innovative materials, processes and concepts. Stability, safety and reliability of the lightweight construction systems are optimized.

Principal applications

– Lightweight construction concepts, component developments
– Lightweight structures
– Lightweight vehicles

Key R&D areas

– Materials development
– Materials behavior (simulation)
– Production processes
– Joining technologies
– Assessment of components and systems

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White biotechnology
Nature's own chemical plant

White biotechnology at the Fraunhofer-Gesellschaft
White biotechnology refers to the industrial production of organic basic and fine chemicals and chemical agents with the aid of optimized enzymes, cells or microorganisms.

Principal applications
– Platform chemicals for polymers (polyester, polyamide, polyurethane)
– Fine and specialty chemicals for vitamins, pharmaceuticals and cosmetics

Key R&D areas
– Enzyme design and screening
– Biotransformation and product harvesting, process integration
– Manufacturing, characterization and evaluation of bioproducts

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The price of petroleum is rising steeply – a situation that also severely affects the chemical industry, for mineral oil is the starting material for many of its products. The raw petroleum is split into its constituent parts in a refinery, where they are converted into a variety of basic chemicals. The chemical industry transforms these into the wealth of chemical products we use in our everyday lives: plastics, paints, detergents, adhesives, medicines.
Germany is the world's third largest producer of chemicals, after the USA and Japan. The chemical industry is one of the most important branches of industry in Germany, and a major supplier of basic materials to customers in many other sectors, including vehicle manufacturing, packaging, electrical and electronic engineering, the construction industry, pharmaceuticals and food processing.

From petrochemicals to biochemicals

As we all know, stocks of fossil resources are rapidly declining. The only practical alternative source of carbon-based materials for the manufacture of chemical products is biomass. The chemical industry in the USA intends to obtain one fourth of the organic basic chemicals it needs from renewable raw materials by the year 2030. European chemical companies and biotechnology firms are also investing considerable research efforts into the development of processes that will allow them to use biogenic raw materials.
There are already a few types of plastic available produced from renewable resources and typically used as packaging material or to make disposable tableware. But not all plant-derived chemicals are suitable for use in their natural form – many of them have to undergo further chemical processing. In the natural materials cycle, this work is often done by enzymes. Living cells use these protein molecules as catalysts to control their metabolic processes. The products of these enzymatic reactions include widely used compounds such as lactic acid or other organic acids and alcohols – substances of great interest to the chemical industry.

The new challenge

Admittedly, this reorientation will not be easy to accomplish, given that the existing industrial processes are entirely geared to working with petroleum. Before biomass can be employed on a large scale as a source of raw materials, industry needs assurance that it will be available in sufficient quantities, and a guarantee of consistent quality and competitive prices. The biotechnology sector also has to solve a number of problems before being able to manufacture chemical products on an industrial scale. It is a question of finding the most suitable enzyme or a microorganism capable of breaking down the cheaply produced raw material, optimizing processes and, where necessary, filtering out unwanted byproducts.
Industry is constantly searching for better enzymes. Those that it discovers could allow researchers to develop new processes that would prove useful in areas of manufacturing in which no biotechnological solutions exist at the present time. This is no longer the domain of trial-and-error experimentation: These days, the DNA of a multitude of organisms is systematically investigated using high-throughput screening methods to test huge numbers of promising candidates simultaneously and under a wide range of conditions. Computerized analysis techniques enable new variants of identified enzymes to be tailor-made for all imaginable types of application.

Working in unison to promote modern chemistry

The accomplishment of this paradigm shift in the principles of chemical production calls for joint efforts by chemists, biologists, biotechnologists, physical scientists and process engineers – areas in which the Fraunhofer Institutes excel. Their strengths are united under the banner of an interdisciplinary approach that goes by the name of "white biotechnology". Together they will be able to help industry shorten the development time-frame for new products and processes.
The transition to white biotechnology promises to create new jobs and boost exports of advanced technologies and innovative products. Furthermore, the use of renewable resources and environmentally sound processes will help to meet demands for the sustainable management of natural resources and responsible business practices.

Biostat production plant: Algae produce a valuable red dye for the cosmetics industry.

Tailored light
Using light as a tool

Tailored light at the Fraunhofer-Gesellschaft
The synergistic effects of the collected expertise in coating, micro- and nanostructuring techniques available at the Fraunhofer Surface Technology and Photonics Alliance enable completely new developments, and not only in medical engineering and biotechnology. Industrial users will also benefit from new methods in joining technology and production engineering, especially those employing lasers.

