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NANOPHOTONICS

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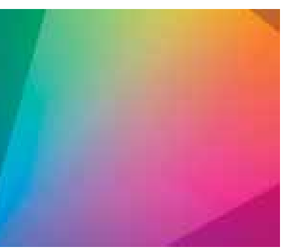
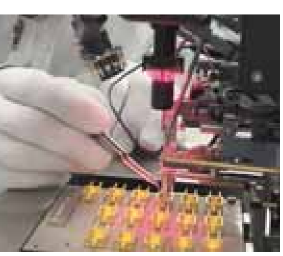
Contents








Worldwide BEACON bold APPOINTMENT POLICY

The new Collaborative Research Centre [Sonderforschungsbereich] for "Semiconductor Nanophotonics: Materials, Models, Components" with its integrated Graduate College commenced work in Berlin and Magdeburg at the beginning of 2008. Under this umbrella, over 100 scientists are now carrying out research on novel types of photonic devices, nanomaterials and the relevant mathematical models.

For an initial four-year period, the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) has granted almost 11 million euros in external funding. The planned duration of the project is twelve years, with a total planned funding of approximately 35 million euros. The State of Berlin and the European Union have allocated further grants for the development of competitive infrastructures, ensuring the establishment of Berlin as a leading research centre in the field of semiconductor photonics both in Germany and across Europe. This comprehensive approach guarantees optimum working conditions for an international beacon project based on huge scientific expertise from the surrounding region.

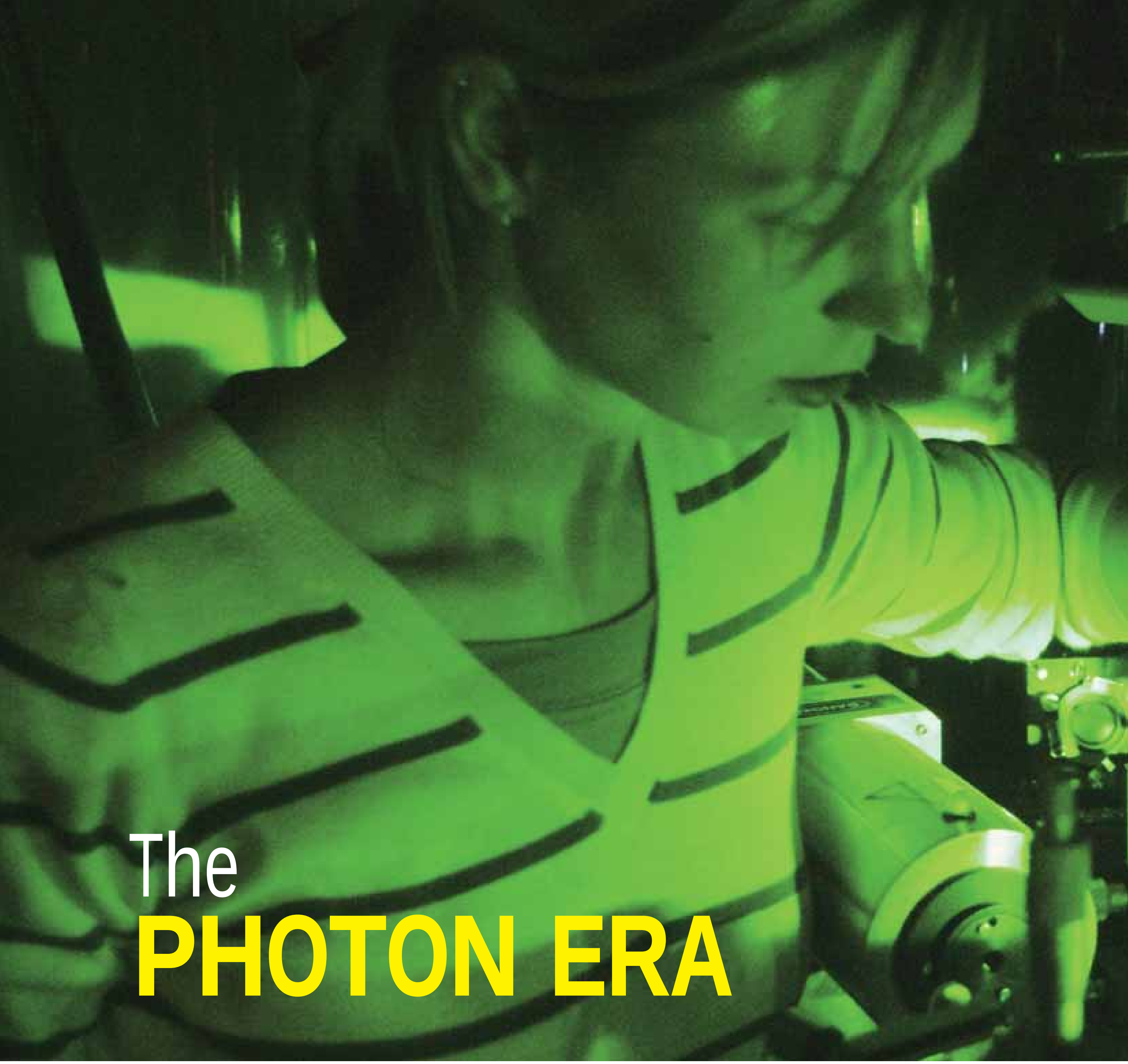
The basic research being carried out at the universities and the applied research being done at the extrauniversity institutes are linked in a unique way. The creation of the Collaborative Research Centre emphasises the significance of the participating institutions constituting the geographical centre for nano-optoelectronic research in Germany. The institutions include the Technical University (TU) Berlin which is the coordinator for the project, the Humboldt University in Berlin and the Otto von Guericke University in Magdeburg, as well as major Berlin research institutes such as the Ferdinand Braun Institute for High-Frequency Technology, the Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute), the Weierstrass Institute for Applied Analysis and Stochastics and the Konrad Zuse Institute for Information Technology.

The light from this scientific beacon also shines out to promote a number of projects carried out in co-operation with existing and spin-off companies, bridging the gap between science and commerce. I am certain that many economically viable solutions will emerge from this Collaborative Research Centre. The participating institutes and research groups function as incubators for new ideas, new products and innovative solutions which, in a unique way, are able to accelerate the transfer of knowledge in a field of technology which is of greatest interest for today's innovation in Germany.

In this brochure, we present a selection of the initial projects which constitute this comprehensive program. Subsequent publications, events, summer schools, … will ensure that the ideas emerging from this research are made accessible to the public.

I would like to express my pleasure about this excellent integrated scientific approach being pursued, and my gratitude for the commitment and dedication to all who are engaged in the project. I would like to wish the scientists in the Collaborative Research Centre and the integrated Graduate College much success and I hope that the readers of this brochure will experience many "flashes of light" from this beacon.

Prof. Dr. Kurt Kutzler
President, TU Berlin
June 2002–March 2010



The PHOTON ERA

Optical components make use of elementary light particles and are the motor of economic development in the 21st century. Areas previously dominated by electric current and electrons will, in future, be the domain of rapidly moving photons which will take over the tasks of data transfer, materials processing, chip manufacturing, environment control and material analysis. Nanostructured semiconductors are one of the major materials used as the basis for these optical components.

By Prof. Dr. Dieter Bimberg, ML

All components and devices in which light plays a major part constitute the domain of semiconductor photonics. Light is generated from an electric current or transformed into electric power.

Light-emitting diodes, known as LEDs, require far less energy than conventional electric bulbs or lamps in order to generate light in important areas of the spectrum, ranging from the infrared to the ultraviolet, enabling many different applications. Within the next few years, LEDs will force electric bulbs out of the market, leading to a significant saving in energy. In addition, completely new applications will be developed, e.g. in the field of water conservation. Even today, most of the remote controls at home would be unthinkable, were it not for LEDs.

The laser diode is proving to be even more of a multi-talent. These devices have been known for over 40 years. In the year 2000, Zhores Alferov and Herbert Krömer were awarded the Nobel Prize for their idea of the heterostructure laser and its practical implementation. However, it is only in recent times that innovative laser diodes and systems based on these have paved the way for completely new applications which were previously unthought-of. They are increasingly replacing conventional electrical and mechanical devices. Only by means of laser diodes it is now possible to achieve the huge data rates in the field of information and communication technology enabling

The author of this text is the Director of the Institute for Solid-State Physics and of the Nanophotonics Centre at the TU Berlin, Chairman of the national Competence Centre for Nano-Optoelectronics and the Federal Government Association of Nanotechnology Competence Centres in Germany “AGeNT-D”. He was elected to the German Academy of Sciences Leopoldina in 2004 and is elected fellow of both APS and IEEE.

the present and next generation internet, connecting peacefully humans to humans. Within one second, multiplexed lasers can send well over 1,000,000,000,000 units of information (one terabit per second) through an extremely thin light fibre or through air. Their enormous spectral resolution protects mankind and the environment on the basis of new analytical methods. Laser diodes can cut, weld and melt, they can be used to operate on tumours located on the retina of the human eye or they can detect individual cancer cells in the bloodstream.

Germany is one of the nations in the forefront of the budding photonics industry. According to a study carried out by the Federal Ministry of Education and Research, there are already over 140,000 people working in this field and the cumulated annual growth rate in the last decade was about 12 percent. The significance of photonics is witnessed by the German Future Prize awarded by the President of the Federal Republic of Germany in November 2007 to a research team consisting of scientists from the Osram Opto Semiconductors Company in Regensburg and the Fraunhofer Institute in Jena. These researchers have developed the most efficient LEDs worldwide for use in everyday applications. Still more important is the bestowal of Nobel prize in December 2009 to three pioneers of photonics.

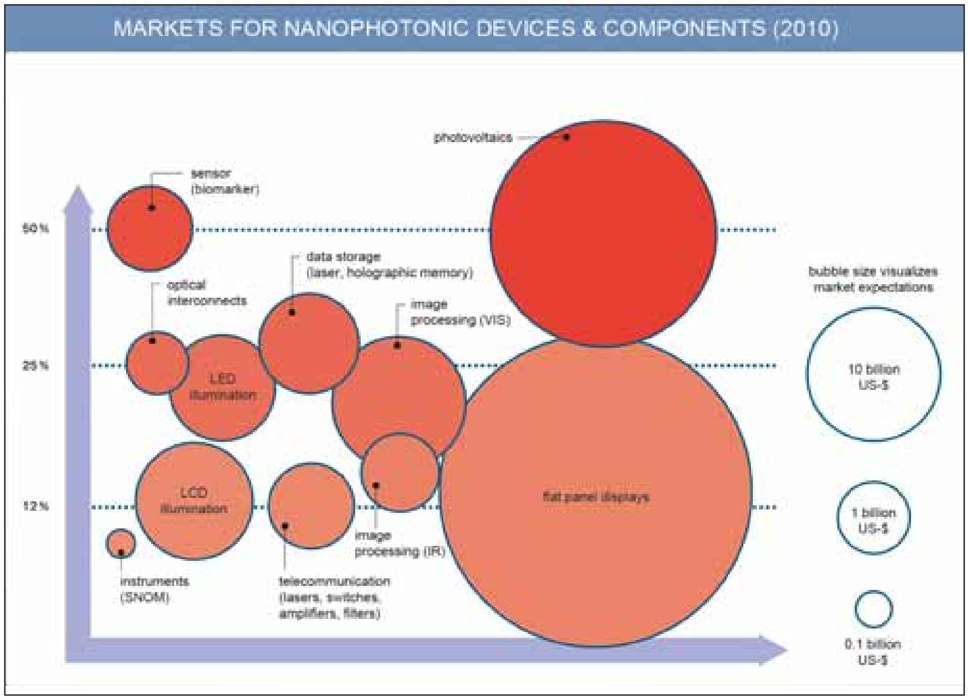
INNOVATION ASCERTAINS EMPLOYMENT

At the beginning of the twentieth century, Osram, Siemens and AEG, the most important pioneers in the era of light, had already set up their headquarters in Berlin. It was here that AEG had begun the mass production of electric bulbs in 1883. Today, we are reaching the end of the era of glowing tungsten filaments. New jobs are taking over from old ones. Berlin is now one of the most important centres of practical research into compound semiconductors, semiconductor nanostructures and innovative photonic components based on these – both in Germany and in Europe as a whole.

In the field of photonics, there exists law similar to that governing electronics or computer industry: The price for a specific “service” is halved every 18 months. This leads to enormous cost pressure: Companies are required to invest considerable sums of money in the further development of their products or in developing new ideas. The TU Berlin recognised this need at an early stage. Here, scientists, physicists, engineers and mathematicians combine the results of basic and applied research using the most modern industrial production methods for semiconductor nanomaterials, to manufacture innovative components and process these in ultra-clean rooms to create chips which are then integrated into complete modules. A scientific idea can only be turned into a high-end product with a large job-creating turnover, if all levels of the value chains from material to module are covered economically. To reach this goal, TU Berlin can rely on the close co-operation of research institutes, universities and companies in a way which is absolutely unique. All partners are only a short distance away and easily accessible.

On January 1, 2008, the German Research Foundation approved a Collaborative Research Centre for a 12-years project on “Semiconductor Nanophotonics: Materials, Models and Components” for the TU Berlin and its research partners. The initial grant amounts to more than eleven million euros and 35 million euros are planned for the total duration of the project. This guarantees that Berlin will head the race in Germany in this strategically important area of research. In order to ensure the stability of this success, the European Union also granted considerable ERDF (European Regional Development) funds. State funding from the state “Future Fund” and the programme ProFit was granted for the purpose of developing the infrastructure and for pioneer projects carried out jointly by the participating institutes and companies.

The TU Berlin, together with its partners and in conjunction with countless small and medium-sized companies, has woven a tight network which, on account of intelligent ideas, is playing a leading role in the growing world market for LEDs and laser technology. Co-operations are also being financed within the scope of the 7th EU Framework Programme and NanoSci-Era for research and technological development. More and more companies are entering this new field and are moving to our region in order to be close to the researchers and their laboratories, which are leading in the world in their variety and equipment. Thus, with the participation and support of major research institutes, in particular the Fraunhofer Institute for Telecommunications (the Heinrich Hertz Institute) in Charlottenburg and the Ferdinand-Braun-Institut für Höchstfrequenztechnik in Adlershof, a dynamic growth centre has emerged in and around TU Berlin which is opening up the markets of the future and creating new jobs. ■



NANO in focus

Industrial lasers are good business

Industrial lasers are gaining ground. They are used on an industrial scale for welding, cutting, drilling, labelling and scanning in the automobile industry, in the production of solar cells, in manufacturing chips or even in the cutting of diamonds, to name only a few. Laser systems are responsible for the major sector of the market for machining sheet metal and foils. This world market is predicted to rise to seven billion US dollars by 2010.

It is mainly the European manufacturers who are increasingly developing new laser products and applications for the world market. The keys to success are highly qualified researchers, scientists and engineers and co-operation with research institutes. Cheap or unqualified workers from Asia play no part here yet. Fibre lasers pumped with semiconductor diodes are increasingly replacing solid-state lasers which are considerably less energy-efficient.

