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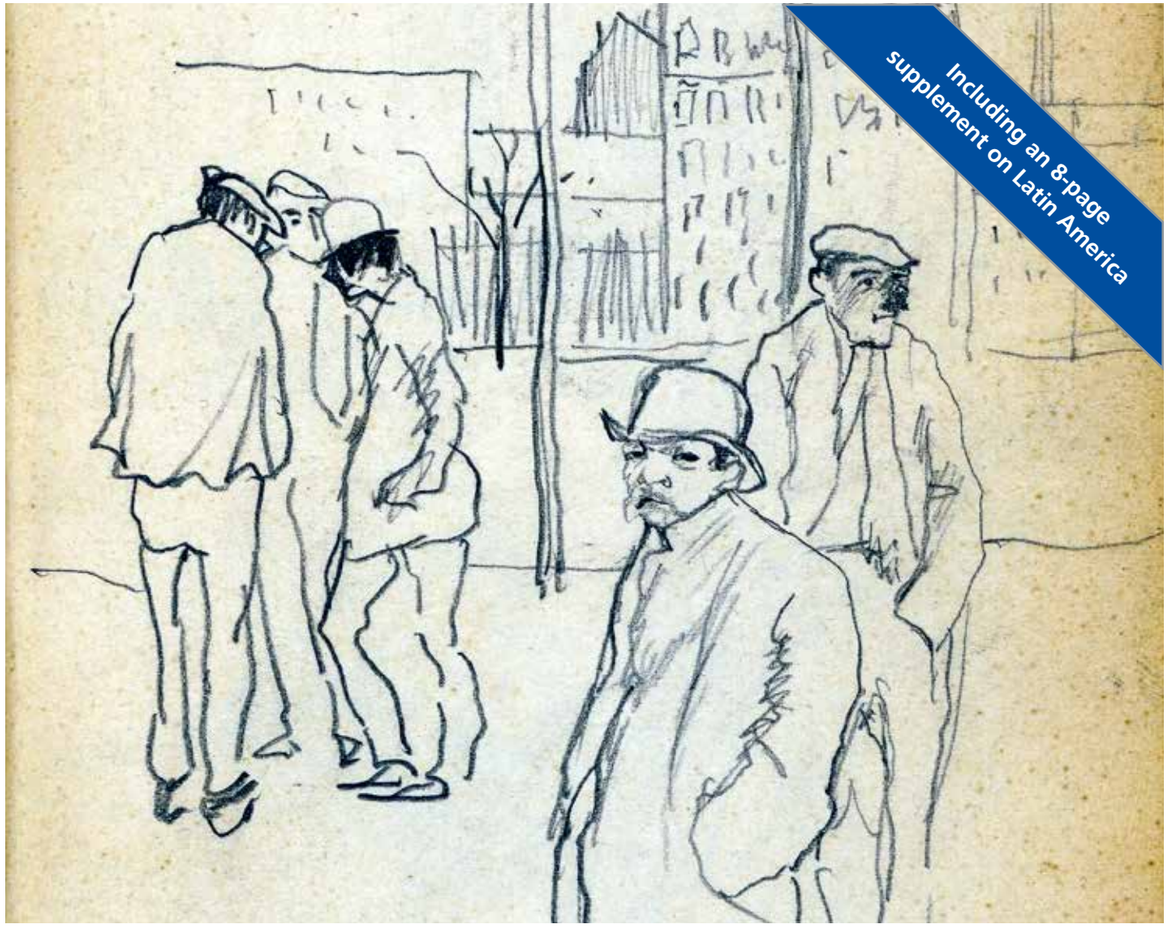

August Macke: The Artist in Dialogue with Himself | **Excellence Initiative:** We Take it Literally | **Refugee Scientists and Academics:** Contributing to Integration | **Extinction Learning:** Don't Forget… | **Carbon Nanotubes:** Strong, Conductive and Defect-Free | **Laser Technology:** Miniaturisation is the Name of the Game

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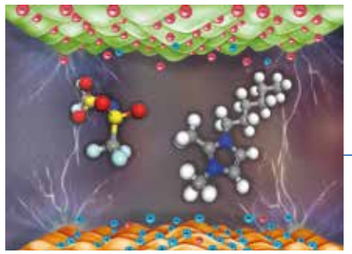
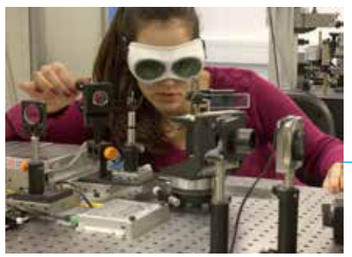
Cover: LWL-Museum für Kunst und Kultur

The expressionist August Macke and his paintings are famous. His lesser-known drawings, here a street scene from Berlin from 1907/1908, are now digitally available to the public and research communities.