Principal applications
– Fiber lasers
– Projectors
– Sensor systems
– Next-generation lithography
– New joining, structuring and coating techniques

Key R&D areas
– Beam sources and beam-shaping systems
– Photonic manufacturing and processing techniques
– Integration of optical components in microelectronic circuits
– Optical data transmission

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Optical technologies count among the key technologies of the 21st century. They revolutionize the flow of information in optical networks, while non-contact materials processing is constantly finding new areas of application thanks to the efficient use of beam sources. Optical sensors combine speed and selectivity, and achieving further structure miniaturization in microelectronics is possible only through the targeted use of tailored light.
The predominant factor driving these developments is the laser, which allows light to be very specifically applied in the dimensions of energy, time and wavelength. Understanding the complete beam source/application task demands the close cooperation of experts in the fields of optics, medicine, biology, telecommunications, metrology, electronics, materials science and production engineering.

Twinkling fibers
Fiber lasers and fiber amplifiers are based on optical fibers that can internally generate laser radiation. Because of their low light output, applications were limited to data transmission and metrology up until just a few years ago. Since then, however, high-power fiber lasers have become available that have around ten times higher beam quality and five times the service life of standard diode-pumped Nd:YAG lasers.
This permits their use in applications involving cutting, welding, or coating large components from a distance of several meters. The position of the tool heads now only needs minimal adjustment by robots. Scanning mirrors are able to guide the beam rapidly from one position on the workpiece to the next ("on-the-fly") due to their near-zero inertia. But fiber lasers using ultra-short pulses also open up a number of new possibilities for applications in micromachining.

Terahertz radiation

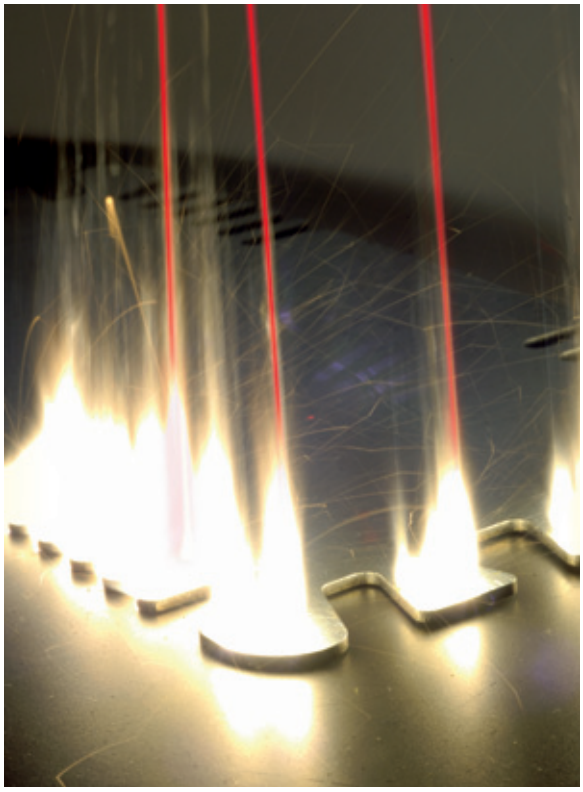
The terahertz band of the electromagnetic spectrum is so named because of its frequency – 10^{12} hertz – which corresponds to the region between far-infrared and microwave radiation. Because of the fundamental problems associated with generation and detection, "T-rays" had previously found few technical applications. But considerable efforts to commercially exploit the technology have recently manifested themselves around the world. Fiber lasers, once again, are promising candidates to provide powerful beam sources pulsed in the femtosecond (10^{-12} s) range.

An alternate approach for generating terahertz radiation stems from the development of ultra-high frequency electronic components. In contrast to X-ray devices, applications using terahertz radiation can be operated without the need for shielding. Similar to visible light, they can penetrate a variety of materials and deliver images from which conclusions can be drawn on the chemical nature of the materials. This creates potential applications in safety and security systems, because it allows detection of dangerous substances or weapons through textiles and packages. There is also potential for related applications in production monitoring and quality assurance.

Extreme ultraviolet (EUV)

This area of the electromagnetic spectrum lies between X-ray and ultraviolet radiation, with wavelengths of just a few nanometers. As with the X-ray band, standard optical sources and beam-forming components such as lenses, prisms and mirrors cannot be employed. Completely new light sources and optical components must be developed in order to make flexible, tailored light available using EUV.