The research and development work being carried out in Berlin in particular, at the TU Berlin, the Ferdinand Braun Institute, the Lumics and PBC Laser Companies, and Jenoptik Diode Labs, is already focusing on the next-but-one generation of high-brilliance, high-performance semiconductor lasers which achieve 50 percent wall-plug efficiency. These lasers will provide an economical and ecological replacement for other lasers and open up further new markets.

Radiant RESEARCH prospects

Semiconductor Nanotechnology is concerned with tiny objects consisting of only a few atoms. Photonics is the science of light. Now, the two sides of the medal which belong together are finally put together: The MONA project is working on the guidelines for future research support in Europe.

Mankind is striving out into the cosmos; satellites are transmitting pictures of Mars, Saturn and Pluto to the Earth and, at the same time, we are delving deeper and deeper into the mysteries of the nanocosmos. Nature is revealing its innermost secrets on the level of atoms, electrons and photons. Scientists are discovering or using quantum physical effects, paving the way for completely new sets of applications. Semiconductor nanotechnology and photonics are moving closer and closer together.

Experts working on the MONA (Merging Optics and Nanotechnologies) project have carried out investigations to determine the priorities for research support in Europe, which is necessary in order for Europe to play an important part in developing these new industries. MONA began in 2005 and the study ended in summer 2007. “Nanomaterials, production methods for tiny components and photonic applications belong together” explained Tom Pearsall, the Managing Director of the governing body of the European Photonics Industry Consortium (EPIC) in Paris, one of the people who had a major involvement in the work of the MONA project. “The new science of nanophotonics needs to be able to take advantage of a rapid knowledge transfer from the laboratories to the industry. Europe must create the necessary conditions for this.”

Within a period of 30 months, the MONA teams, with essential participation of scientists from Berlin, analysed the conditions necessary for nanophotonic research and sunrise nanophotonics industry to be able to convert ideas as quickly as possible into products with the help of seed capital. The MONA roadmap outlines the challenges presented by nanomaterials: specific research into nanomaterials, their manufacture and future mass production, their effects on the environment and standardisation. The MONA teams defined the target markets in which Europe can develop its strengths – on the basis of innovation and research. The authors of the study emphasise the fact that the final aim must be an improved implementation of the synergies between nanotechnology and photonics.

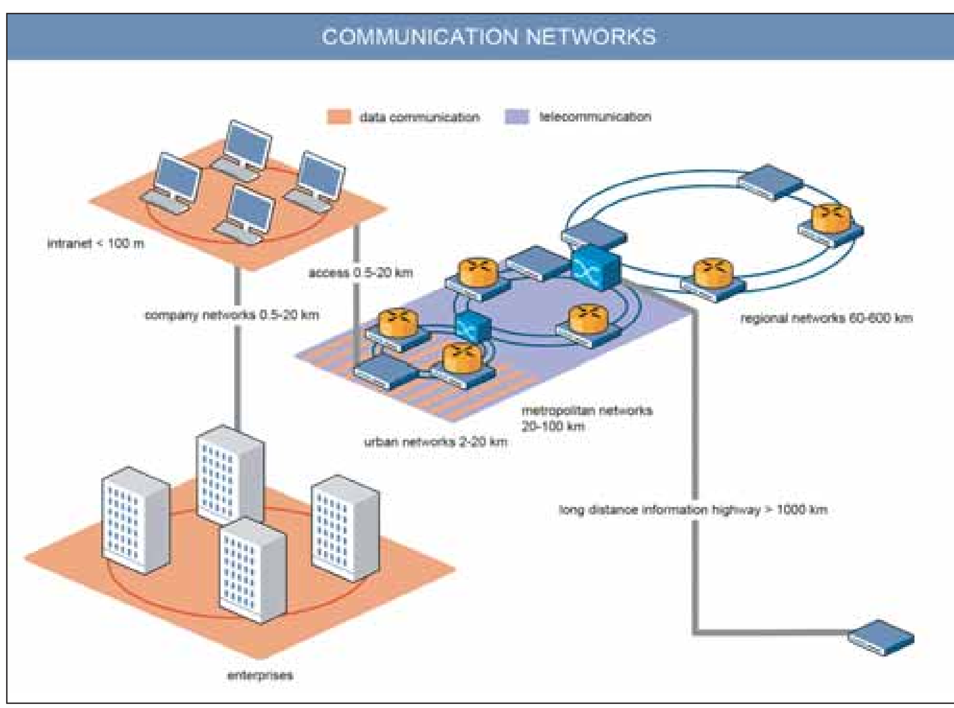
For displays, monitors and lighting technology, light sources must be found which are, most importantly, highly brilliant and highly efficient. LEDs (light-emitting semiconductor diodes), organic displays (OLEDs) or displays consisting of carbon nanotubes (CNTs) which are only a few nanometres long offer opportunities for lower-

ing energy consumption and thus achieving the EU climate policy aims. In years to come, these elements will replace traditional light bulbs. Some major light bulb manufacturers have already announced that they plan to withdraw from light bulb production by 2015. Osram (Germany) und Philips (Netherlands) are two leading manufacturers of displays and lighting technology with headquarters in Europe. However, the world market for displays is still dominated by Asian companies, with European ones catching up.

The MONA researchers suggest that Europe should focus on the manufacture and supply of light sources and flexible displays. Both of these product groups belong to the domain of nanophysics. In the field of organic displays, Europe could assume a strong position, at least as a supplier of components. The second largest market includes optical transmitters, amplifiers, receivers and connectors for the transmission of data in regional and local networks. Whereas electric signals transmitted via copper cables and metal wires have dominated the scene up to now, optical components are increasingly coming to the foreground. Lasers are able to emit high frequency photon pulses and attain data transfer rates which, until recently, were only a thing of imagination.

SHORT DISTANCE OPTICAL DATA COMMUNICATION IS ENTERING THE MARKETS

Optical data technology will merge with advanced semiconductor technologies. Chips must be able to communicate efficiently both with one another and with their environment, without complicated detours. Although optical fibre technology and optical data transfer have been successfully used in long-range applications (telecommunication) for 20 years, short distance technologies are only in their initial stages or in the planning stage as far as ultra close-range applications are concerned, such as communication between the chips on a circuit board or between one circuit board and another.



However, the demand of data users for computers and networks which operate more and more rapidly is putting pressure on scientists to develop innovations in this field, a pressure which will, in time, gather its own momentum: The degree of upheaval to the technological basis of local data networks will be measured in terms of months rather than years. According to Prof. Dr. Nikolai Ledentsov, Managing Director of VI Systems, a Berlin company which is a spin-off from the TU Berlin: "We expect to have the Ethernet, based on glass fibres and with a capacity of 100 gigabit per second within two to four years. We only have two years time to develop our optical transceivers and receivers, to test them and to put them into mass production".

In the opinion of Prof. Dr. Dieter Bimberg, Professor for Applied Physics at the TU Berlin and the patron of the new Berlin Collaborative Research Centre "Semiconductor Nanophotonics": "There is a mass market for optical interconnects. They will revolutionise data networks." The new Collaborative Research Centre, which is organised from the TU Berlin, exactly reflects the recommendations of the MONA study. It is focusing on strategic research topics to a degree which is hard to find in other research centres worldwide. Dieter Bimberg is convinced that "MONA is pointing the way to the future. Nanophotonics provide Europe with the opportunity to develop a new key industry."

The authors of the MONA study predict that: In future, the production, transfer and implementation of light using nanophotonics components will be of great importance: LEDs, displays, endoscopes and lasers will soon become an essential part of production technology, lighting technology, data transfer, medicine and scientific analysis. The experts all agree that: Following on the footsteps of the electrification era, we enter now the era of photons; the economic and scientific application of light. ■

The MONA roadmap is available from EPIC, Paris

www.epic-assoc.com

INTERVIEW

"We need somebody like

Tom Pearsall is the General Secretary of the European Photonics Industry Consortium (EPIC) in Paris and knows this field better than practically anyone. Pearsall provides us here with some information concerning the opportunities offered by photonics, the hurdles to come and the role which can be played by a university such as the TU Berlin in the network of optoelectronic technologies.

Space travel, nanotechnology and wind energy are words on everyone's lips. Why not photonics?

Photonics is an extremely rapidly developing technology with applications in many different fields, which is why it is very difficult to develop a strong impact in public opinion. A great deal of effort is required to keep up with this rapid development. There are very few large companies, two examples being Zeiss and Osram Opto Semiconductors in Germany. Most of the enterprises are small, often budding new businesses which develop a technology until it is commercially viable and then they are bought by a big one. If you google the word "photonics", you will get about 100,000 hits. If you google "nanotechnology", you will get more than six million …

Changing this would be a task for EPIC …

Of course, we need more public relations work in order to make people aware of photonics. One reason for missing presence in public is that the components are so small. Hardly anyone is aware that there is a great deal of laser technology inside a CD player. This is a silent industry – no-one advertises for photonics, but rather, for mobile phones or MP3 players; however, these devices wouldn't make a sound if it weren't for photonics.

You mentioned the high rate of innovation in this field. What do you consider to be the reason for this trend?

Photonics is the starting point for almost all the other fields of technology: For integrated microchips, for biomedicine and genomic analysis, for data networks and entertainment electronics. Photonics is the engine which propels the other industries forwards. In order to make components smaller, lighter, cheaper and more energy-efficient, light is gradually taking over more and more of the tasks formerly performed by electrons. Unfortunately, the problem is that many governments have not yet become sufficiently aware of these connections.

Can you explain that?

It's quite simple. The national research budgets and the funding planned for photonics within the scope of European programmes are all small. A few large companies such as Siemens and Samsung invest a great deal of money in research, but mostly on systems. Some companies invest one tenth of their turnover in their laboratories because photonics products change so rapidly that there is hardly time to earn money from them. Anyone wanting to stay at the top of the game has to invest constantly. This, however, is not enough to disguise the fact that there is a shortage of public funding. Sad to say, there is no hope of improvement at present.

Steve Jobs”

What do you think about the support provided in Germany?
On a European scale, the Germans rate more-or-less as heroes as far as the funding of photonics is concerned. We cannot complain about Dr. Schavan (the German Federal Minister for Education and Research), seeing that Germany has considerably increased its budgets for optoelectronics and photonics in the past few years. Researchers have felt this and things are moving. The German scientists and firms are very successful.

Instead of relying on public funding, it would be possible to take advantage of private venture capital. Why does the industry consider this to be a problem?
I know of a couple of venture capital companies which are investing in photonics, but it’s hard work; there’s no quick money in this business. It’s not the same as with Google: In photonics, it is necessary to push ahead with experiments and scientific developments. The market volume is not as large as in the internet business; the expected returns on investments are often only medium-term and slow.

How can this be changed?
We need role models, people like Steve Jobs from Apple. If we had frontmen like this, we would be in a different position altogether. But even Steve Jobs couldn’t carry on his business without us. He transformed the telephone into a visual object which is full of photonic components. Perhaps I can persuade him to take a sabbatical and work for us for a while.

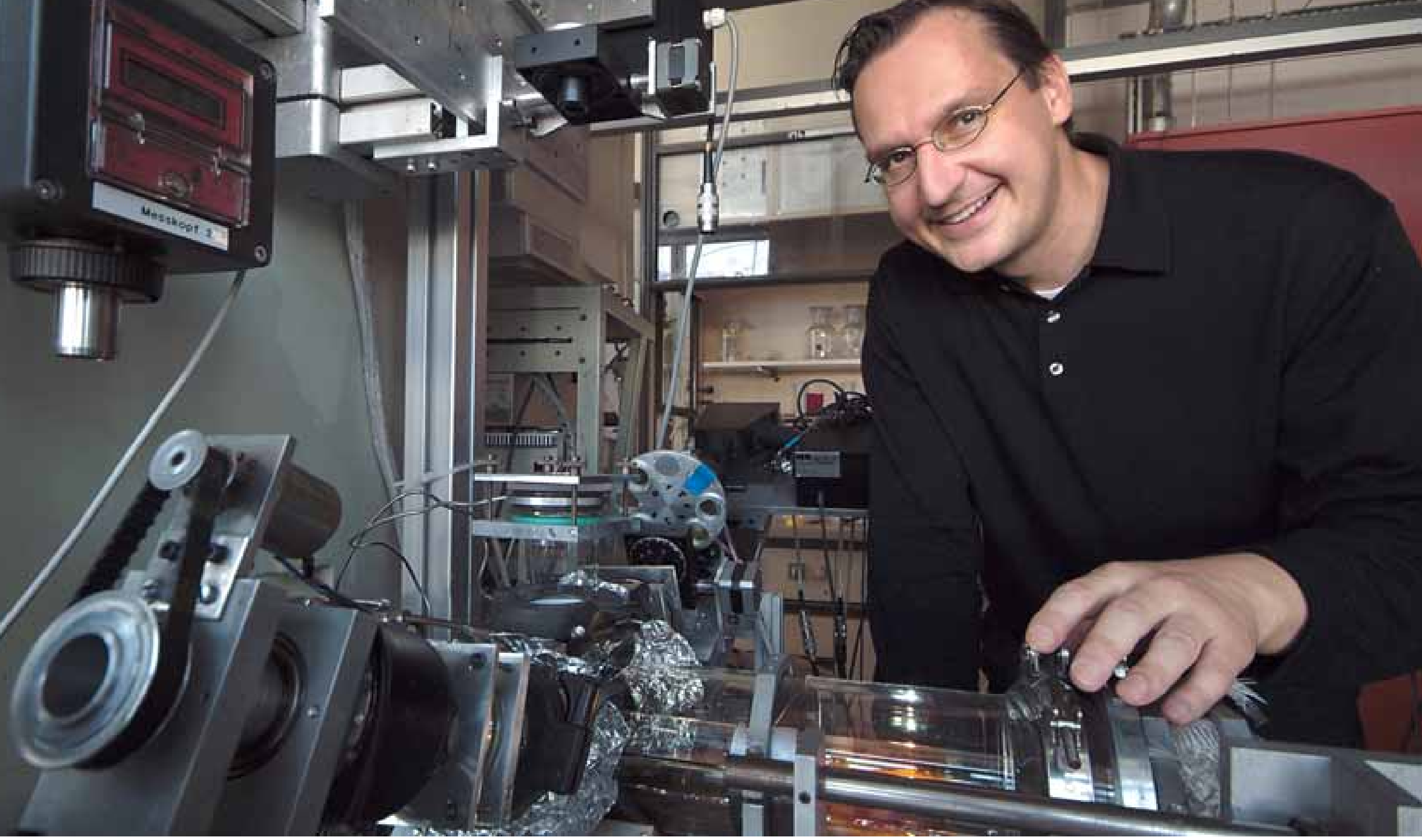
A university like the TU Berlin certainly won’t be able to engage Steve Jobs, but it can do a great deal indeed for photonics. What do you see its strengths?
The new Collaborative Research Centre in Berlin is a wonderful thing. It will attract people from across the world and is a real beacon for Europe. Professor Bimberg, who conceived the application for funding did a great job. He is also working at the forefront of our MONA project. This European project, which we have just launched, is concerned with the connection between nanotechnology and photonics. In my opinion, one of the most important factors is that the TU Berlin is extraordinarily successful with its spin-off firms. We’re not dealing with individual research work, but with the commercial applications of photonics. It is necessary for the scientific results to be quickly transformed into imaginative products. But that isn’t the only challenge for the colleagues in Berlin.