Peter Strohschneider

Excellence Initiative: We Take it Literally

As we await decisions on a new federal/state initiative, it is still unclear how politicians will fulfil their mandate and self-imposed goal of shaping the research system. But they have basically already committed themselves to the continuation of the principles that have made the Excellence Initiative so successful thus far: the funding of top-level research that is open to all research fields and a science-driven process.

Research policymakers have a mandate to set the course for research. In order to fulfil it, they must perform a delicate balancing act between political requirements on the one hand and the particular functional framework of research on the other.

This would be virtually impossible without a spirit of trust and close cooperation between politicians and the research community. This cooperation makes it possible to lay out the prospects of the research system along a generous time horizon and create the necessary scope for the discovery and development of new scientific knowledge – and thus also of our modern science-based society.

Through the Excellence Initiative, which began in 2006/2007, those responsible for science policy at the national and state levels have fulfilled their mandate in a highly successful and internationally regarded – indeed admired – way, for the benefit of German research.

The Excellence Initiative had a clear objective, towards which the funding lines, clearly categorised by function and format, were oriented. The different criteria of the funding lines determined the competition, and the distribution of funds was in accordance with the results of this competition as established through scientific review and evaluation and therefore with the aims of the Excellence Initiative. The functions of the Excellence Initiative for the ongoing development of the research system, the programme objectives of the funding lines, the assessment and decision process, and the subsequent distribution of funds formed a direct functional link.

It's important to remember all this in the first weeks and months of the new year as we await the long anticipated – and hopefully positive – decision on a new federal-state initiative to take the Excellence Initiative to the next level. Indeed, it is still not sufficiently clear, at least to the research community, how politicians will fulfil their mandate and self-imposed goal of shaping the research system this time around. This is in spite of a policy document in which politicians undertook to continue the principles that have enabled the Excellence Initiative to become so successful over the last decade.

I am referring to the resolution to introduce a new federal-state initiative, finalised by the federal government and the governments of the federal states on 10 December 2014. The text is fully committed to the principles mentioned before: it talks about enhancing the capabilities of our higher education institutions by funding the best research and through profile development and cooperation in the research system.

The key features of the new federal-state initiative will include a science-based selection process that will promote the transparency and acceptance of funding decisions. Indeed, it was the very nature of the trusting collaboration between politicians and the

Illustration: DFG / Gorczany

research community in the realisation of the aims of the Excellence Initiative, as well as the science-based nature of its processes, that earned this competition and the resulting funding decisions such exceptional recognition both nationally and internationally.

The new federal-state initiative will also demand enormous effort and commitment on the part of the research system, in many respects and in all phases of the process: the political negotiation of the competition rules, the design of funding formats, and the intellectual and institutional preparation of proposals and scientific reviews. Last but not least, achieving the aims of the initiative will require financial resources of a significant scope, and making these available is a budgetary challenge that should not be underestimated.

In this sense, too, the resolution is the most important document so far in terms of the further development of the Excellence Initiative. It makes the functional connection between competitive aims, funding instruments, processes and finances unmistakably clear. It would not do to simply allocate more money to the universities, and neither could the actual functions of the competitive process – namely its varied and dynamic contributions to the ongoing development of research and the research system – be simply tacked on to the distribution of resources as an afterthought. Finance is a means, not an end in itself.

There is no other way to read it: the resolution reached by senior government representatives is intended to secure the successes of the Excellence Initiative and take the progress achieved a step further, to ensure that the funding formats in the new initiative are aligned to their objectives – and not for example to balance opportunities in a non-science-based resource allocation process – and it calls for science-driven selection processes.

The DFG, which has acquired a wealth of experience in the Excellence Initiative, has described many times over the last two years the directions that it believes the funding formats and processes of the new round of competition should follow. We have proposed concrete development measures for the clusters of excellence funding line, which have been broadly welcomed both in the research community and by politicians.

The broad consensus in the DFG is that the following points are crucial to the new initiative as a whole: Funding lines and procedures must satisfy the standard of excellence; universities and top-level research must be the focus of all measures; and there must be a competitive process at the level of both research fields and institutions. Equally importantly, there must be openness in competition for all research fields and topics, there must be funding periods that can extend beyond normal project durations, and there must be access to the competition

▶ *continued on page 4*

▶ *continued from page 3*

for both previously funded projects and new proposals. The decision-making system must be adapted to the architecture of the funding lines and must ensure science-based review processes and decisions in a two-stage procedure (draft proposal/full proposal); in practical terms this also implies that funding decisions will not be possible much earlier than 2018 and that a form of bridge funding will therefore be necessary for projects that are currently receiving funding.

I would like to add that a decision-making process can only be considered science-based if the scientific quality of proposals takes priority over all other considerations – including criteria which, legitimate in themselves though they may be, arise from subject-specific or political priorities or regional proportional considerations. The principles of clear and fair science-based decision-making processes for research funding are particularly important to the DFG. In its funding activities it puts these principles into practice at an acknowledged high level. It cannot and will not deviate from these principles and the resulting standards of quality, either now or in the future. These have also been the foundations of the Excellence Initiative and its impacts on research.