One important field of application for EUV will be lithography for finely structured microelectronic circuits. Perfecting this technology will ensure strategically important access to micro- and nanoelectronics, which are already assigned a key role in all branches of industry. EUV microscopes will make the smallest dimensions accessible, especially in areas that cannot be explored using electron microscopy.



Lasers in industry: Directing the beam using special mirrors enables rapid, complex welding operations.

Polytronics
Printed circuits – luminescent wallpaper

For the past several years, light-emitting, conducting plastics have been revolutionizing microelectronics and photonics. "Polytronics is a ground-breaking technology platform. The fusion of microelectronics and electrically conductive polymer materials will radically influence many applications over the next five to ten years," notes Professor Herbert Reichl, director of the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin. Areas that stand to benefit from these smart plastics include medical and power engineering, the packaging and clothing industries, life sciences, and logistics.

Intelligent products for a networked world

With its ability to perform a multitude of technical functions and suitability for low-cost mass production, polytronics provides the technical foundation for a networked world. Polytronic transponders are already set to be employed soon in supermarkets as intelligent price tags. All the customer has to do is push the products in a shopping cart past a reader device, and a receipt is printed on the spot. In the textiles branch, the transponder can be used to verify the authenticity of designer clothes. Manufacturers could also store important additional information that the buyer can retrieve later, such as instructions for washing or fabric care.
Smart clothing that can be used by bicycle couriers, for instance, is already in use. It incorporates a navigation system, a back-warming pad and an automatic security system based on a transponder sewn into the clothing that recognizes the owner of the bicycle and automatically releases its lock. Power for the IT systems is supplied by the bicycle's dynamo. Organic light-emitting diodes (OLEDs), made from organic material, are enabling the development of a new generation of wafer-thin, pliable displays that offer excellent image quality. The first OLED self-illuminating display panels are already on the market.

Polytronics at the Fraunhofer-Gesellschaft
The term polytronics refers to the fusion of plastics-based system functions and the "smart plastic" concept.

Principal applications
– Organic LEDs for displays and lighting
– Multifunctional components for IT and communications, life sciences and robotics
– Polymer solar cells for integrated energy supply
– Low-cost electronics and system functions that can be manufactured directly by the end user using inline, large-area processes

Key R&D areas
– Multifunctional polymer materials and composites
– Process technology for polymer-based components

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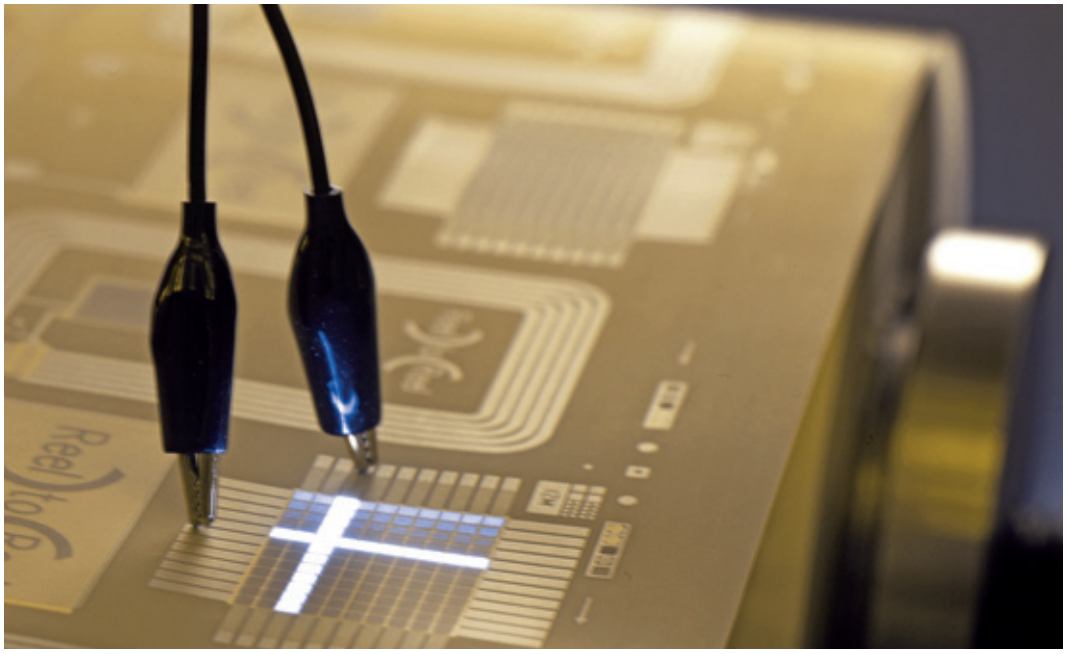
Roll-to-roll