What’s the other one?
The far greater challenge in my opinion is that everyone concerned has to endure a great amount of activity and stress. If you are permanently required to produce innovations, you require a great amount of energy and that takes its toll. Therefore, it will be important to concentrate on strategies and co-operations in order not to get bogged down in details. There is even a third challenge: We have to reconcile the large number of scientists involved. And also the expectations held by the people who have put their money on the table.

The interview was conducted by Heiko Schwarzburger.

Frontman in a budding new industry

In 1968, **Tom Pearsall** graduated from Dartmouth College and, two years later, he completed his Master’s degree at the University of London. In 1973, he completed his doctorate in Applied Physics at the Cornell University. Subsequently, he worked in the famous Bell Laboratories where he carried out research on problems of optical communication technology. He invented the first compound semiconductors made of indium, gallium, arsenic and phosphorous (InGaAsP) from which he developed components for glass fibre networks. In 1976, he moved to Thomson/CSF in Orsay, France, where he developed photodetectors made from indium gallium arsenide. In 1981, he resumed work at the Bell Laboratories where he commenced research into semiconductors based on silicon-germanium. In 1990, he was the first person to be called to the Boeing-Johnson Chair for Semiconductor Technology at the Washington State University in Seattle. Together with Thomas Furness, he founded the Human Interface Laboratory in Seattle. In 1996, Tom Pearsall was named as Fulbright Senior Scholar at the CNRS/Max Planck Institute in Grenoble. From 1998 to 2002, he directed the research into planar photonic crystals for Corning in Fontainebleau, France. In 2003, Pearsall launched EPIC. Today, this organisation has members in 16 European Union countries. EPIC played a leading role in the founding of the European Technology Platform Photonics-21.



A BEACON for NANOPHOTONICS in Berlin

The German Research Foundation is investing more than eleven million euros in order to support the research being carried out at the TU Berlin and its partner institutes in the region into new types of nanostructures and photonic components based on these. The focus is on III-V-semiconductors as the material basis, new generations of devices and their mathematical models.

The new Collaborative Research Centre "Semiconductor Nanophotonics: Materials, Models, Components" will strengthen Berlin's prominent position as the most important region for research into optical and nanotechnologies and their further development. The Technical University of Berlin is coordinating the project. Other bodies participating in this new beacon research project are the Humboldt University and the Otto von Guericke University in Magdeburg and four other major Berlin research institutes: the Ferdinand Braun Institute for High-Frequency Technology, the Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute), the Weierstrass Institute for Applied Analysis and Stochastics and the Konrad Zuse Institute for Information Technology. A total of 26 principal scientists and over 100 scientists will be researching into new types of photonic components, nanomaterials and their mathematical models. As Prof. Dr. Michael Kneissl, spokesman for the Collaborative Research Centre (photo) explains: "Our work is based on these three pillars."

Prof. Kneissl was called to the Chair of Experimental Nanophysics and Photonics at the TU Berlin in August 2005. In addition, he is carrying out research into optoelectronics at the Ferdinand Braun Institute in Adlershof.

The focus of the new Collaborative Research Centre is on III-V-semiconductors. As Kneissl explains, “Using gallium nitride, gallium arsenide or indium phosphide, it is possible to achieve all the wavelengths which are currently significant in the field of optoelectronics, whether they are in the ultraviolet or the infrared range. For scientists, this opens up a huge variety of possible applications: The use of visible lasers points the way to laser television and images which require only a minimal amount of energy while exhibiting a degree of brilliance and colour previously unknown. UV light emitted by specially constructed LEDs can be used to sterilise water.”

VAPOUR DISCHARGE LAMPS REQUIRE A LARGE AMOUNT OF ENERGY

Up to now, UV light has been generated by vapour discharge lamps which are very energy inefficient. These mercury vapour lamps emit light at a variety of wavelengths. “By using an LED, the required wavelength spectrum can be set very precisely and LEDs use far less energy” as Michael Kneissl explains. “Gallium nitride, for example, is already being used today in order to illuminate the displays of mobile telephones.” When excited by a minimal electric current, this semiconductor emits blue light. Because the LED chip is surrounded by a phosphorescent material which emits yellow light, the result is white light. Up to now, television screens and computer monitors have been regarded using large amounts of energy. Compact semiconductor lasers could also take over from large gas lasers and replace them with smaller, more compact systems. In this way, it is possible to construct new types of laser scanners for cell analysis which excite pigments in human body cells. The evaluation of this analysis is then done using a fluorescence spectroscope. In this way, it is possible to find evidence for the spread of cancer in the body by tracing individual cancer cells which reach the bloodstream and swim in it – previously undetected. As Kneissl says, “It’s like looking for a needle in a haystack. There are about five to ten cancer cells to every one million blood cells.” The new laser diodes are also used in high-power data transmission networks and telecommunications in which data is transmitted at rates of gigabits to terabits per second.

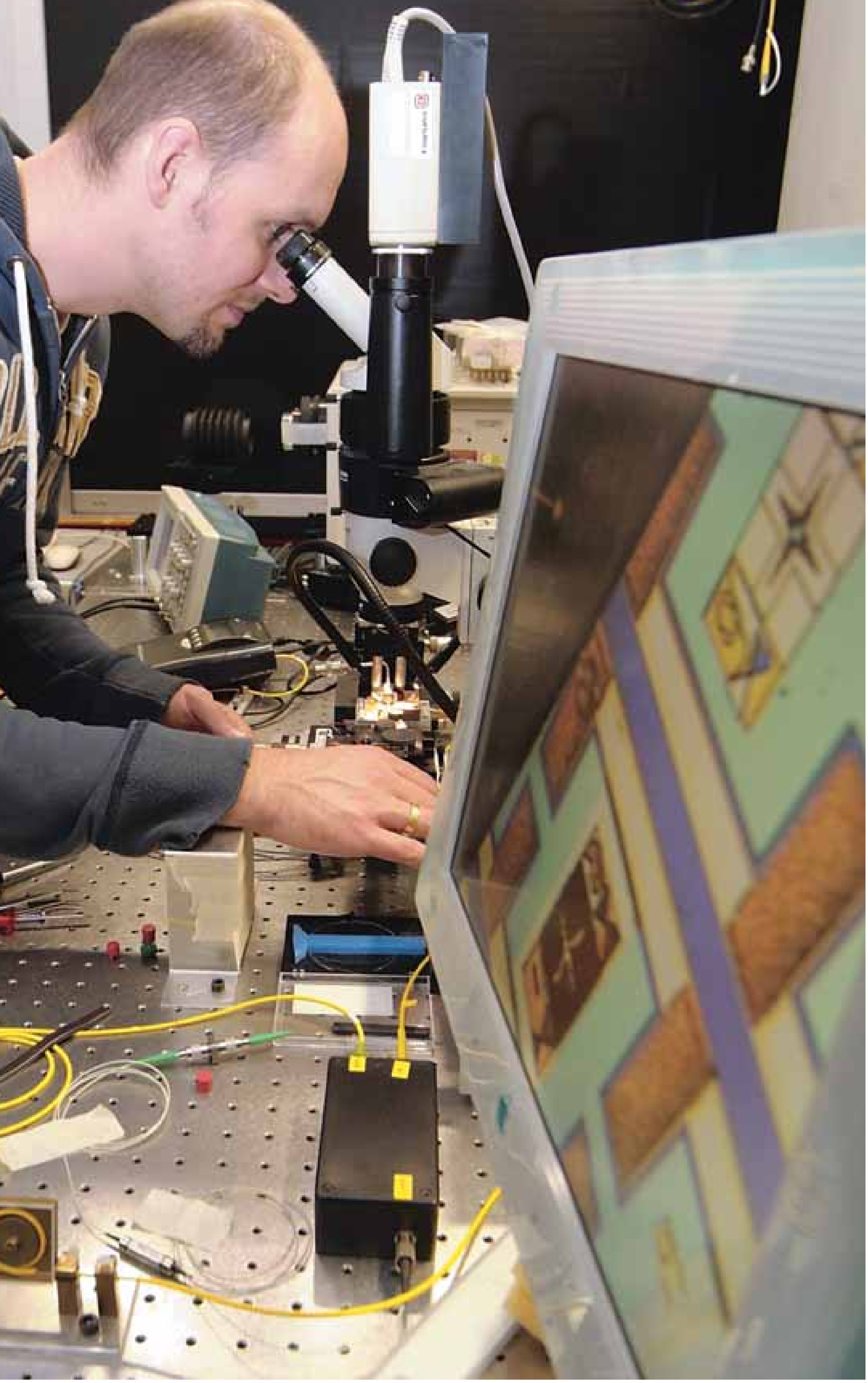
The Collaborative Research Centre has been initially approved for a period of four years. It is planned to run for twelve years. The connection between the basic research being carried out at the universities and the applied research being done at the other institutes is unique. “Our aim is to develop completely new applications and create spin-off firms which convert our results into marketable products” according to Prof. Dr. Dieter Bimberg, who conceived the Collaborative Research Centre and attracted to the project the most competent scientists from the region extending from Berlin to Magdeburg. “I am thinking of brilliant high-energy lasers, powerful laser projection systems, data-encoding systems using quantum cryptography, the terabus for ultrafast computer connections or the 100 gigabit Ethernet.” The President of the TU, Kurt Kutzler, is convinced that nanophotonics is an important pacesetter for science and commerce. As he says, “I am certain that this Collaborative Research Centre will provide many solutions which can be applied to industry. The approval is confirmation of our bold appointment policy of bringing back excellent young scientists from the United States and integrating them into teams together with our most successful local researchers.”

In Germany and Europe, there is no other comparable Research Association which can boast such a wide range of experts and specialist groups. The network consists of mathematicians, material scientists, physicists and electrical engineers. “It is particularly the co-operation between groups who are working out theories and other groups who are concentrating on experimental work which makes the project so unique”, says Dieter Bimberg. “This allows us to co-operate in a league with the large international players like Intel, Agilent, IBM, Toshiba, and Osram Opto Semiconductors. ■

Talent promotion in the Graduate College

An integrated Graduate College for Semiconductor Nanophotonics has been founded in conjunction with the Collaborative Research Centre. This method of promoting young, talented researchers relies on the experience of the participating universities and institutes. It is essential that students in the fields of physics, mathematics and engineering co-operate in order to span the scientific and technological bridge between theoretical models and real devices. The College network provides optimum conditions for this goal and will additionally attract international talents.

Guest scientists and their mentors, the tandem supervision of graduate students by universities and research institutes, common events such as the graduate seminar or the Nanophotonics Day held in conjunction with industry, and participation in national and international conferences are the major building blocks of the new College. Parallel to the scientific education offered, students are also trained in social and communication skills. One major aim of the project is to win women over to science and to promote their talents. Lab days for female pupils and special coaching programmes such as the virtual college for female graduates, and reimbursement of the costs for child care are amongst the tools which are used.



LIGHT as a STIMULANT

In a few years time, the metropolitan area networks will have to cope with rates of more than 100 gigabits per second. Optical amplifiers will play an important part in their implementation: Even light can weaken slightly on occasions …

A super-highway in the data network: Gradually, light is beginning to replace electricity as a carrier of data and information. In times gone by, copper cables as thick as your arm were the backbone of telecommunications and regional networks. Nowadays, enormous amounts of data are transmitted through light-weight glass fibres. As Dr. Matthias Lämmlin, a postdoctoral student at the Institute for Solid-State Physics at the TU Berlin explains. “Even when light is conducted through a glass fibre, power is lost and the light intensity is weakened.” Matthias Lämmlin is an expert for amplifying components made from semiconductors which help light on its way. “In high-power networks, an amplifier is needed approximately every fifty kilometres, otherwise there is such a high loss in light intensity that the information is corrupted.”

Lämmlin specialises in optical amplifiers which are constructed like lasers but do not have a resonator. As he explains, “The semiconductor device is powered by electricity in order to put the charge carriers into standby. When weak light enters the component, the excited semiconductor is forced to emit additional light at the same frequency. Thus, the intensity of the input signal is amplified and the light can continue on its path at increased distances.” The amplifiers consist of layers of gallium arsenide and aluminium gallium arsenide into which layers with islands of indium arsenide are inserted. “The layer stacks are deposited by means of an epitaxial growth process at a temperature of 500 degrees Celsius. The indium arsenide islands arrange themselves and vary only slightly in size. They are known as quantum dots.” These quantum dots are between five and twenty nanometres in size. One nanometre is equivalent to a millionth of a millimetre. In comparison to this, an ant would be a monster.

NANOMETRE-SIZED ISLANDS

Optical communication networks operate on infrared light with a wavelength of 1300 nanometres. Without these nanometre-sized islands, the structures would emit light at wavelengths of approximately 1100 nanometres. The quantum dots shift the spectrum so that the amplifiers emit light at the desired wavelength. In addition, the size distribution of the quantum dots influences the extent to which the wavelength of the incident rays may vary. This enables light at different wavelengths to be amplified simultaneously. As Dr Lämmlin explains further, “Light at one wavelength corresponds to one data channel. A second channel can be transmitted even if the wavelength of a second light ray differs only mere by five nanometres from the first ray.”

Physicists are dreaming of an amplifier which can amplify the complete band width of the data bundle at one time, and we have a lot of work to do before we can attain this goal. Matthias Lämmlin gives us a preview: “It will take only another three to five years to develop a real product. We are already testing several prototypes, but we do not yet have any components which comply with all the system requirements at the same time. This is why the next Ethernet standard, which transmits 100 gigabits per second, will only become introduced after the year 2012.” Thus, the research on these amplifiers will be completed “just in time”.

The preliminary work being done by Lämmlin will serve as the first step in modernising the twentieth century data highways to become the multi-laned information superhighways of the twenty-first century, in the course of which the data traffic in the metropolitan cities will far exceed the capacity of our present networks. As Lämmlin says, “Before that happens, we will have to find a lot of answers to our questions. One of our most difficult problems at the moment is that light travelling through glass fibres does not only decrease in intensity, but also changes its polarisation. Our amplifier reacts very sensitively to this. Our aim is to develop an amplifier which functions independently of polarisation.” That means: We continue to bake layers, to deposit quantum dots, to carry out different processes, to construct and to push the measuring devices to their limits. Lämmlin is receiving support from one of the Alexander von Humboldt Award winners from Technion in Haifa, from a young Korean Humboldt Fellow who formerly worked in Urbana, Illinois, and from a postgraduate and two students who are writing their theses on the subject. The work is also being supported by the State of Berlin in its funding programme “ProFit”.