This also means that modifications to the processes for the new federal-state initiative would be justifiable where funding has been approved without the framework of project deadlines. Here, too, scientific dignity and political legitimacy must be balanced in the interests of the acceptance of the competitive process.

In this context, we understand the resolution that science-based processes and decisions will be needed for the new federal-state initiative as an acknowledgement of the DFG's proven approach and an expression of political confidence in one of the most important quality assurance mechanisms in the whole German research system.

Professor Dr. Peter Strohschneider
is the President of the DFG.

Refugee Scientists and Academics: DFG to Facilitate Participation in Research

Universities and project leaders can apply for extra staff with immediate effect / Contribution to integration in research and society

The DFG plans to help scientists and academics who have fled their home countries to participate in DFG-funded research projects and thus contribute to the integration of refugees in research and society. At the beginning of December, DFG President Professor Dr. Peter Strohschneider presented a package of measures to the Joint Committee of Germany's largest research funding organisation. The basic aim of these measures is to allow supplemental proposals to be submitted for existing funding projects which would enable the participation of qualified researchers or those in training.

"The integration of people who have been forced to flee in fear of their lives is a duty for all groups in society. The academic and research community, which has always been based on openness and plurality, can and must do its part," said Strohschneider. "Although we cannot say for sure how many, it is certain that the people now coming to us as refugees include researchers at the training stage or people already established as researchers. We know this from enquiries that have already been sent to the DFG regarding funding opportunities."

To use DFG funds to help improve the situation at least a little for refugee scientists and academics, there is no need to set up new funding programmes, the DFG President continued. In fact, there is already scope within existing project funding to integrate qualified individuals into funded projects. In particular, this can be achieved through supplemental proposals for existing projects, which the original applicants are free to submit in certain circumstances – for example if additional researchers, whose participation would bring additional benefit to the research, become available after the project is approved.

"We want to expressly encourage all higher education institutions and project leaders to make use of these additional opportunities," said Strohschneider.

Various concrete options are available to refugees with an academic research background. For the short-term integration of refugees at all academic qualification levels, supplemental proposals can be submitted for staff posts or guest funding. For the longer-term integration of established researchers, the Mercator module is a suitable option. This can be used to cover accommodation and travel costs and also provide remuneration at a level which, as with guest funding, is based on academic qualification. Staff posts, guest funding and Mercator funding can be applied for in all DFG funding programmes. The budget for this will be dependent on the number of people who can be integrated in funded projects in this way.

Refugee scientists and academics can also participate directly in Research Training Groups, Collaborative Research Centres and other DFG-funded coordinated projects. The financial resources for this do not have to be specially requested with a supplemental proposal; appropriate measures can also be financed from previously approved funds. For example, refugees with a bachelor's degree or comparable qualification can receive a qualifying fellowship for later doctoral research in a Research Training Group or be accepted directly into such a group.

Project leaders and higher education institutions are responsible for deciding how researchers should be integrated in a project, said the DFG President.

Destroyed homeland: the Syrian city of Homs in autumn 2015.

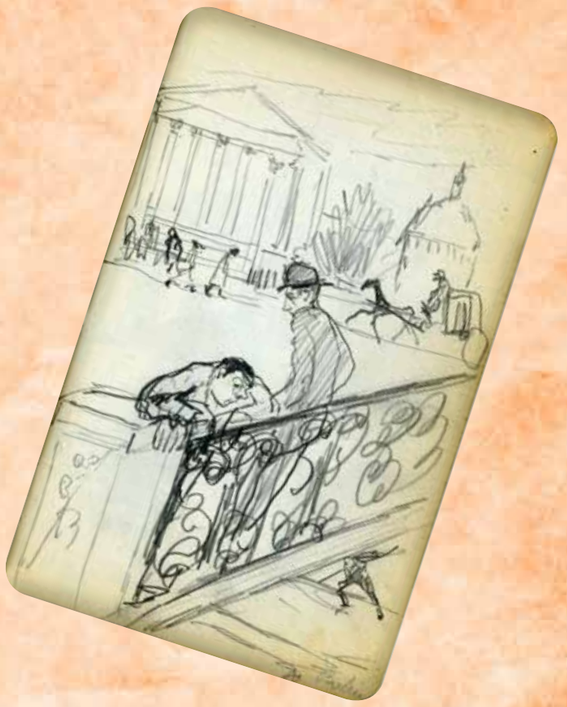
It is also up to the higher education institutions to work out the legal details, such as appraisal of academic qualifications or the signing of fellowship or employment contracts.