In the late 1970s, American and Japanese scientists discovered that plastics could be endowed with conductive properties through a process known as doping, whereby individual atoms of another substance are incorporated in the polymer. This process makes it possible to produce polymers with a wide range of properties: conducting, semiconducting or electroluminescent. Light-emitting, conductive plastics are the materials of tomorrow. They are transparent and can be used as sensors and actuators, for data transmission and storage, and for energy generation and power storage.

An additional advantage of these plastics is that they can be processed in a fluid state, which facilitates low-cost mass production using established manufacturing techniques. In a process similar to offset printing, electronic circuits are already being manufactured on the basis of conductive polymers. In roll-to-roll processing, the circuits are laid down on thin film and directly printed onto the package. This provides the basis for low-cost electronics that open the door to undreamed-of possibilities. But polytronics cannot – nor does it aim to – compete with silicon technology, since polytronic chips are slower and can only store a comparatively small volume of data.

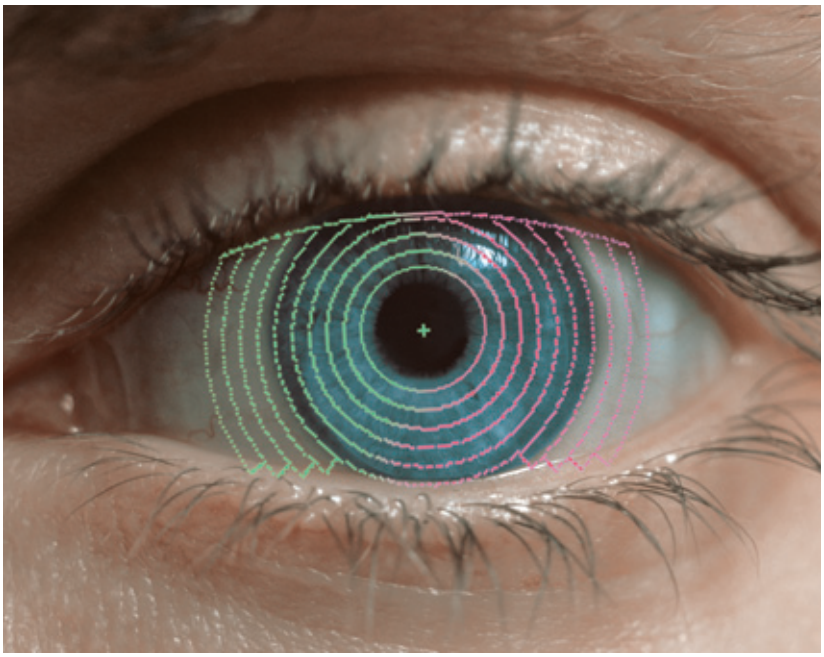
Polytronics research

A dozen or so Fraunhofer Institutes are pooling their expertise in the areas of global networking, ambient intelligence and low-cost electronics. Through the development of pioneering application demonstrators, the Fraunhofer-Gesellschaft can provide substantial support to industry in the implementation of polytronics in product development. Smart plastic will be an important theme for scientists. The first in-house research programs in this area have already begun. Potential applications include intelligent keyboards, bifunctional displays, and film-based polymer sensor systems.



The discovery of conductive, light-emitting polymers creates new perspectives for displays and monitors.

tomorrow's



Biometric methods such as iris recognition aid in personal identification.

Security
The reassuring face of high tech

The nations and societies of the Western world have been experiencing a new and complex threat to their security in recent years, which has made them cognizant of their vulnerability on a number of fronts. A central reason for this is their high reliance on technical systems and the growing complexity of the interwoven networks of the information society. In addition to the threat of terrorism, a danger is also presented by organized crime. Countermeasures to combat these hazards are being initiated on multiple levels and assigned a high priority. These efforts, which must be applied on a broad scale, not only concern protecting the lives and health of citizens, but also defending property and information against attacks and unauthorized access.