The amplifiers on which this research work is being carried out are of major importance for the large European TRIUMPH network which is subsidised by the EU. Many of the layers the group is using are obtained from partners in the European Network of Excellence known as SANDIE (Self-Assembled Semiconductor Nanostructures for new Devices in Photonics and Electronics) and, above all, from “Innolume”, a company which is a joint spin-off from the TU Berlin and the loffe Institute in St. Petersburg. “This European network enables our work at the TU Berlin to proceed at a far greater rate, so that we are on a par with Japanese companies such as Fujitsu.” He is convinced that the work is well worth the trouble. “These amplifiers are not only important for data networks in urban areas. They could, in principle, be used for optical connections between computers, servers or buildings, or for processing of optical signals like wavelength conversion. In the near future, we will already need to transmit at a rate of about 40 gigabits per second. An amplifier is needed at every junction point which means that there is an enormous demand for these tiny components.” ■

NANO in focus

Scalpels made of light

Lasers are also gaining ground in the field of medicine because no scalpel made of metal can cut into body tissues, organs or bones as precisely and with such minor side effects as a laser. Due to the fact that heat is applied to an exact point, the target tissue decomposes immediately without affecting the surrounding tissue layers at all, or only minimally. By using semiconductors, the wavelength emitted can be precisely adjusted to meet the requirements of the therapy concerned. The devices are handy and economical. For quite a while now, laser systems have been established in the fields of ophthalmology and cosmetic surgery. The value of this market in the year 2008 was estimated to be about 4.1 billion US dollars. Large manufacturing companies such as Zeiss Meditec announced a record turnover. The annual growth rate in this market is about 15 percent.

FORMULA-ONE LIGHT on the DATA SUPERHIGHWAY

The wide data superhighways of the future will allow for enormous transmission rates. The local networks and the connections between computers, servers and intranets will then be the bottlenecks in the system. The newly-emergent company VI Systems, a spin-off from the TU Berlin, is now entering photons in the race to replace slow copper wires. The company patented the idea: the EOM BR VCSEL (Vertical-Cavity Surface-Emitting Laser).

Worldwide communications: Within a period of only a few years, the internet has spanned a closely woven network across the globe. Gigantic data streams are flowing from one continent to another 24 hours a day. The intercontinental worldwide web is supported by a backbone of arm-thick cables made of glass fibres, often laid under the oceans, which connect urban regions and large metropolitan areas. According to Prof. Dr. Nikolai Ledentsov, Professor at the Ioffe Institut in St. Petersburg and up till recently a Guest Professor at the TU Berlin, "Copper wires and metal connectors still dominate the scene as far as close-range applications are concerned. In the light of the increasing amounts of data, copper is reaching its limits. If we want to further increase the transmission rate, we will have to change to using glass fibres to connect computers, servers and intranets. Electrons are too slow; photons are taking over the field." Nikolai Ledentsov is an acknowledged expert in the field of semiconductors, lasers and photons, the smallest particles of light. In order to open the doorway for ultra rapid information networks, he and some of his colleagues from the TU Berlin founded the VI Systems company. The researchers developed laser diodes which permit data rates of 40 gigabits per second. As Ledentsov explains, "The existing copper cable network cannot be extended at will. Optical conductors and contacts made of glass fibres are lighter and more economical."

The intercontinental data superhighways are already conceived to handle high bit rates and already transfer data by means of light. The local networks are the bottleneck. "If the data rate exceeds ten gigabit a second, glass fibres are also interesting for close-range applications. The increase in copper prices is an additional factor which is forcing us to modernise." He estimates that the market for optical connectors is worth about 40 billion US dollars worldwide. In the future, the connection between rapid memories in computers will also be implemented using extremely fine glass fibres. Ledentsov maintains that this segment of the market is worth about 37 billion dollars. "Old technologies are being forced out of the market at an extremely fast rate." In the year 2005, the state of the art was connections with four gigabits a second. "In 2007, the rate was already eight gigabit. In 2008, the networks reached a rate of approximately ten gigabits. Four years later, we expect it to increase to 40 gigabits, and the year 2012 will also mark the

advent of the 100 gigabit Ethernet." Since the year 2000, the data rate in modern communication networks has multiplied by 30.

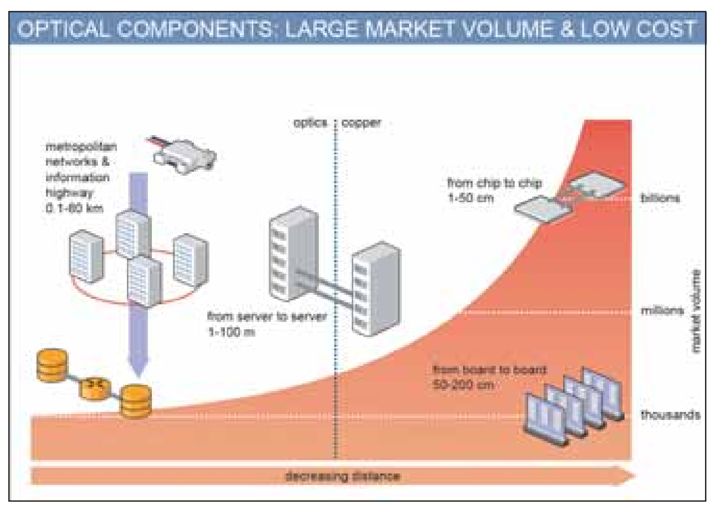
VI Systems is entering the market with its patented concept of the EOM BR VCSEL with which it hopes to become premium supplier of the market for short-range networks. These lasers can transmit light signals e.g. at a wavelength of 850 nanometres – that is 850 millionths of a millimetre. "Our aim is to present prototypes in 2010 which can achieve 40 gigabits per second", says Ledentsov. VCSELs are constructed of more than 50 different layers of semiconductors and the light is emitted perpendicular to the layers. This differentiates them from what are known as "edge-emitters" in which the light rays are emitted parallel to the layers. In order to be able to transmit data, this light must be modulated at the bitrate of the data signals. It is switched on or off, amplified or weakened. In order to increase the switching speed, an external modulator must be inserted after the edge-emitters as a second component. Both form a module. The modules are complex to manufacture and have a correspondingly high price. In the future, powerful edge-emitters will continue to be used for data superhighways but, for short distance communication, e.g. between computers, we now have more cost-effective solutions.

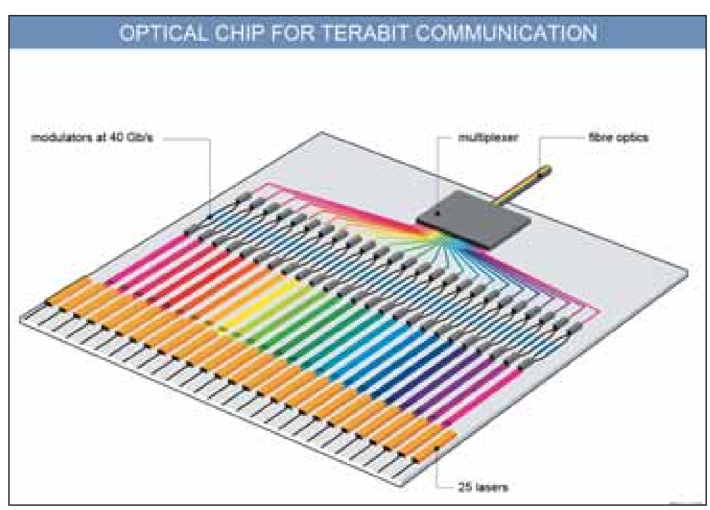
The aim of VI Systems is to integrate mirrors structured using nanotechnology directly in the device where they can transform the data inside the laser into digital light pulses. Dr. Ledentsov is certain that; "This will mean that we can produce the devices more quickly and more economically. We intend to begin mass production within the next two years." Annually, approximately 250 million personal computers are sold worldwide. VI Systems estimates that there is a market potential of more than two billion laser devices a year.

An investment company has joined forces with VI Systems which is intending to establish the manufacture of the superfast diodes in Berlin. The TU Berlin, VI Systems and other European partners have received funding from the EU for a three-year research plan worth 3.3 million euros together with the world leader in microprocessors and interconnects Intel. Ledentsov reported that: "In this co-operation, VI Systems will design the devices, the TU Berlin will be responsible for processing the layers and Intel will test the devices in their systems." The initial experiments have been very promising. A prototype of an "EOM VCSEL" reached an electrical switching speed of 60 gigahertz and, on the optical side, a directly modulated VCSEL reached data rates of 30 to 40 gigabits per second. According to Ledentsov, "The devices require only a minimal pump current and promise to have a long operating life. Our problem is that, up to now, there are no detector modules which are able to process such a high data rate at this wavelength. This is why we also plan to develop such fast detectors together with the VCSELs.

As for 2010, we plan to deliver prototypes of emitter and detector modules integrated with driver/receiver electronics. In 2011, we expect to start mass production of 40 gigabit modules. In this business, it is important to be very quick, otherwise you can't stay at the top."

www.v-i-systems.de





Brilliant COLOURS for laser TV

The human eye perceives light as colour in many and varied shades. In video displays and in printing, various methods of mixing colours are used. But the magic really begins when lasers are brought into the picture.

Mankind today is a product of evolution. For millions of years, all the possible shades of leaf green predominated life on our planet and, even today, we all incorporate a bit of the jungle. As Dr. Udo Pohl, an adjunct professor at the Institute for Solid-State Physics at the TU Berlin explains, "Our eye is trained to perceive fine nuances of the colour green. In this green, the solar spectrum is at its maximum, but it is this very colour green which is causing us problems because shades of green cannot be adequately realised on monitors or printers using conventional colour-preparation techniques." Within the scope of what is known as the "RGB model", it is possible, in principle, to mix all the colours of the colour triangle formed by red, green and blue. "The light sources which have been available for RGB up to now exclude a vast number of the colours of the visible spectrum when the colours are mixed, or they are extremely costly. By means of innovative lasers, we are able to create far more colours in impressive quality, thereby making use of almost the entire visible spectrum."

When laser researchers speak of "colour", they mean light at a certain wavelength and frequency. The green range starts at about 520 to beyond 560 nanometres; i.e., the green light waves are 520 millionths of a millimetre long. The red shades are grouped in the region of about 650 nanometres; blue and violet at about 470 to 380 nanometres. For projection purposes up to now, the three elementary colours have generally been created by light sources such as light-emitting diodes or lamps.

Continued page 18

"On the way to the next generation of lasers"

Brilliant colours and VECSELs are important topics in the industry. TOPTICA Photonics AG in Munich is co-operating with the group of researchers working with Professor Bimberg at the TU in Berlin in the context of the large, Europe-wide "NATAL" project. Dr. Wilhelm Kaenders, the CEO of Toptica, explains the reasons for his company's engagement in this research.

Why is Toptica AG taking part in the research into VECSELs for the red, green and blue (RGB) colour models?

Because they provide access to a spectral region which has been very underdeveloped up to now (1100 to 1300 nanometres), VECSELs are of great interest to us in order to round off our product range. Furthermore, the VECSEL approach is scalable far above the one-watt limit in terms of output power. In our experience, this limit, which applies to the established types of edge-emitters, has proved to be very restrictive.

Which products at which market do you expect to emerge in this field in the course of the next few years?

We would like to round off our range of scientific diode laser systems in this region of the spectrum. The efficient method of doubling the frequency, a specialty of Toptica AG, is particularly interesting as we can use it to replace the inadequate laser systems which have been around for decades, such as the dye lasers in the red, yellow and green regions of the spectrum which are at present used for research purposes. For these applications, we need narrow-band and wavelength variable light sources. Of course, industrial markets are also of interest to us, but these can only be dealt with in the framework of further initiatives. This will be done in a joint co-operation project with the Osram Opto Semiconductors.

How does the co-operation with the scientists from the TU Berlin function? What role does Toptica play?

The TU Berlin is contributing to the project its know-how concerning the growth of quantum dot semiconductors by MOCVD which is unique in the world. The semiconductor discs from Berlin are being completed to form complete components by one partner in England and another one in Finnland, after which we can handle them ourselves. At the end of the production chain, we make the semiconductor structures really emit light in prototypes and demonstrators and according to the exact specifications. The Berlin scientists can then experience the real fascination of the laser as the result of our integration work. They contributed the most important step, the epitaxy.

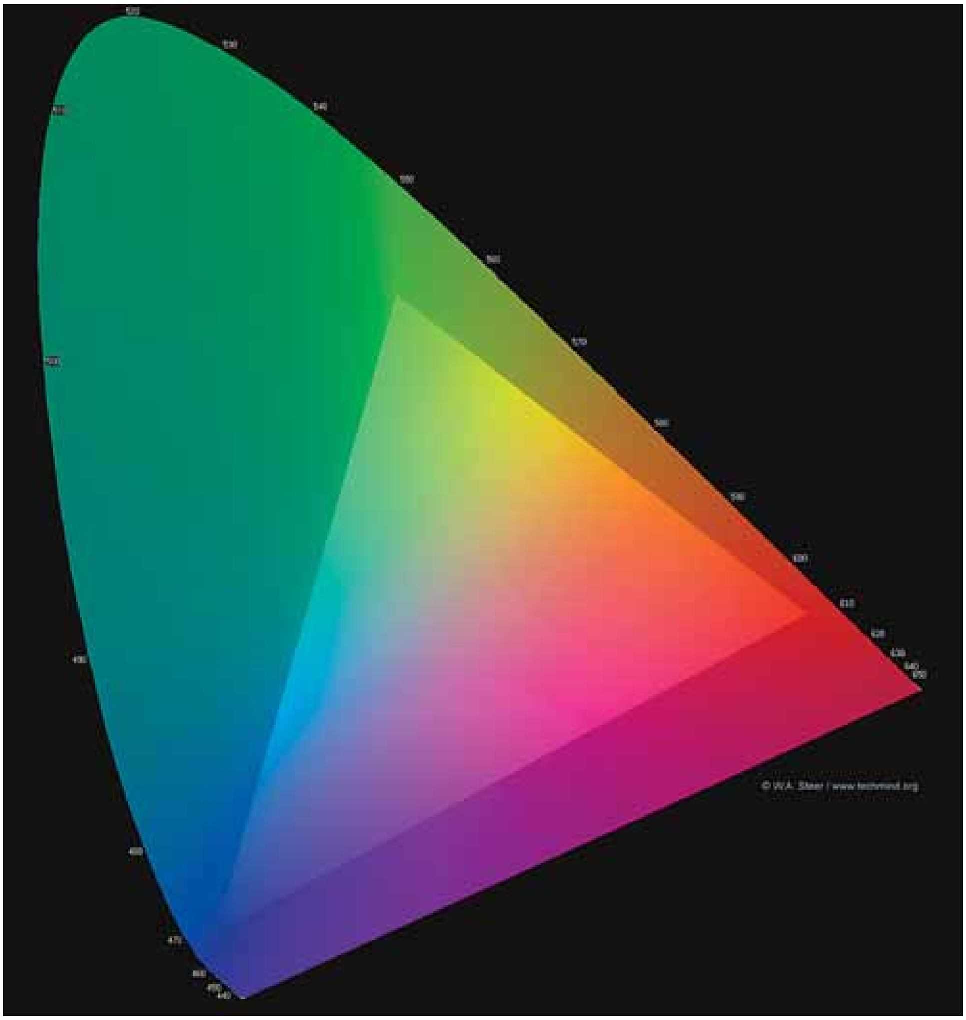
The interview was conducted by Heiko Schwarzburger.