Strohschneider concluded: "We as the DFG want to create the financial and organisational framework needed for participation in the projects we fund in an efficient, flexible way. We are confident that this will make a positive contribution to the integration of refugees in our research system and our society."

Hermann Arnhold and Tanja Pirsig-Marshall

The Artist in Dialogue with Himself

As a painter, August Macke is one of the icons of Expressionism. His drawings, however, are less well known, and yet they represent one of the most impressive artistic achievements of the 20th century. Now a digitisation project in Münster is making this richly varied œuvre available online.



Out on the street, I nearly always have my sketchbook to hand in order to attain, little by little, mastery of the movements of people and animals, because this is something no professor can teach and it is the most important thing of all." August Macke (1887–1914) was just 18 years old when he made this observation in a letter to his parents. It is evident even at this early stage what importance the medium of drawing would have for him and his work. In the short period of ten years, between 1904 and 1914, he produced a multitude of drawings that surpass his other work in scope and variety.

His friend, the writer Wilhelm Schmidtbonn, recalled how Macke would draw incessantly, sitting, lying down, standing or walking. With his pencil and sketchbook always to hand, he recorded events around him, transfixing fleeting moments on paper: people strolling in the park, on the lakefront or along the street, figure studies, dancers and acrobats, couples, people looking at window displays, impressions of his travels in Tunisia in 1914, and sketches that seem almost like little cartoon strips.

His views of landscapes and cities provide a vibrant picture of his travels and the places he visited, and these graphic representations take different forms: notes, sketches, studies and pictorial drawings can all be found in his sketchbooks. The range of techniques he employed is also unique, comprising pencil, red chalk, Indian ink, white and coloured chalk, ink pencil and pastels.

Although Macke drew prolifically, there were phases during which he scarcely picked up a pencil. Almost a third of the images in his sketchbooks, amounting to over 3000 double-sided pages, date from his student years. As his experience grew, the character of his sketches changed: he continued to record a great deal but his drawings were increasingly related to his paintings. Many sketches can be identified as preparatory work for later paintings by the accompanying notes. In the last two years of his life, the sketch became more prominent again, more autonomous and more pictorial. He produced an impressive collection of works in black and white. However, his sketchbooks are unique for another reason too: they have been almost entirely preserved, much more so than for other artists, with a total of 80 surviving volumes.

Varied themes and subjects: August Macke drew almost everything he saw. These male nudes were done on the front page of a sketchbook dated 1908.

A tête-à-tête observed (from left): back view of a seated couple, couple arm in arm in three-quarter profile facing right, standing man with hat and woman, standing couple, back view of lively dancing couple, couple dancing to the right and back view of two men.

Illustrations: LWL-Museum für Kunst und Kultur, Münster

As well as observing his surroundings, Macke was interested in the old masters and contemporary ideas in painting. Working from paintings in museums, from books and from reproductions helped him to immerse himself in the works, study the processes and formal structures, and find himself as an artist. His output also tells us which originals he was familiar with, which artists inspired him and which models he studied.

Macke's interest in Arnold Böcklin, Max Klinger and the English Pre-Raphaelites is evident, as is an interest in James McNeill Whistler and the French Impressionists. He got to know them initially from reproductions before seeing the originals in Paris. As well as contemporary work, his sketchbooks reveal an interest in Egyptian and Greek art, with copies of Renaissance works. Works by Dürer and Michelangelo appear increasingly during his second visit to Italy in 1908.

Illustration: Hanna Neander/LWL-Museum für Kunst und Kultur, Münster

Self-portrait of the 19-year-old August Macke, 1906, oil on canvas.

Macke's sketchbooks provided him with a source of inspiration to which he returned time and again. They served as a store of motifs and observations, a collection of material on the basis of which he developed further ideas. But their prime importance derives from their sheer variety and their completeness. The development of his creative output, from his first steps in drawing to his thoughts and considerations on colour and form, is reflected and can be perceived in his drawings. Ideas that make up the essence of his art emerge as themes, and nearly all changes in his work proceeded from these drawings.

His sketchbooks also give us a glimpse of his day-to-day life – alongside the sketches are personal names, street names, addresses, appointments, timetables, texts of telegrams, notes, expenditures, travel notes, inventories and exhibition concepts. To this extent, they are much more than just artistic documents: they are records of Macke's life, revealing his personality in all its facets. The sketchbooks provide an account of a life and a life's work, which makes them both a unique source and a historical document in which the versatility of the artist and his epoch are portrayed.

The books themselves are unimposing. Macke generally used

small black notebooks and frequently drew on squared paper. He also used exercise books, which contained many fewer pages than the notebooks, or pads with tear-off pages rather than sketchbooks with thicker, specially made paper. His small notebooks accompanied him everywhere he went, serving as journals in which he recorded everything he saw and experienced, often sprinkled with hand-written notes. These are personal documents, whose intimate form was not intended for public consumption. All except one were hand-numbered and dated by his wife, Elisabeth Erdmann-Macke (1888–1978). Gaps in the sequence of numbers indicate that some volumes have been lost. During Macke's lifetime there were other sketchbooks, which were presumably taken apart by the artist himself and have survived only as single sheets.