Detecting and monitoring critical substances

The detection and monitoring of explosives and chemical, biological and nuclear agents is a key element in providing security against physical threats. Many sensors are based on microelectronic circuits that emit microwave, EHF, or terahertz radiation, which are reflected back off the objects being monitored. X-ray radiation can detect impurities in food as well as weapons in luggage. Complementing these physical sensors are biological, electrochemical and chemical sensors, which can be used not only to detect hazardous materials and pathogenic microorganisms but also, for example, as a reliable means of monitoring the quality of food and drinking water.

Information security

The purpose of IT security is to protect IT systems, based on criteria such as confidentiality, integrity, availability, authenticity, accountability and liability. The holistic approach to security management covers electronic applications, services and terminal equipment in networks – wireless as well as wired – that are becoming increasingly more complex. Security measures must guarantee reliability, efficiency and usability, but must also provide adequate protection against illicit intrusions. Applications range from work environments for individuals and teams to corporate and business processes, through to security-critical infrastructures, such as online banking or control systems for entire power utilities and factories.

Threat reconnaissance and monitoring

One of the chief factors in security is early detection and analysis of threat sources. Monitoring and identification technology are the keys to achieving this. Methods range from global, long-term monitoring of critical regions using satellite remote sensing, to security checks at crossing points on national frontiers and access control to sensitive areas such as bank premises and airport departure halls.
Biometric techniques are especially well-suited to personal identification and verification. Doors will not open, documents cannot be viewed, certain security-relevant measures cannot be carried out until the subject's fingerprint, voice or face is recognized. Old-fashioned keys and PINs will soon become obsolete. Methods based on identifying people by means of unique, unchangeable attributes are still too prone to error, and can often be circumvented through simple means. For this reason, the trend is toward new identification systems that can examine and match multiple parameters simultaneously.

Direct and active protection

The purpose of direct protection is to avoid or minimize injuries and damage that can result from the use of various weapons. In this area, a considerable number of scenarios have to be played out on an experimental basis, the results of which often serve as a foundation for computer simulations. Researchers then use these data to develop new materials such as bulletproof glass, shock-absorbing metallic foams and tear-resistant fibers, with a continually enhanced ability to withstand the effects of violent force. "Non-lethal agents", or substances and devices that effectively hinder aggressors or temporarily incapacitate them, represent another broad field of development.

Security technologies at the Fraunhofer-Gesellschaft

Among the security technologies offered are security concepts by Fraunhofer researchers such as threat and risk analysis, biometrics, data and communications security, analysis, detection and sensors for security-relevant materials such as illegal drugs and explosives.

Principal applications

– Sensors
– Cryptography
– Image analysis software
– Simulations of scenarios and component behavior

Key R&D areas

– IT systems
– Detection and monitoring of critical substances
– Biometric personal identification
– Materials and mechanical engineering

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Researching with Fraunhofer today for market success tomorrow

1949

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The Fraunhofer-Gesellschaft is a provider of research services: We work for clients in industry, commerce and public administration. Our business is built on innovation, and our objective is to transform scientific research into innovative products and applications.

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We work on a global scale

Globalization affects the entire economy – including the market for research and development services. An international presence is synonymous with the ability to compete, establish fruitful contacts and actively follow (or even initiate) technological trends.

For this reason, and for many years now, the Fraunhofer-Gesellschaft has been setting up affiliated research centers and representative offices in the chief economic regions of the world: in Europe, the USA and Asia.

We offer fixed-duration partnerships …

Research is an important factor in business success, but it requires considerable investments. Every company has an interest in organizing its innovation activities as efficiently as possible.

Contract research can help to provide an affordable solution: Engaged as partners for the duration of a specific project, the Fraunhofer Institutes carry out the requested work to professional standards and within a defined schedule. The costs are relatively low and easily calculated in advance.

We have many satisfied customers: The majority of collaborative projects between industry and the institutes are based on follow-on contracts.

Number of people employed by the Fraunhofer-Gesellschaft

Year	Number of employees
1949	3
1959	135
1969	1,250
1979	2,200
1989	6,400
1999	9,000
2005	12,500

1979

… and services on demand

We develop, implement and optimize processes, products and systems through to technical and commercial maturity.
We help our customers to reorganize their operations and implement new technologies by:
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– information and communication technology
– process engineering
– environmental and power engineering
– biomedical research and medical engineering
– structural engineering
– market studies and technology assessment

2005

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