An overview: TOPTICA Photonics AG

Toptica was founded in 1998 by two physicists. Today, the company, which has its headquarters in Munich, has more than 80 employees, of whom about 35 are physicists or engineers. In addition to the main headquarters in Bavaria's capital, Toptica also has a subsidiary in Rochester in the USA. The development and production of custom-made laser solutions for industry and research work have allowed us to achieve an export share of almost 80 percent. Due to the fact that this development is closely linked with the work being done in research institutes, Topica is able to profit from the well-developed German research infrastructure. In return, we provide the institutes, which are generally publically funded, with quick, uncomplicated access to the market in order for them to test and exploit new approaches. For example, our co-operation with the Ferdinand Braun Institute in Berlin has, for years, enabled Toptica to gain an important market advantage in the field of semiconductor lasers compared to our international competitors. Furthermore, Toptica is the only European company which develops and manufactures its own reference drives for the characterisation of new red and blue storage media (DVD, HD-DVD and Blue-ray). Recently, in an intensive co-operation with the group of researchers headed by Professor Susanna Orlic at the TU Berlin, we investigated the way in which holographic writing methods can contribute to a further, fourth generation of optical storage media.

During the coming years, the company will continue to search for talented researchers from German universities, especially for young researchers who are aiming to have the fruits of their technological concepts converted into commercial products.

www.toptica.com



“These methods waste a great amount of energy because the light sources emit their light rays across a wide range containing different wavelengths”, explains Udo Pohl. “A laser, on the other hand, only creates light at one specific wavelength. Furthermore, this light can also be concentrated onto a very small surface. Therefore, we need only three emitters – red, green and blue – in order to be able to transmit light across vast distances, using a minimal amount of energy. Five watts of electrical power are sufficient to enable a laser to transmit pictures with enormous depth resolution and high brilliance, even on rough surfaces and across distances of many metres. As Pohl says, “A five-watt lamp certainly can’t manage that”. The idea of using lasers to project coulour images is not new. The innovation in the approach taken by the physicists at the TU Berlin, however, is the creation of a precise beam of light with high intensity without using complex lenses or a jumble of mirrors. Only a brilliant, and precisely accurate beam can be introduced into glass fibres without large energy losses and then even be directed around a corner. “There are glass fibres, liquid lasers, solid-state lasers and semiconductors. In solid-state lasers, there is a crystal which is excited by means of light. Semiconductors are usually pumped electrically to be able to emit light. We are developing a technology in which a simple pump laser excites the slice of a semiconductor structure which has a different wavelength defined by nanostructures to produce light. In this process, the beam of light created inside the semiconductor flies back and forth between an external mirror and the semiconductor chip and leaves this resonator through a small transmission window in the mirror. This type of laser structure creates a large intensity of light and also has an excellent beam profile, which means that: The laser is practically round in shape when it emerges from the external mirror and is hardly weakened at all when transmitted across large distances.

This innovative laser operates under the name of VECSEL (vertical-external-cavity surface-emitting laser – engineers love acronyms) which combines a high performance yield with brilliant beam qualities. “The more pump power we use, the more efficient is the transformation of electric energy into light”, a further advantage mentioned by Udo Pohl. “The system can be freely scaled.” In our tests, we have already achieved five watts of luminous power and the energy efficiency from pump

2.7 million euros from the EU

The European Union has been promoting research into powerful, multi-coloured VECSELs in its NATAL project (6th Framework Programme for Research). For this research, the EU has spent approximately 2.7 million euros. Other groups are participating in addition to the research group headed by Professor Bimberg at the TU Berlin, including research groups from Tampere in Finland, from Strathclyde (Great Britain) and from the Chalmers University in Gothenburg (Sweden). Engaged on the industrial side are the Topica AG from Munich, OptoCap from Livingston in England, EpiCrystals in Tampere and Osram Optical Semiconductors in Regensburg. Toptica manufactures the laser sytems and Osram is planning to take over the production of the VECSELs and the semiconductor chips later on an ISO 9000 certified base.

light to VECSEL is between 20 and 50 percent. From the power supply to the precisely accurate laser beam we have reached over 10 percent efficiency.

In order to be as flexible as possible in creating the colours of the light, the researchers at TU have replaced the insulator material in an optically pumped disc laser by a semiconductor. The insulators can only emit light at one specific frequency, for example red from ruby crystals. Pohl explains that, "If we introduce quantum films or quantum dots of other atoms, we can tailor the colour as we wish. We integrate one of the two mirrors of the resonator into the semiconductor structure which makes it possible to mass-produce." The reason is obvious: Nowadays, coloured images are being created and shown everywhere, which is why an RGB system comprising VECSELs will be more suitable for the mass market.

In experiments, the scientists at the TU Berlin have produced a VECSEL which emits light at 1040 nanometres. This wavelength is near to the infra-red region and is invisible to the human eye. By means of a trick, the scientists have succeeded in doubling the frequency of the light. This is explained by the physicist: "Because the resonator is open, we are able to insert a small non-linear crystal into the path of the laser. The laser excites this crystal to emit light at double the frequency of the laser beam. Thus, the wavelength is shifted into the green region which has been searched for so long and which is so important for RGB. In conjunction with our partners, we are using this method to create red, green and blue and are enjoying our great success.

The VECSELs are still in the experimental stage, but, even now, we are predicting a brilliant future for them. Using only a few watts from the power socket, they achieve an output power for which gas lasers, for example, would require one hundred times as much pump energy. High-performance lasers with such excellent beam qualities could also promote analytical techniques for materials and molecules. In the field of medicine, these extremely accurate lasers can be used to make specific blood components visible. ■

INTERVIEW

"More and more manufacturers will join in"

Peter Leibinger is the Vice Chairman of the Board and Managing Director of the Laser Technology/Eletronics Division of TRUMPF GmbH. He is responsible for research and development and for scouting new operating areas.

What does TRUMPF hope to achieve through research on high-brilliance lasers?
The TRUMPF Group is both the market leader and the leader in technological development in the field of material processing lasers. This is also true for the field of diode-pumped solid-state lasers. Our customers are manufacturers of both industrial products and consumer goods. We would very much like to maintain our leading position in the global marketplace. This is why we are investing a great deal of energy in the research into diode lasers and their development. We are convinced that, in the medium term, industrial lasers will be predominantly based on semiconductor technology. The development of high-brilliance diode lasers is the logical consequence of this policy.

Which technology is favoured at TRUMPF?
We at TRUMPF always favour the laser technology which is most suitable for the individual customer and the relevant applications. In the long run, semiconductor lasers have the potential to replace many – if not all – of the current laser concepts. Presently, TRUMPF is still focusing on all types of laser technology from semiconductor lasers to carbon dioxide lasers, from disc lasers to fibre lasers.

How are these lasers going to change our lives in the years to come? What new applications are possible?
The trend which is already developing today is towards more powerful industrial lasers which are at the same time more cost efficient, a trend which will continue in the future. This will certainly lead to a wider use of lasers in manufacturing processes. For example, motor vehicles welded with lasers are both lighter in weight and more stable. When more powerful and more cost-efficient lasers become available, more and more manufacturers will choose to use them.

How does the co-operation with the scientists from the TU Berlin function?
We are just entering into this co-operation so I can only say that the initial meetings with Professor Bimberg were very pleasant. Although, this could also be because we both come from Stuttgart …

The interview was conducted by Heiko Schwarzburger.

Market leader in industry lasers

With 1.94 billion euros of turnover and a headcount of around 7,300, the TRUMPF group is one of the world's leading production engineering companies. The holding comprises the three business units Machine Tools/Electric Tools, Laser Technology/Electronics and Medical Engineering. Their core business includes machine tools for the flexible machining of sheet metal by stamping and metal forming, and for laser processing and bending. The company headquartered in Ditzingen near Stuttgart is the technology and world market leader in the field of industrial lasers and laser systems. With more than 50 subsidiaries and branch establishments, the group is represented in almost all European countries, in North and South America and in Asia. Their factories are located in Germany, China, France, Mexico, Austria, Poland, Switzerland, Taiwan, the Czech Republic and in the USA.

www.trumpf.com

HEAVY EQUIPMENT is being scrapped

Following on the footsteps of flat-screen monitors and HDTV, a new generation of moving images abbounces itself: Lightweight and energy-efficient laser projectors provide brilliant colour as we have never seen it before, although they are small enough to fit into a matchbox.

Returned from overseas: Up until four years ago, Professor Dr. Michael Kneissl was carrying out research work in Palo Alto, in a think tank run by the electronics concern Xerox which manufactures photocopying devices, among other products. “While I was there, I developed nitride-based semiconductor lasers intended for use in fast, high-resolution laser printers”, says Prof. Kneissl, age 43, physicist now lecturing and researching at the Institute of Solid-State Physics at the TU Berlin. “In these devices, conventional infra-red lasers were used. Because the minimal spot size of a laser printer depends on the wavelength of the laser, shorter wavelengths mean better resolution. We need light with very high photon energy; i.e. green and blue lasers, up to the violet region, which is required for extremely high-resolution printers.”

Michael Kneissl has been Professor at the TU Berlin since August 2005 and he is also Head of the GaN Optoelectronics Business Area at the Ferdinand-Braun-Institut für Höchstfrequenztechnik in Adlershof. He has remained faithful to nitride lasers, because it is not only photocopying technology which can be improved by the use of green and blue light. They also play an extremely important role in data technology, although usually invisible: Conventional CD-ROMs must have both write and read heads, operating with infra-red lasers at a wavelength of 780 nanometres. This is an incredible 780 millionths of a millimetre, which is just how close the data tracks on the disc are to one another. DVDs, which appeared on the market a few years ago, marked a leap in storage capacity. They operate on a laser with a wavelength of 650 nanometres, which is why more information can be stored on the disc. The latest innovation is the “Blue-ray” or “High-definition” DVD in which a blue-violet laser with a wavelength of 405 nanometres is responsible for writing the information. One-sided (single-layer) blue-ray DVDs can store 25 to 30 gigabytes which is 40 times more than a CD-ROM.

The lasers can also be used to project brilliant colours onto displays, for long-range applications or through glass fibres which require only a very small amount of current in order to pulse the laser diodes. As a general rule, colours are mixed from three elementary colours: red, green and blue. What is known as the “RGB colour model” was also the basis of colour television technology. Every computer monitor makes use of it to display millions of colour nuances. However, the elementary colours in these devices are created using lamps or electron beams and require an enormous amount of energy. Laser TV can achieve much higher colour brilliance; moreover, semiconductor components are far more durable than large monitors. The concept is simple: The laser dot which is formed from the three elementary colours is directed via a mirror into a screen. Red lasers are already available. We now have to develop green and blue lasers to the point where the whole projector will fit into a match-

box. As Kneissl explains, “When the laser beam emerges from the semiconductor, it diverges at too great an angle. The aim is to create a beam which is so highly-defined that it can easily be directed into a glass fibre. Achieving this degree of high-brilliance is one of the main aims of our research work.”

Up to now, it has been practically difficult to obtain blue semiconductor lasers from any laboratory, whereas true green laser diodes do not yet exist at all. The research group headed by Prof. Kneissl at the Ferdinand-Braun-Institut has now dedicated itself to this task. Light-emitting diodes (LEDs) in these colours, however, are already commercially available. In contrast to lasers, LEDs have a wide spectrum of 20 to 30 nanometres and emit light at a large angle which makes it very difficult to focus the beam. Osram Opto Semiconductors, one of the five largest manufacturers of LEDs worldwide, has joined the research work at the TU Berlin as an industrial partner. As Kneissl explains, “Blue LEDs achieve an energy yield of 60 percent in laboratory tests. A conventional light bulb hardly manages more than 5 percent, meaning that 95 percent of the energy is wasted. LEDs have a far higher degree of luminous intensity than lamps. According to Kneissl, “While a conventional lamp ceases to emit light after about 1000 hours, an LED operates for between 50 000 and 100 000 hours without losing its brightness. Red and green LEDs are well-known as they are used in traffic lights. They are based on indium gallium nitride.”

In order to be able to produce semiconductors with the desired characteristics for lasers and LEDs and to test possible types, the TU Berlin has recently extended its nano-laboratory, which is unique in Europe. As Kneissl reports, “We have just set up a brand new installation for vapour phase epitaxy for nitride semiconductors which complements the old facility. There are two further installations at the Ferdinand-Braun-Institut in Adlershof with whom we are in close co-operation, and we are planning to purchase another.” ■

Future Award for LED researchers

Horst Köhler, the President of the Federal Republic of Germany presented 3 years ago the Future Award 2007 to a team of researchers from Osram Opto Semiconductors in Regensburg and the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena, Germany, Dr. Klaus Streubel (photo on the right.). Dr. Andreas Bräuer and Dr. Stefan Illek (photo on the left) are carrying out research into new types of light-emitting diodes for everyday applications. These scientists have successfully increased the luminous intensity of light-emitting diodes. LEDs transform electric power into light more efficiently than conventional electric bulbs. Due to the fact that they require only a minimal amount of energy, they can make a major contribution to carbon dioxide reduction. The Award is valued at 250 000 euros.

INTERVIEW

"Getting ready for the global markets of the future"

Dr. Uwe Strauss is the Head of the Laser Development Department at Osram Opto Semiconductors in Regensburg, Germany. Here, he gives us some information concerning what the industry is hoping for and why Osram Opto is participating in the research work.

Why is Osram Opto participating in the research work being done on visible lasers?
Osram Opto Semiconductors develops and manufactures visual, sensory and lighting components. Visible lasers are particularly important for these applications. They are very compact light sources with especially high luminance which is why one of the products being developed by Osram Opto Semiconductors is lasers in the red, green and blue regions of the spectrum, intended for use in laser projection technology. Red lasers are also called for in the field of medicine, for example, for activating medical substances in the body.

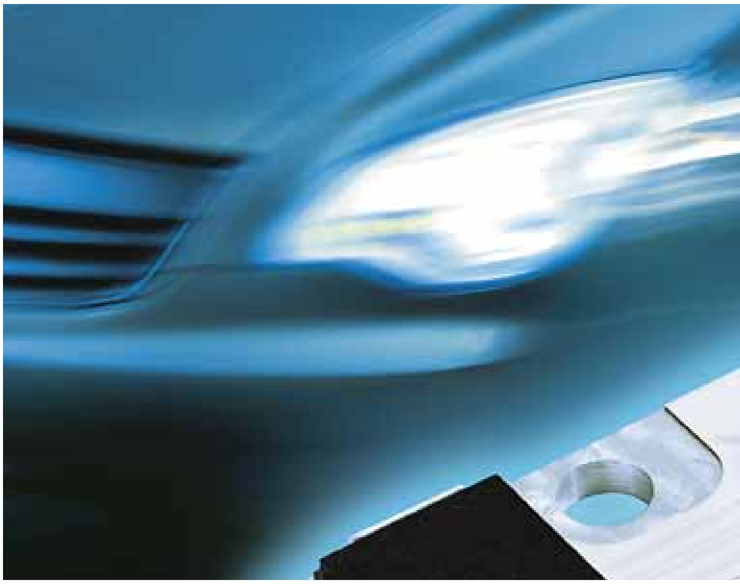
Which products do you expect to see in the next few years?
For laser projection, we are aiming to produce laser sources for complete pico projectors as stand-alone or add- on devices and components for integrable modules known as "embedded systems". These can reproduce enlarged, high-resolution images in connection with notebooks, mobile phones, PDAs, cameras, gaming consoles or navigation devices and data glasses.