August Macke as portraitist. Above: Swiss painter Louis Moilliet (1880–1962) in a relaxed pose. Below: Arthur Samuel and Elisabeth Macke (1888–1978), whom the artist married in 1909, and whom he depicted over 200 times. On the left edge is a check strip designed to ensure optimum reproduction during the digitisation process.

Illustrations: LWL-Museum für Kunst und Kultur, Münster

The whole inventory – with the exception of two books not discovered until later – were lent to the museum in Münster in 1957. The occasion was the first retrospective of Macke's work, celebrating what would have been his 70th birthday. It was also the first major exhibition of his work and included a large number of his works on paper that had never been on show before. Following their acquisition in 1975, the sketchbooks were studied by experts and published in a printed catalogue raisonné with black and white reproductions.

The LWL-Museum für Kunst und Kultur holds the complete collection of Macke's surviving notebooks, which can only be exhibited rarely, with one double page open, due to their condition and the nature of the materials used. His other drawings are not available for public viewing and cannot be viewed in the archive due to their conservation condition, which demands minimal handling. The visitor is therefore unable to experience the special character of the individual drawings, the numerous different representations and the materials used, as only one page can be viewed when on public display.

To allow people to discover the sketchbooks properly and make them available to a wide audience, the museum decided to digitise the collection. Requests are constantly received for publications of individual sketchbook pages, but there is no longer any need to subject them to the physical stresses of photographing, the images taken for the catalogue no longer being suitable for this purpose. Unlike photography, which requires the sketchbooks to be laid out flat and weighed down with a glass plate, scanning has only a minimal impact on the books, some of which are now extremely fragile. A special rocker was built that could hold the book at different angles, avoiding the excessive strain that would be caused to the sensitive bindings by pressing them flat.

Illustration: LWL-Museum für Kunst und Kultur, Münster

Illustration: Kunstmuseum Bonn

Two acrobats: depicted with verve and bold strokes in a sketchbook and as a modern masterpiece completed in 1914.

In addition to the sketchbooks, the complete inventory of the artist's works on paper and documents from the archive, including drawings done by Macke in letters and on postcards, were digitised. As a result, the entirety of Macke's works and materials held by the museum has been visually documented for the first time and is now available as a unique source. This major project forms part of the museum's intention to digitise its entire collection and make it available online, a project which has been a focus of its work in recent years, especially while the museum was temporarily closed for reconstruction. Following the re-opening of the museum in September 2014, August Macke's drawings and his many and varied materials will gradually be made available online.

Dr. Hermann Arnhold
is the director and

Dr. Tanja Pirsig-Marshall
is a specialist in modern art at the LWL-Museum für Kunst und Kultur, Münster.

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www.lwl.org/LWL/Kultur/museumkunstkultur/?lang=en

Axel Ockenfels

Illustration: Lisa Beller

Axel Ockenfels, a recipient of the Leibniz Prize in 2005, researches and teaches as Professor of Economics at the University of Cologne. He is the spokesperson for the University of Cologne Excellence Center for Social and Economic Behavior, the spokesperson for the DFG Research Unit "Design & Behavior: Economic Engineering of Firms and Markets" and the founding director of the Cologne Laboratory for Economic Research. Ockenfels has built an international reputation through his pioneering research in behavioural economics and market design. In addition to his research and teaching roles, he also advises governments, market platforms and companies. He is a member of the North Rhine-Westphalian Academy of Sciences, Humanities and the Arts, the Berlin-Brandenburg Academy of Sciences and Humanities and the academic advisory board of the Federal Ministry for Economic Affairs and Energy. The Frankfurter Allgemeine Zeitung *recently ranked him as one of the three most influential economists in Germany.*

Illustration: Zhu Dieteng / fotolia

Tit for Tat

Whether in online business, corporate bonus systems or multilateral negotiations, reciprocity can be the key to success. By using experimental methods and models drawn from game theory, behavioural economists are seeking to put this principle to effective use.

People respond to incentives. Game theory helps us to understand these reactions better. People do not always react in a rational, self-interested way, though, as game theorists like to postulate – but nor is human behaviour merely irrational or chaotic. It often follows systematic and predictable patterns. In recent years, empirical research has therefore played an increasingly important role in the study of economic and social behaviour. What is notable is that the combination of mathematical and experimental methods has proved to be particularly fruitful. Many fundamental strategic and psychological principles of cooperation and conflict can now be explained on this basis.

However, economics researchers and behavioural researchers are no longer satisfied with simply describing abstract, conceptual insights. They are also interested in the question of how to design markets and companies in real situations in order to be successful. To answer this question we must consider many details and real-life complexities ignored by traditional economics research. This includes legal, ethical and institutional factors as well as the quirks of human behaviour. The economist therefore becomes an engineer, whose goal is to develop markets and incentive systems that work robustly even when the assumptions of rational behaviour and perfect markets do not apply.

In keeping with Leibniz' motto theoria cum praxi, this "economic engineering" has many useful and successful applications. Its success stories include the design of power, telecommunications and internet markets, assistance with negotiations, the optimisation of corporate procedures and many more. Economics has been dragged out of its ivory towers and laboratories and put to use for the benefit of research and society.

One important example of the beneficial mutual influence of practice and basic research is reciprocity. Reciprocity is an embedded human principle: I'll do to you as you do to me. If other people are nice to me, I'll be nice to other people. If they are uncooperative, I will become less willing to cooperate, and unfriendly behaviour may even be punished to my own cost. In this way, reciprocity can create incentives for trust and cooperation between individuals. A good understanding of how and why reciprocity develops is therefore essential to the question of how to create a framework that will support cooperation and avoid conflict.

The strategic aspects, the underlying motivations, the cognitive and neuronal influencing factors and the evolutionary basis of reciprocal behaviour have all been the subject of intense study in recent years. This foundation is solid enough to incorporate reciprocity into the design of real markets and incentive systems. This can be illustrated with some examples from our research.

The first example concerns the effectiveness of online reputation systems, which allow people to evaluate each other's behaviour and without which many social and economic online platforms would be inconceivable. One reason why people voluntarily take part in such systems is positive reciprocity. In line with the principle of reciprocity, people who write good things about other people are often rewarded with positive feedback. Trustworthy and cooperative behaviour pays off.

On the other hand, there may also be negative reciprocity in the

Left: Prices, markets and consumers: information flows are of crucial importance in the digital economy. Below: Computer-based behavioural research in a Cologne laboratory.

Illustration: Simon Dirsing and Thomas Schorn

Foto: Fabian Stürtz

form of "retaliatory feedback". If a buyer publicly announces their dissatisfaction with a seller, the seller may then complain about the buyer and therefore damage the buyer's reputation too. The fear of retaliatory feedback means that little negative feedback is given in the first place. Due to this kind of distortion of reputation information on the internet, many actors are unsatisfied and markets based on reputation systems may not function efficiently.

We are therefore developing reputation and conflict avoidance systems that channel digital information flows on the internet in such a way as to retain the positive effect of reciprocity on trust and cooperation while minimising the negative aspects. For example, the risk of revenge feedback can be reduced by making feedback anonymous, adroitly aggregating the information or delaying publication. To make sure these systems work robustly, they go through extensive testing. Behavioural models derived from game theory provide conceptual insights into strategic incentives. The effectiveness of a new mechanism is probed in "wind tunnel tests" in the laboratory, and controlled field tests reveal behavioural and institutional complexities, which in turn inform the game-theoretical analysis, and so on. As a result, our research contributes to more trust and cooperation on online platforms.

Graphic: inueng/fotolia, Montage: Herling

Favouritism at work? Satisfaction suffers when an individual's bonus is smaller than those of colleagues.

Another research project is concerned with the question of how incentive mechanisms affect managers. Many companies tussle with the problem of designing suitable incentive systems. In one study we surveyed thousands of managers in a large corporation. The anonymised survey data were linked with individual data on the payment of bonuses. It became apparent that the assumptions made by the economics textbooks were wrong. For example, the absolute monetary value of a bonus does not play a statistically relevant role in manager satisfaction: more money does not automatically make a manager more satisfied or more motivated.

What counts is the social context. For example, an individual's satisfaction and performance both diminish when his or her bonus is lower than that of other managers, regardless of the absolute amount. Laboratory experiments and behavioural theory can map out the underlying mechanisms of effect. Once again, reciprocity plays an important role: people who are comparatively less well treated are less motivated and willing to cooperate. One finding that emerged from our studies is that seemingly irrelevant information about social comparisons can have a robust and systematic impact on the effectiveness of incentive systems.

Reciprocity is also crucial to the success of negotiations. We are currently investigating the conditions under which the cooperation-promoting aspects of reciprocity can be utilised in international negotiations on climate protection. Our studies reveal that negotiations on CO_2 prices, unlike previous negotiations on CO_2 reductions, can increase the likelihood of successful international cooperation. Sometimes, however, the goal is not more cooperation, but less. This applies for instance to "oligopolistic competition", a market situation involving a large number of buyers and a small number of sellers, because in this scenario cooperation between companies is usually to the disadvantage of the consumer.

Illustration: Dominic Akyel

At the new Center for Social and Economic Behavior at the University of Cologne, economists and psychologists are collaborating to investigate the basic principles of social and economic behaviour.