Does a market for these products currently exist?
The innovations we are aiming at are directed towards the global marketplaces of the future which, at present, are in the process of developing. We can see real opportunities for laser projectors within the next three to five years. Mobile telephones have the highest potential as they will require millions of visible lasers. The prerequisite for these products is, that they become much less expensive so that they can penetrate the market in very high numbers. The projector unit – and therefore the laser light source too – must be offered in a price range which is equivalent to today's prices for optical data storage media. After about 2011, we will require an additional few hundred thousand laser sources for data glasses, PDAs, iPods, gaming consoles, laptops etc. They will be ready for the market soon.

How does the co-operation with scientists function, for example with the researchers from the TU Berlin? What role does Osram Opto play?
Laser light sources are highly innovative areas in which research is being carried out on a worldwide basis. Osram is working in the field of visible lasers together with various universities and research institutes. Co-operations of this type are sometimes organised in research associations subsidised by the German Federal Ministry of Education and Research. However, we also co-op-

An overview: Osram Opto Semiconductors

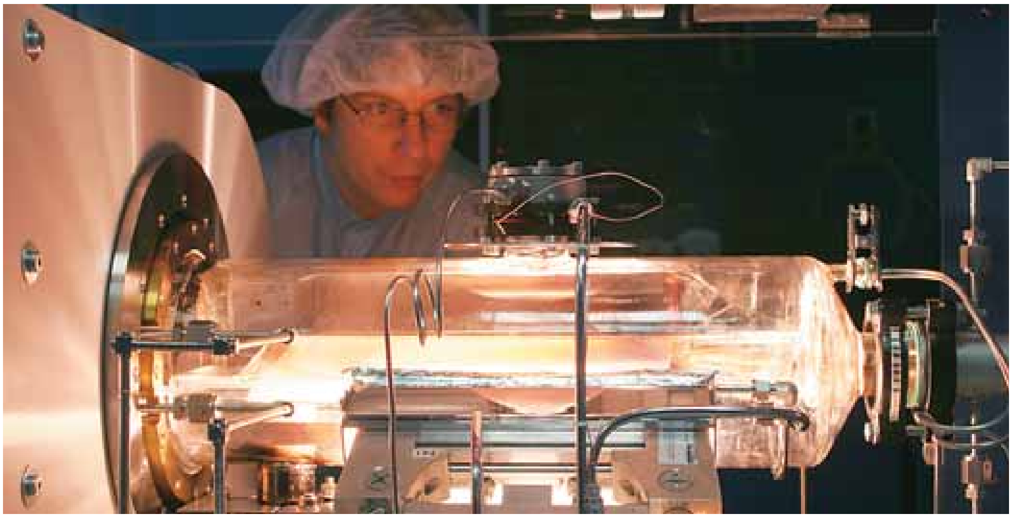
This Siemens semiconductor subsidiary began manufacturing and selling LEDs in Regensburg as early as the nineteen-seventies. The cornerstones of product development were, among other things, the advent of SMT technology (surface mounted technology) which was marked by the Top LED in 1990, the first blue LED in 1994 and also the first LED thin-film chip in the year 2001. In April 2003, the most modern opto-chip production facility in the world was opened in Regensburg-Burgweinting, Germany. The new facility manufactures chips for LEDs, laser diodes and sensors. Osram Opto Semiconductors is also established in the USA and its American Head Office is in Santa Clara. The concern has more than 3500 employees worldwide of whom 1500 are in Regensburg. Osram Opto Semiconductors holds more than 3000 patents which cover the entire scope of semiconductor technology. A large number of these cover the technologies concerning the industrial manufacture of LEDs and lasers based on gallium nitride and indium gallium nitride.



erate on a bilateral level, or Osram provides support in the organisation of research co-operations between universities. Examples of such co-operation projects are “Rote Halbleiterlichtquellen für medizinische Anwendungen” (Red semiconductor light sources for use in medicine) or “Technologien für ultrakompakte und mobile Laser-Projektionssysteme” (Technologies for ultra-compact and mobile laser projection systems). One example of a co-operation on a purely university level is the development of green lasers on the basis of gallium nitride. Although this subject is still a long way from the technical demonstration stage, it is important that preliminary work is being done effectively in this field. One of these main areas of research has just been set up at the Technical University in Berlin with funding by the German Research Foundation, a project which we fully endorse.

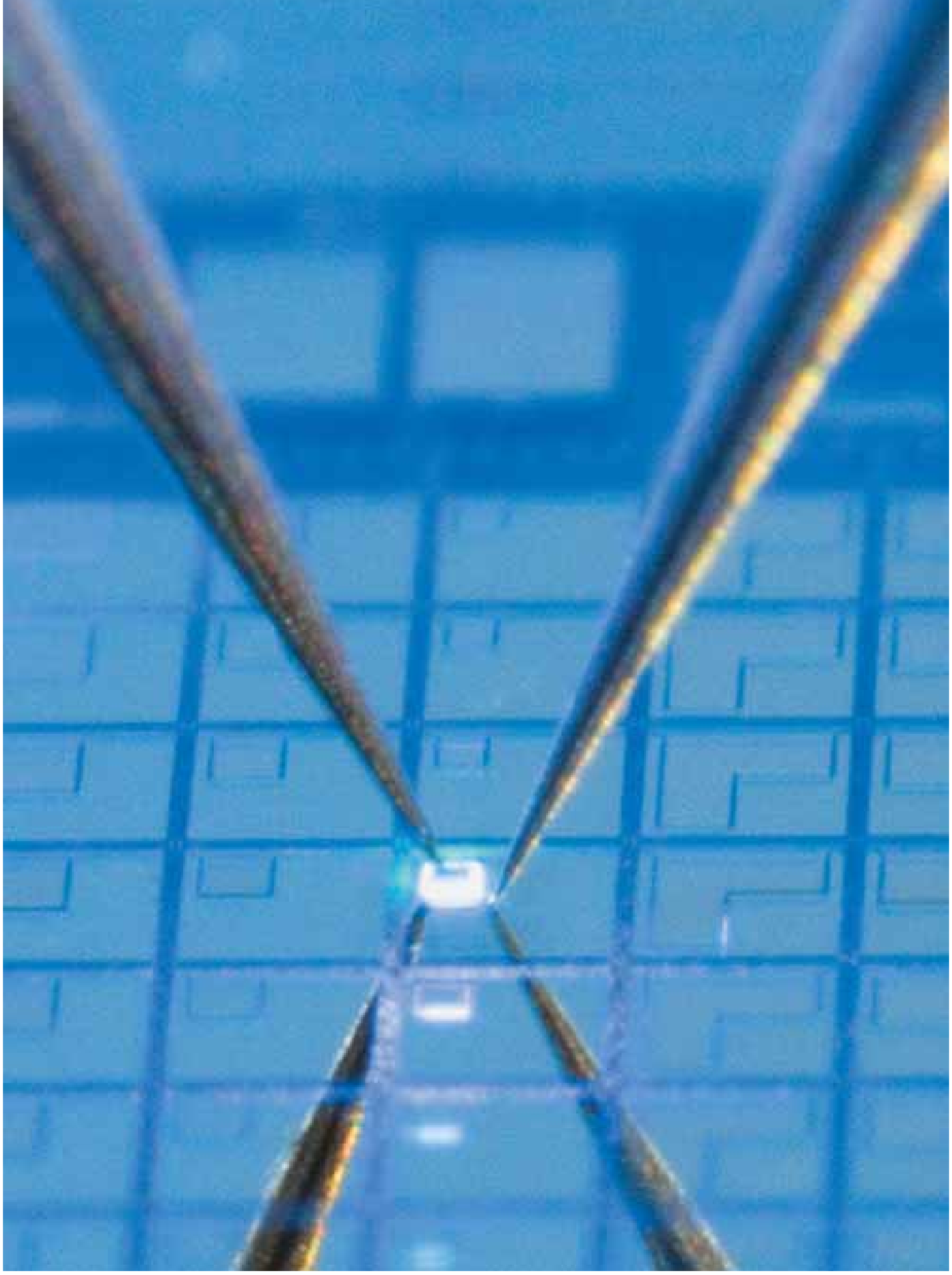
This interview was conducted by Heiko Schwarzburger.

A strong partner in Adlershof: the Ferdinand-Braun-Institut



The TU Berlin and the Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH) have been working together on various projects for many years. Within the new Collaborative Research Centre “Nanophotonics”, there is also a close co-operation with the FBH Diodes Lasers Business Area headed by Dr. Götz Erbert. The Institute is focusing here on increasing the brilliance, efficiency and reliability of high-power laser diodes based on III/V semiconductors. It covers the entire value-added chain and develops laser diodes with a wide range of wavelengths, from the visible region of the spectrum to the NIR (near infra-red) region. Such lasers are used, e.g., for material processing, fibre lasers, medical technologies and metrology. The Ferdinand-Braun-Institut is an internationally recognised competence centre for III/V compound semiconductors which combines boast strong competencies in materials and process analysis, comprehensive device measurement techniques, and excellent tools for CAD. The results obtained from research done at the FBH lead to close collaboration projects on an industrial level and to successfully transfered innovative product ideas via spin-offs. TU Berlin and FBH are working together in the Collaborative Research Centre in their joint research on new types of high-brilliance lasers in the near infra-red region and in the visible range of the spectrum and into UV LEDs. The scope of the joint work far exceeds what is generally understood as a research co-operation. The spokesman for the Collaborative Research Centre, Prof. Dr. Michael Kneissl, is both a Professor at the TU Berlin and Head of the GaN Optoelectronics Business Area at the FBH. In this field, the Ferdinand-Braun-Institut is focusing on the development of laser diodes for the blue-green region of the spectrum and light-emitting diodes (LEDs) for near and far UV. Prof. Dr. Günther Tränkle is not only the Director of the FBH, but also a Professor for Electrical Engineering in the special fields of Microwave Technologies and Opto-Electronics. Research on both university and non-university levels benefits from these multiple connections and from the positive synergetic effects and new ideas emerging from this co-operation.

www.fbh-berlin.de



Fighting VIRUSES with LIGHT

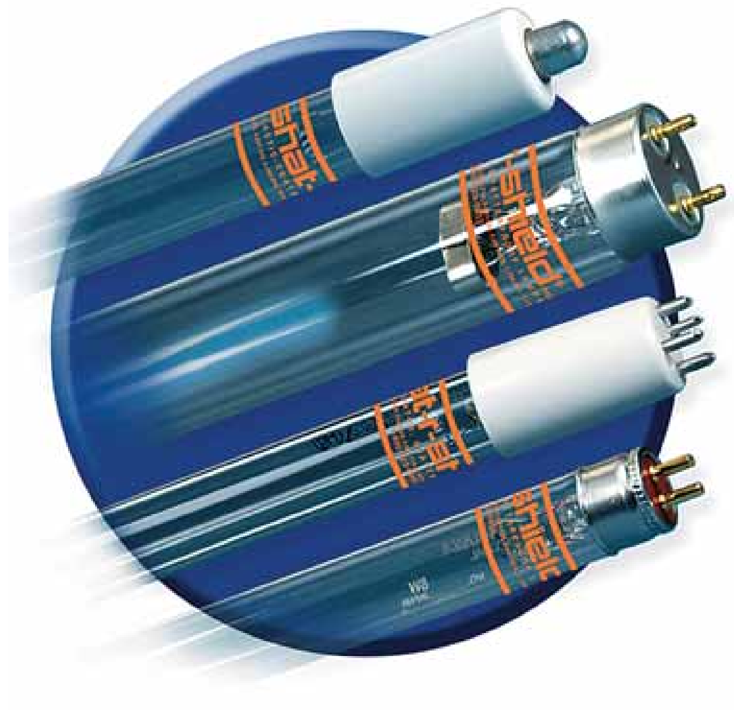
Innovative light-emitting diodes for ultraviolet radiation can indeed be used to purify water and to set dental fillings, but their main advantage is that they save a great amount of energy and space.

Money makes the world go round: In days gone by, a bank officer only had to look at a bank note to be able to tell whether or not it was genuine. Nowadays, he makes use of high technology. The new Euro notes or Her Majesty the Queen's pound Sterling, for example, contain fine threads which are woven into the paper and which emit light when viewed under ultraviolet excitation. The human eye is of little use here, because ultraviolet light is beyond the violet part of the visible light spectrum. It comes to Earth in rays of sunlight and is therefore practically omnipresent, but its intensity is so low that it is hardly noticeable. Specific portions of the UV spectrum are completely blocked out by the Earth's atmosphere.

RICH IN ENERGY

Ultraviolet light is very rich in energy which makes it lethal for many organisms. As Dr. Michael Kneissl, Professor for Physics at the TU Berlin and Head of the GaN Optoelectronics Business Area at the Ferdinand-Braun-Institut für Höchstfrequenztechnik explains, "With the aid of special lamps, water is subjected to what is known as UVC radiation which has a wavelength of 100 to 280 nanometres. Bacteria and viruses absorb the UV photons whose energy break the DNA bonds, meaning that the organisms cannot reproduce. The reproduction chain is interrupted." This technology is standard practice for water hygiene in the United States, however. Up to now, however, mercury vapour lamps have been used for this application and they are just as devilish as bacteria and viruses. Kneissl explains further: "Our aim is to replace the mercury lamps with UV light-emitting diodes (UV LEDs). In order to do so, however, we still have a few bridges to cross because the development of LEDs for ultraviolet light is about ten years behind the technology for red, green or blue LEDs. Therefore, a great amount of research must be done in the fields of semiconductor materials and chip technology."

In order to be able to disinfect water, light must have a wavelength between 265 nanometres and 280 nanometres. The scientists at the TU Berlin and the Ferdinand-Braun-Institut have a more ambitious aim: They want to develop UV diodes at wavelengths between 210 and 400 nanometres. As Michael Kneissl says, "A light-emitting diode requires much less drive current than a light bulb whose energy is mostly converted into heat. An LED for UV light does not require a warm-up period. The wavelength of the light it emits can be optimally adjusted for any individual application, which is a far cry from the mercury lamp whose wavelength is not adjustable." Furthermore, LEDs last 50 to 100 times longer than conventional light sources.



In many regions on Earth, the poor quality of drinking water is a growing problem, not just in crisis areas. In Africa, South America or even Southern Europe, water must be heated and boiled before it can be used for drinking or food. Michael Kneissl's vision is to "build UV LEDs directly onto the water tap. Then, it would be of no importance where the water had come from, because it could be purified at the exact place where it was needed." This technology is not generally known in Germany. In order to kill bacteria in drinking water, the water in the tank must be heated for a short period of time to a temperature of more than 65 degrees Celsius. This requires enormous amounts of heat energy. LEDs emitting ultraviolet light could be powered by means of solar cells, which would render the process of water disinfection quite autonomous. This solution is particularly interesting for regions which are cut off from civilisation. But not only there: In Kneissl's in-box, there is a query from Airbus. Water tanks in aeroplanes also need to be disinfected – as quickly, easily and unproblematically as possible.

The team of researchers lead by Michael Kneissl are working on LEDs whose wavelength inside the UV region can be precisely adjusted. This allows medical applications. Whereas, for example, harsh ultraviolet radiation can cause skin cancer, UV light at a wavelength between 310 and 320 nanometres can have a healing effect on psoriasis. "For this application, the UV light-emitting diode is superior to the mercury vapour lamp because the radiation of the mercury lamp cannot be adjusted." Using LEDs, it would also be much easier to cure pigments and plastics. A dentist, for example, makes use of this technology in order to set dental fillings using UV lamps. Ultraviolet light is also used for hardening the pigments on supermarket packagings to make them water-resistant. The research being done in Berlin is receiving support from the Heraeus Noblelight Company in Hanau, Germany, which is one of the major manufacturers of UV lamps. Kneissl reports that: "Heraeus is expressing great interest in our research into LEDs, also concerning the curing process using ultraviolet light. Our aim is to convert our ideas and solutions into useful products as soon as possible. LEDs save energy, replace mercury vapour lamps and open up a range of new technological applications for UV light." ■

NANO in focus

An advance in diagnostic techniques

Within a period of 20 years, lasers have adopted an important role in the diagnosis of illnesses. By means of laser technology, it is possible to detect various types of cancer at an early stage and other alterations in body tissue or disturbances to body cells can also be recognised. Laser images have a very high resolution and can be perfectly evaluated using modern visualization technology. Laser-based cameras can be introduced into the body on very thin tubes and these endoscopes can be linked to minimal-invasive operation techniques using laser scalpels.

Several large electronic companies are into this business, for example General Electric (GE) from the USA or the German Siemens AG. During the last years, the sector was veritably held in suspense by multiple company takeovers.

New NICHES for LASERS

The Lumics Company is one of the worldwide specialists in laser diodes. It is about to open up a new business sector: lasers for welding, cutting and writing.

Adlershof is very important for the TU Berlin, not only when it comes to research. Some of the companies which are setting up in this largest science park in the formerly "East" German state, are spin-offs from the university. They are now covering specific niches in the laser technology business. The Lumics Company in Adlershof manufactures laser components for applications in telecommunication, metrology and industry. Tens of thousands of laser components, usually no larger than a finger nail, leave the factory each year. 22 employees achieve an annual turnover of close to 4 million euros, more than 50 percent of which is overseas. According to Dr. Nils Kirstaedter, the founder and Managing Director of Lumics, "Over half our turnover is made with pump lasers for amplifiers in the field of telecommunications". Laser diodes amplify the light waves in glass fibre networks where they are spaced approximately every thirty to seventy kilometres apart. "We have now been able to greatly expand our range of products to include laser-beam sources for material processing and for applications in the field of medicine." Lasers by Lumics are used to screen food or blood, and the spectra enable scientists to detect contamina-

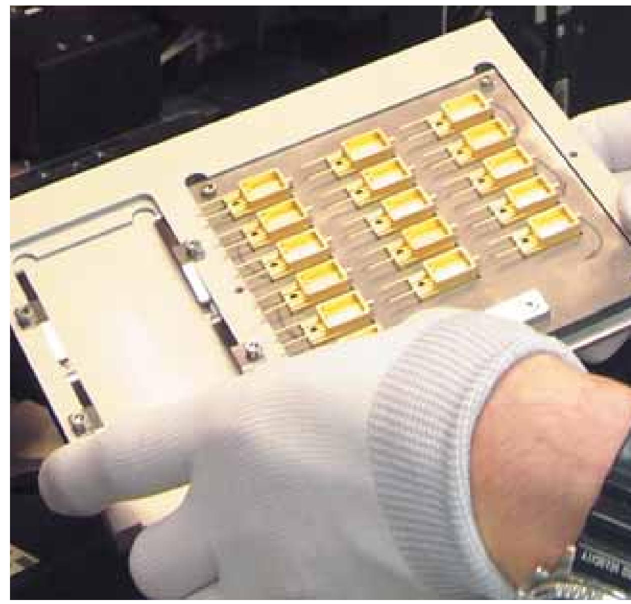
tions. A pulsed fibre laser at a wavelength of 1064 nanometres, for which Lumics specially developed the laser components, is able to cut steel, sheet metal and textiles and is used, for example, in the construction of motor vehicles and in garment engineering. "At the moment, we are in the process of expanding the laser business to include industrial applications. We manufacture lasers which have a wavelength of between 750 and 1100 nanometres. In order to be able to weld or to cut material with these lasers, at least 100 watts of laser power with a pulse power of several kilowatts must flow in a glass fibre which is only a few tenths of a millimetre thick." For more powerful laser welding plants, several kilowatts are required and the fibres are thicker.

Lasers are a universal tool. More and more companies are using them to mark components such as sheet metal, fabrics, foils or plastic bottles. The laser beam moves across the material like a pen and marks the components with an identification number, use-by date or signet. "Up to now, gas lasers or lamp-pumped solid-state lasers which emit light at a wavelength of 1064 nanometres have been used in industry", Kirstaedter explains. "Using small laser diodes, it is possible to manufacture extremely compact lasers which consume far less energy, are easy to pulse and which are also more variable in wavelength. In all applications in which laser diodes are used as direct light sources, they will soon replace the more complicated systems such as gas lasers and solid-state lasers."

THE COMPLETE TECHNOLOGY

Lumics is aiming to further develop and optimise the entire technology, from the chip to the complete laser beam source. In a joint project with the nearby Ferdinand Braun Institute and two other local companies, we are hoping to be able to reduce the costs for industrial laser diode systems to a minimum. As Nils Kirstaedter, a 44-year-old physicist who completed his Doctorate more than a decade ago under Dieter Bimberg at the TU Berlin and was awarded the Carl Ramsauer Prize for his thesis explains, "Our aim is production automatisation, which is why we want to establish a growth centre here in Berlin. This is our answer to the low prices from China. Our partners intend to invest over a million euros and our aim is to reach a price of ten dollars per watt of laser power within the next three years."

One of Nils Kirstaedter's great strengths is the optimisation of production processes. After completing his Doctorate, he worked for SAP for four years in their Head Office in Waldorf near Heidelberg, Germany. "During my time there, I learned to analyse and optimise production chains. That's something which can't be taught at a university. Our customers want a high-quality product in high numbers, delivered exactly on time." The Lumics headquarters is in the Photonics Centre in the Berlin-Adlershof Science Park. Kirstaedter finds it a very great advantage to be so near to important partners,



especially the Ferdinand Braun Institute. "There, we can use the wafer processing technology and at the TU Berlin, we can take advantage of their analytical methods."

The output power of semiconductor lasers doubles every two years. We experience the same phenomenon with computers – and the price of both remains the same. This is the reason why Lumics invests up to one fifth of its budget in research and development. "Our company's aim must be to increase in size so that international customers will appreciate us as being a highly efficient supplier who is very reliable in the long term", Kirstaedter says. "We are a modern production facility which controls its manufacturing processes using data technology and not a workshop where things are done by hand." ■

www.lumics.com

HIGH PRECISION TOOL

A co-operation between researchers at the TU Berlin and researchers from St. Petersburg is now bearing fruits. Photonic band crystal and tilted wave lasers will mean a quantum leap in laser welding technology.

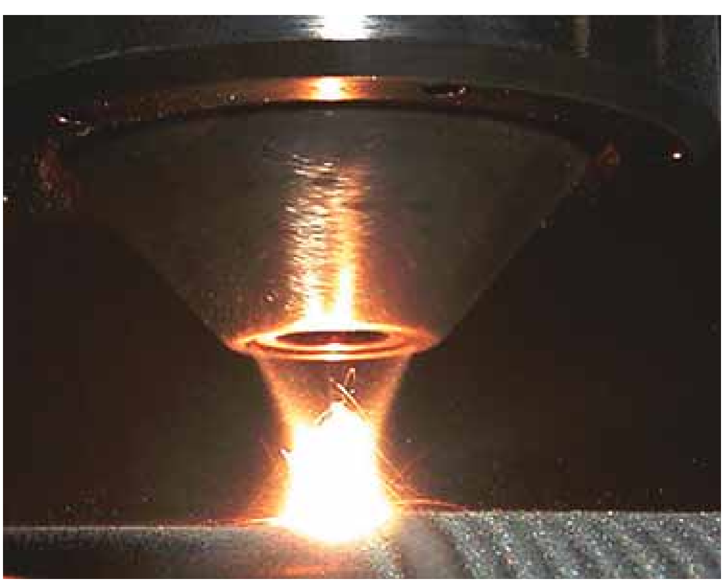
Photonic Band Crystal Lasers GmbH (PBCL GmbH) is a Berlin start-up company which is aiming to develop high-performance lasers with beam quality like solid state lasers based on completely novel concepts. The laser diodes, which are developed in a joint research project with a large industrial investor, will emit an almost parallel laser beam of unprecedented power. As Dr. Fritjof Willmann the CEO PBCL explains, "These components are very inexpensive and very reliable. Our aim for PBCL diodes is is arrays of more than 100 coupled diodes delivering 500 watt and stacks in the multi-kilowatt range. The emission wavelength of oure lasers can be tuned adapting to specific applications across a broad wavelength range. The stacks will then suitable for laser welding or laser cutting. Single diodes are important for use in scanning applications and for analytical purposes."

These laser diodes emit a light beam of high quality and which can easily be transferred into glass fibres. Complex costly optical technology for focussing the beam is not necessary. As Willmann explains, "This means that only a minimum of energy is required to create and transform high output. PBC/TWL diodes allow very flexible use; they can be manufactured cheaply, efficiently and in a compact form." One example of use of such laser stacks is automotive construction, where they are used for welding steel plates for the car bodies. They can also be used to weld foils or plastics; they can be made to cover all the necessary wavelengths. In the solar industry, for example, lasers are used for structuring solar cells at higher speed.

EXCELLENT PROSPECTS

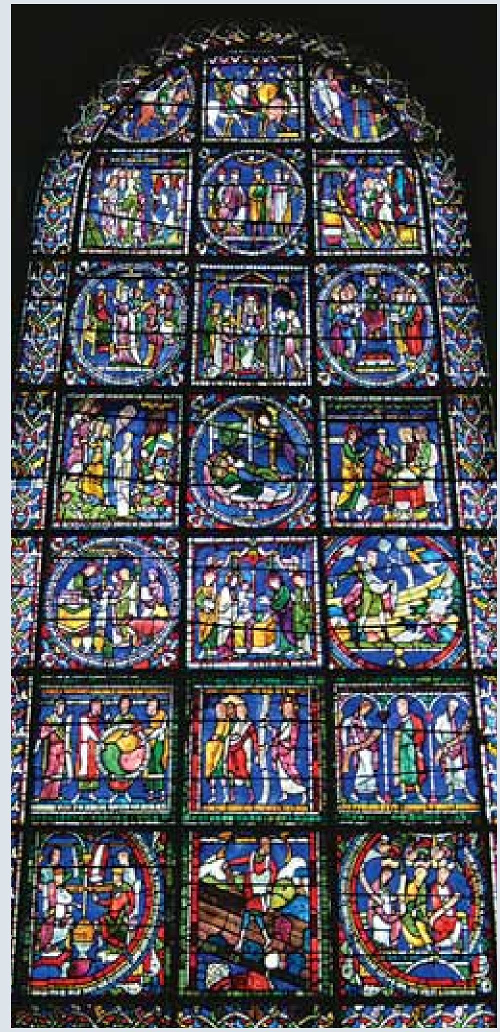
Two of the founders of PBCL are from Russia. Nikolai Ledentsov was a Professor, Vitaly Shchukin was a principal scientist at the famous Ioffe Institute in St. Petersburg which is regarded worldwide as one of the leading think tanks in the field of semiconductor technology. During the last ten years, they have developed the PBC/TWL concepts together with the scientists of Professor Dieter Bimberg from TU Berlin and Konrad-Zuse-Institut, in the frame of research which has already cost more than 1 million euros. A large industrial player joined PBCL as an investor. Siemens has now incorporated PBC/TWL arrays into its laser inspection systems for the first time in order to test them.

The prospects aren't bad at all: The worldwide market for laser processing devices is estimated to reach about ten billion US dollars by the year 2012. The most rapidly growing sectors are diode-pumped lasers and fibre lasers in which several laser diodes emit light into a single glass fibre. More and more industries are making use of lasers to automate their production systems, for there is no other tool which is as energy-efficient and flexible and can operate with such accuracy and so enduringly as a laser, which can get beyond any corner or edge by means of a glass fibre. The worldwide market for lasers used in analysis is estimated to be about 20 billion dollars. As Fritjof Willmann comments, "PBC Lasers GmbH are at the very top of the field in laser technology." In 2011, the company intends to present their technology at the leading trade fair for lasers, Photonics West in San Francisco, California. "Our perspective for the future is to start production of these lasers in the 'opto valley' Berlin", Willmann tells us, "where we can count on the strong development group working at the TU Berlin, FBH and numerous industrial players in Berlin-Adlershof. " ■

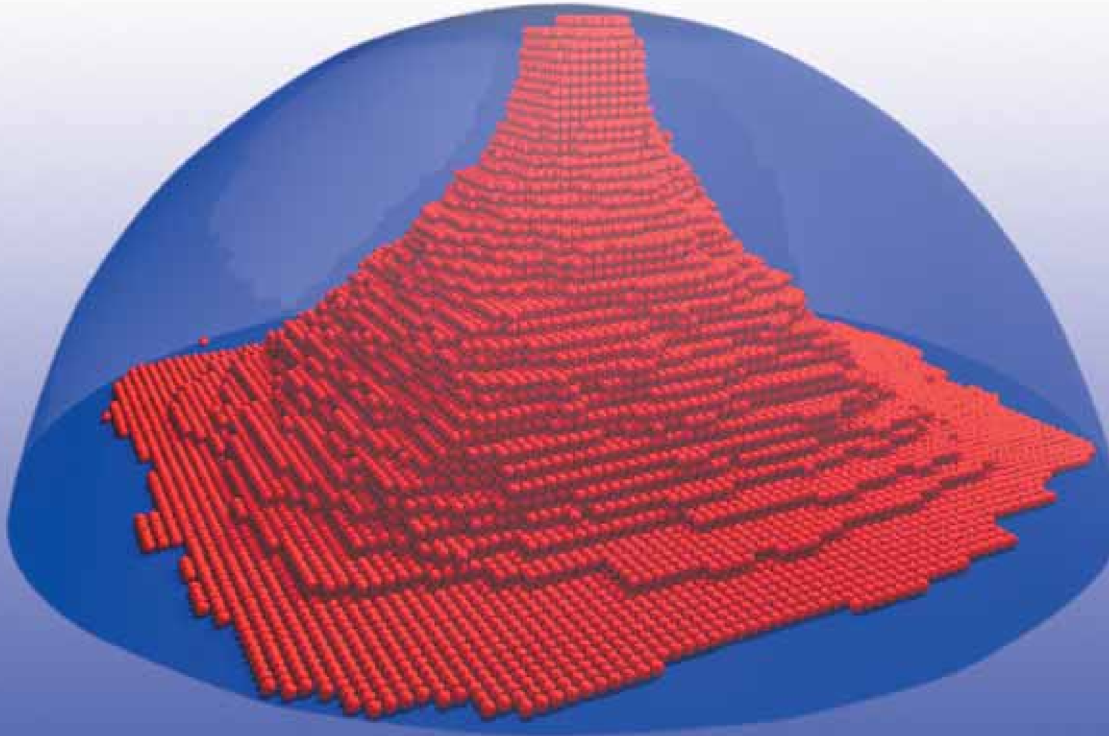


NANO in focus

Colourful church windows



People in the Middle Ages were already making use of the colour-changing effects of quantum dots, although they had no knowledge of modern science. When church windows were made, very small quantities of fine gold dust were added to the melted glass. The melted glass was tempered in accordance with special recipes to yield the property of being able to pass only specific colours when illuminated by sunlight. Nowadays, we know that, by using these recipes, minute particles of gold were created with a few nanometres diameter, whose electrons vibrate in the visible region of the spectrum. The diameter of the particles and hence the frequency at which they vibrate were adjusted by testing, carried out hundreds of years ago by craftsmen with no profound scientific knowledge.