Once again reciprocity comes into play, because a common strategy is to keep the price high only as long as all competitors are doing the same. In modern market and auction design, feedback on the behaviour of competitors and information channels within markets are therefore designed to make reciprocal reward and punishment difficult. For markets with few participants, this means that transparency harms more than it helps.

These examples show that reciprocity is the key to many important social and economic challenges. Anyone who behaves in a reciprocal manner needs information about other participants' positions and behaviours. So whoever has the power to control the flow of information holds a special responsibility as to the outcome of economic and social interaction. This applies equally to incentives in companies and to the regulation of markets – and, in the information age, the design of digital markets and economic systems. Although traditional economics on its own, without the support of behavioural research, can supply useful conceptual insights, it cannot accurately represent many relevant aspects. An incentive system that works with idealised assumptions about human behaviour may fail when faced with more realistic assumptions.

But behavioural economics itself is still a young field of research. A new and promising approach is the integration of modern research findings from areas of psychology relating to the role of cognitive information processing in social and economic behaviour. Economics, including behavioural economics, has so far largely neglected the processes involved in this information processing. In terms of reciprocity, however, we can demonstrate that cognitive mechanisms can be controlled in economic contexts, and that taking them into account can substantially contribute to the quality of economic models. Even subtle manipulation of the process by which decision-makers consider their decisions influences reciprocal cooperation and trust patterns.

It will be some years yet before behavioural economic engineering and economic cognition become established as research fields in mainstream economics. But one thing is already clear: bringing together traditional approaches in economics research and more recent methods in behavioural science helps us to develop solutions that satisfy the current challenges of basic research on the one hand and society and the economy on the other.

Prof. Dr. Axel Ockenfels

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University of Cologne Excellence Center for Social and Economic Behavior: http://c-seb.uni-koeln.de/cseb.html?&L=1

DFG Research Unit "Design & Behavior: Economic Engineering of Firms and Markets": http://economicdesign.uni-koeln.de/

Onur Güntürkün

Don’t Forget …

In everyday life we are continually confronted with situations where previously learned information is no longer valid – a phenomenon that psychologists refer to as “extinction learning”. Researchers are seeking to understand the associated mechanisms at behavioural, neural and clinical level, using pigeons and humans as models. In the long term this research could help us to develop better treatments for phobia patients.

Illustration: DFG/Aussmeier

How many times have you experienced a situation like this? A colleague gets married and changes her surname. Several weeks later, you still find yourself referring to her by her previous name. It may be a little awkward, but sooner or later you adjust to the new name and stop making the mistake. Years later, you suddenly encounter the same person in a different environment – and find yourself addressing her by her former name again. Why has this long-submerged memory resurfaced? And why was it so easy to learn her original name but so hard to remember the new one?

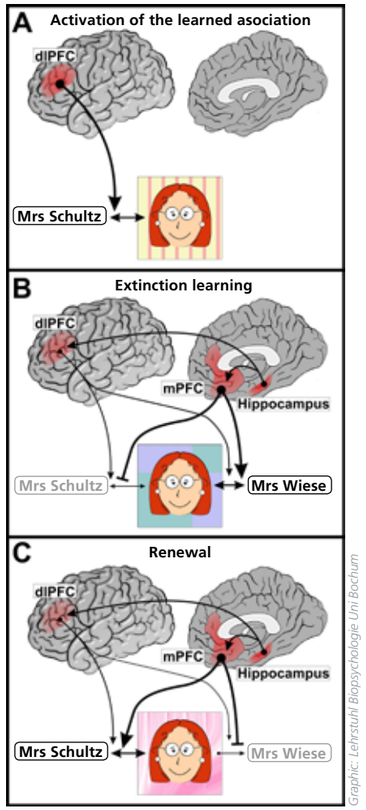
This episode is a typical example of extinction learning. This little-known but very important learning process is being investigated in the DFG Research Unit "Extinction Learning: Behavioural, Neural and Clinical Mechanisms". In extinction learning we discover that something we previously learned is no longer valid. In a constantly changing world, we obviously go through processes of extinction learning all the time.

This form of learning is mainly applied in behavioural therapy for people with phobias, where the learned fear reaction to the phobic stimulus must be suppressed. The problem described in our example applies here too: a patient who has conquered a phobia in a therapeutic context may experience an almost complete return of the phobia at home (i.e. in the previous context). Psychologists call this situation "renewal" because the return to the old context is often associated with a return to the old fear. To gain a better understanding of these processes we must first study more closely what happens in the brain during first-time learning, extinction learning and renewal.

The first time we learn a person's name, changes occur in the synapses (junctions between neurons) in all regions of the brain associated with the appearance and name of this person. When we try to specifically recall this person later, the dorsolateral prefrontal cortex (dlPFC) activates these specific memory traces so that we can recall the person's face, name and many other things we associate with this particular individual.