TORCHBEARERS in the DATA TUNNEL

One single photon can frustrate hackers or lead snoopers astray. It's a difficult thing to send it through a data channel, but there is a prototype in the offing.

Arms race on the data superhighway: New and ever more complicated encoding methods using ever more powerful computers are being invented to safeguard electronic money transfers, military information channels or the red telephone which connects the Office of the Federal Chancellor with the White House. But the opposition is arming too: Hackers, criminals and secret services are using ever more powerful super computers to crack the mathematical encoding algorithms. It's only a matter of time and computer power before the competition enters a new round.

Everything could be so easy: It is impossible to crack a code if the sender and the receiver of the information are the only people who have the key, but only quantum key distribution systems based on quantum mechanical effect yield truly secure keys. Everyone else has to rely on complicated mathematical methods. In what is known as "asymmetrical encoding", the method being used at present, two partners can encode information without exchanging a code in advance. However, the extent of the security provided depends only on how difficult it is for a computer to crack the code. A normal PC would require a couple of million years to crack the codes being used for internet banking at the moment, but the most powerful computer in the world can do it in a mere ten seconds.

One single polarized photon or two entangled onescan put an end to this witch hunt. Two researchers from Professor Dieter Bimbergs group at the Institute for Solid-State Physics at the TU Berlin, Erik Stock (33) and Marc Anatol Lochmann (32), intend to make use of a concept taken from the field of quantum optics to send tap-proof codes – without couriers. As Marc Anatol Lochmann explains, "If one single polarised photon is used for the transmission of the key, it can be seen immediately whether someone is listening in. A photon cannot be split or copied. If someone else is on the line, the photon disappears or changes some of its properties and the key which has been transmitted will not be used." The photon is the basic element of light. It's rather like a torchbearer who goes through a dark tunnel before the rest to see whether the coast is clear.

Erik Stock comments, "We can't prevent data channels from being tapped, but the photon spy will tell us when a transmission is endangered. This information is all that's required in order to break off the transmission or to revert to another channel."

Individual photons present the smallest elements of light. They are microscopic portions of energy which are created, for example, by short electric pulses inside light emitting diodes. The released photons have precisely-defined characteristics, such as a specific frequency, for example. As Lochmann explains, "The difficulty is to ensure that only one single photon is created by an electric pulse and sent through the data channel, not two or three. Weak laser pulses could be used for this, but one cannot be sure whether, in some cases, two or more photons, or none at all, are created."

In order to be able to transmit single photons through millions of sensitive data channels as a sort of security service, we need a technology which is both economical and robust. In this age of endless information networks, this technology must be suitable for being used practically anywhere and, most importantly, it must also be affordable. A single photon emitter must be suitable for mass production. Lochmann continues, "We have developed a component which is very similar to a conventional laser diode. The growth of the semiconductor layers, the processing and the structural technology of this component are also related to traditional diodes. We can draw on the resources of information concerning previous mass production technologies for VCSELs."

These young researchers are setting their hopes on what are known as quantum dots, i.e. minute clusters, formed inside a semiconductor material, in which electrical pulses are converted into photons with specific controlled characteristics. As Erik Stock explains, "A quantum dot is only a few nanometres in size. A whole device usually contains no more than 40 cubic micrometres. In order to connect a wire for the electric pulse to it, the device must be approximately one cubic millimetre in size. One micrometre is equivalent to a thousandth of a millimetre; a nanometre is a mere millionth of a millimetre. The wire which connects the electronic pulse generator is only a quarter of the thickness of a human hair. As Marc Anatol Lochmann says, "It's a very filigran thing."

The growth of quantum dots inside the carrier material occurs according to its own rules. This process is referred to as "self-organisation". In the laboratories of the TU Berlin, between 100 million and 100 billion quantum dots are created per square centimetre and second. As Erik Stock explains, "Just one of these is selected for the creation of the photon. In co-operation with our scientist friends from Russian Academy of Science in Novosibirsk, we are trying to decrease the density of quantum dots. We have been partially successful, and this is a very important factor. In addition, we are narrowing the path of the current so that only a single quantum dot is excited to emit light." Two generations of prototypes already exist and have proved that, in principle, it can be done. "We envisage that we will be able to carry out initial transmission experiments with our second generation of components soon."

A CANNON FOR A SINGLE PHOTON

The focus of the work being carried out by Stock and Lochmann is the emitter, the "cannon", which is to give the starting shot for a single photon with specific characteristics. Scientists in Switzerland have proved that it is indeed possible to protect data lines by using single photons. By means of the far from perfect technology of attenuated laser pulses, they transmitted a message encrypted by single photons between two Canary Islands. Due to frequent empty pulses, the transmission rate achieved using this method is slow and less secure than with a single photon cannon. As Erik Stock explains, "If, by chance, there are two photons underway at the same time, it is theoretically possible to tap the line without being detected. One photon could be transferred out."

Marc Anatol Lochmann is certain that single or entangled photon emitters will be in use for security-critical data transfer in Germany within the next 10 to 15 years. At present, the research team in Berlin is already cooperating with a number of international groups. NATO is funding the research at the TU Berlin, in Russia, England and the USA as part of a "Science for Peace" project headed by the Nobel Laureate Professor Zhores Alferov from St. Petersburg and the Max Born Laureate, Professor Dieter Bimberg from Berlin. "Secure data transfer will be the most spectacular mass application of nanophotonics to be realised in the future. There is a huge amount of work going on across the world in an attempt to build these components and systems based upon them." It is still not clear which of the material systems is the most effective for manufacturing the single photon emitter. The University of Magdeburg is working on similar emitters based on gallium nitride. As Professor Bimberg says "We at the TU Berlin can draw on the pool of knowledge shared by our large research group and can rely on the co-operation with other groups. Without teamwork, it is not possible to make great advances in this field". ■

NANO in focus

EU increases funding

The EU is spending about 2.8 billion Euros on the development of new nanotechnologies and about 300 million euros on photonics. In its 7th Framework Project which runs from 2007 to 2013, the European Union is increasing its funding for the promotion of research into photonics by about 50 percent, taken from two different funding programmes. As far as the 2007 to 2009 submissions are concerned, the increase has become a reality, with funding coming from the European Union ICT (Information Communications Technology) and NMP (Nanotechnologies Materials Processes) projects.

Competence in communication technology – on campus at the Heinrich-Hertz-Institute

The Collaborative Research Centre "Nanophotonics" promotes and funds the close co-operation between the research groups at the TU Berlin headed by Professor Dr. Klaus Petermann and Professor Dr. Dieter Bimberg and the Fraunhofer Institute for Telecommunications (Heinrich-Hertz-Institute, HHI). This research is focussed on the investigation and development of active indium phosphide components, especially of variable frequency quantum dot structures and quantum dot-based semiconductor laser amplifiers.

In the focus of the research and development work being carried out at the Heinrich Hertz Institute are innovations for the digital future – which does not only include the field of modern communication systems, but also the fields of digital media and internet services. The core competences of the HHI include optical communication networks and systems, mobile broadband systems, photonic components and electronic imaging technologies. One of our fields of emphasis are photonic networks, from the high-capacity, flexible long-range network to the close-range broadband network for in-house use. The range of optical components includes all the semiconductor components, which cover the key functions required for optical telecommunication technology and signal processing. The HHI has a processing line which enables researchers to develop and produce optical and electro-optical components and modules. The line covers lasers, optical semiconductor amplifiers and indium phosphide-based detectors with a wavelength between 1.1 µm and 2.0 µm. This includes, for example, lasers with broadband modulation in un-cooled operation such as those required for metro and local networks. Include are also photodiodes with a bandwidth of up to 110 GHz as well as optical semiconductor amplifiers and components for all-optical signal processing, components which create tetrahertz waves, polymer optical waveguides, as well as diffractive optical elements. HHI has also received international recognition for its experience in the field of active quantum structures in the 1.55 µm wavelength range.

Due to its wealth of expert experience and the possibilities it offers in the field of high-frequency metrology, the HHI has also become an internationally recognised competence centre for all-optical signal processing and the development of high-speed modules for optical communication.

www.hhi.fraunhofer.de

Research projects in the field of applied mathematics: Weierstraß Institute for Applied Analysis and Stochastics

The Weierstraß Institute for Applied Analysis and Stochastics (WIAS) which is based in Berlin-Mitte conducts research projects in selected fields of applied mathematics. The aim of the projects is to contribute finding solutions to complex problems in the fields of industry, science and technology. The Weierstraß Institute has a holistic approach: It follows the entire process of problem solution from interdisciplinary modelling through to the mathematical and theoretical interpretation of the models and on to specific numerical simulation.

The research being done at the Weierstraß Institute is concentrated on nanoelectronics and optoelectronics, optimisation and control in process technology, phase transformations and multi-functional materials, stochastics in natural and economic sciences, problems concerned with flow and transport in a continuum as well as numerical methods in analysis and stochastics. The WIAS has approximately 100 researchers and is linked to the research being carried out in Berlin through a multitude of joint projects. The new Collaborative Research Centre 787 "Semiconductor Nanophotonics" has received a new highlight with the beginning of this excellent and many-faceted cooperation with the TU Berlin, for example through several researchers who hold joint professorships, and the DFG (Deutsche Forschungsgemeinschaft – German Research Association) Research Centre Matheon.

www.wias-berlin.de

"Integrated Research Training Group"

Semiconductor Nanophotonics: Materials, Models, Devices

Promotion of young researchers is in the focus of the Integrated Research Training Group (IRTG) "Semiconductor Nanophotonics: Materials, Models, Devices". ITRG provides a structured doctoral candidate program within the frame of the Collaborative Research Center SFB 787:

- New tools for the education of excellent PhD candidates in the scientific fields represented by the projects of the SFB 787 beyond traditional approaches of specialized courses are developed.
- Guiding is provided to them to become responsible researchers early in their career.

Thus IRTG enables its doctoral candidates through conceptual evolution and education to graduate on internationally outstanding professional level. The tutoring/scholarship program integrates selected science and engineering students as early as possible into research projects, using the synergies of combining the excellent research opportunities within the SFB 787 with an intense scientific education and professional-social training. A key element is intense cooperation between the participating universities and the external research institutes on the educational level beyond science. A dual mentoring program (one mentor from university, one from a research institute) is organized for the PhD candidates. The multifaceted modular concept is based on multidisciplinarity and combines intense scientific subject introduction with continuing education and qualification, promoting team competence, personal and soft skills. Key elements of the program include:

- Annual introductory three days spring school (above Graal-Müritz, May 2008).
- Biweekly presentation of own research by the PhD candidates and postdocs in the IRTG seminar,
- Regular workshops with representatives of the photonic industry (Nanophotonics Day)
- A topical symposium at the annual spring meeting of the German Physical Society, jointly compiled by outstanding external international invited speakers as well as IRTG members.
- Coorganisation of the annual International Nano-Optoelectronics Workshop iNOW, with the University of Berkeley, University of Tokyo, Tokyo Institute of Technology and Tsinghua University Beijing, with outstanding international researchers as tutors, being part of our international networking and bridge building activities.

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The **Collaborative Research Centre:** an overview

Collaborative Research Centre 787 “Semiconductor nanophotonics: Materials, Models, Components”.

The research projects

Materials for high-brilliance green laser diodes

Prof. Dr. Michael Kneissl, Technische Universität Berlin
Prof. Dr. Günther Tränkle, Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin

Growth of InGaAs quantum dot structures for innovative devices

Prof. Dr. Udo Pohl, Technische Universität Berlin
Dr. André Strittmatter, Technische Universität Berlin

Modified InP-based quantum dot arrangements for light emitters

Dr. Harald Künzel, Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute), Berlin
Prof. Dr. Udo Pohl, Technische Universität Berlin

Atomic structure of nanomaterials: HRTEM, Electron holography and XSTM

Prof. Dr. Michael Lehmann, Technische Universität Berlin
Prof. Dr. Mario Dähne, Technische Universität Berlin

The electronic structure of nanoscaled objects

Prof. Dr. Axel Hoffmann, Technische Universität Berlin
Prof. Dr. Dieter Bimberg, Technische Universität Berlin

Electron-photon interaction in semiconductor nanostructures

Prof. Dr. Christian Thomsen, Technische Universität Berlin
Prof. Dr. Axel Hoffmann, Technische Universität Berlin

The quantum-optical limits of photonic component theory

Prof. Dr. Andreas Knorr, Technische Universität Berlin

Dynamic modelling of quantum dot lasers and amplifiers

Prof. Dr. Eckehard Schöll, Technische Universität Berlin

Multi-dimensional modelling and simulation of VCSELs

Dr. Uwe Bandelow, Weierstraß Institute for Applied Analysis and Stochastics, Berlin
PD Dr. Frank Schmidt, Konrad Zuse Institute for Information Technology Berlin
Prof. Dr. Alexander Mielke, Weierstraß Institute for Applied Analysis and Stochastics, Berlin

Effective models, simulation and analysis of the dynamics of quantum dot components

Prof. Dr. Jürgen Sprekels, Weierstraß Institute for Applied Analysis and Stochastics, Berlin
Dr. Matthias Wolfrum, Weierstraß Institute for Applied Analysis and Stochastics, Berlin

The **Collaborative Research Centre:** an overview

QP surface emitters: lasers, amplifiers, single photon emitters

Prof. Dr. Dieter Bimberg, Technische Universität Berlin

Single photons for quantum information processing

Prof. Dr. Oliver Benson, Humboldt Universität Berlin

GaN-based single photon emitters and VCSELs

Prof. Dr. Alois Krost, Otto von Guericke Universität Magdeburg
Prof. Dr. Jürgen Christen, Otto von Guericke Universität Magdeburg

High-brilliance semiconductor lasers

Dr. Götz Erbert, Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin
Prof. Dr. Dieter Bimberg, Technische Universität Berlin

Dynamics of edge emitters for multi-terabit systems of the future

Prof. Dr. Dieter Bimberg, Technische Universität Berlin

All-optical signal processing using quantum dot-based semiconductor amplifiers

Prof. Dr. Klaus Petermann, Technische Universität Berlin
Dr. Colja Schubert, Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute), Berlin

Integrated Graduate College "Semiconductor Nanophotonics: Materials, Models, Components"

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- Humboldt University Berlin
- Otto von Guericke Universität Magdeburg
- Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin
- Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute), Berlin
- Weierstraß Institute for Applied Analysis and Stochastics, Berlin
- Konrad Zuse Institute for Information Technology Berlin (ZIB)

THE NEW COLLABORATIVE RESEARCH CENTRE "SEMICONDUCTOR NANOPHOTONICS"

Overview of partners from science, research and industry