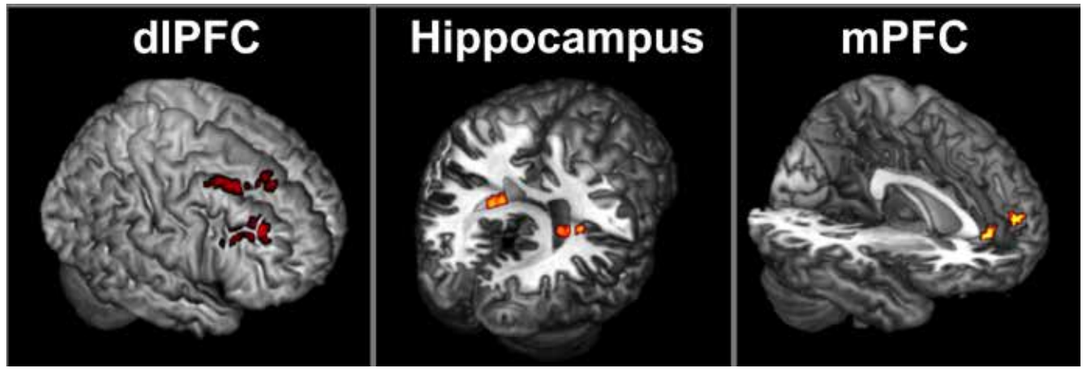
When a person's name changes, these memory traces have to be modified. When this happens the old name is not "deleted", but only inhibited. This has three implications. Firstly, we can conclude that extinction learning is a new, inhibitory learning process, not a process of forgetting. The inhibition of the old name and the reorganisation of the association between the person and the new name is organised by the medial prefrontal cortex (mPFC). Secondly, the old name still exists in our memory even if we no longer think about it and even come to believe we have forgotten it. Thirdly, the inhibition of the old name is stored together with the context. This last point is very important and needs to be examined in more detail.

The change of name is learned in a particular context – let's say at the office where you and your colleague work. With extinction learning, the hippocampus stores the fact that the information was learned in the office. Extinction learning is therefore associated with a particular place. You can probably see already why, in a new environment, you suddenly address your colleague by her former name. The hippocampus signalled



Graphic: Lehrstuhl Biopsychologie Uni Bochum

Schematic representation of the brain processes during learning, shown in side view (left) and medial view (right). (A) The dorsolateral prefrontal cortex (dlPFC) can activate a learned association between a person and their name. (B) In extinction learning the hippocampus encodes the changed context (the background colour has changed) and sends this information to the PFC. Medial parts of the PFC (mPFC) suppress the previous association and participate in the activation of the new one. (C) In renewal the previous association is incorrectly activated because the person is encountered in a new context.



Illustrations: Neurologie Bergmannsheil Uni Bochum

While the dorsolateral prefrontal cortex (dlPFC) is involved in learning and recalling an association, the hippocampus encodes the learning context. Parts of the medial prefrontal cortex (mPFC) are involved in extinction learning and the recall of the previously suppressed association.

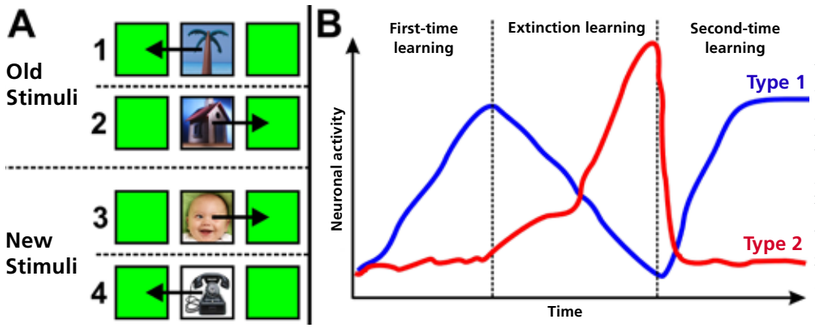
a context other than the office, the inhibition associated with the previous name by the mPFC was therefore bypassed and the suppressed memory trace with the old name was reactivated. Experiments by the Research Unit have shown that stress makes it more difficult to retrieve information from the memory and also increases the focus on contextual information, making it more likely that we will make a mistake in a situation involving a change of context.

So far we have talked about behaviour and the relevant areas of the brain. But what happens in these areas at neural level? To investigate this, the research team developed an experimental design where pigeons in a conditioning chamber learn to associate particular pictures with pecking from a disc on either the left or the right. The birds learn that they must peck the left disc when a palm tree or a telephone appears and on the right disc when they see a picture of a house or a baby. If the pigeon makes the correct choice, food appears for a few seconds; if the wrong choice is made the light in the chamber briefly switches off. The pigeons are therefore motivated to always make the correct choice. The process is repeated about 1000 times in a day, and each time the bird sees one of the four pictures shown at the top of page 20. The birds quickly learn within the course of a day which disc to peck for each of the four pictures.

On the next day the pigeons are placed back in the same test chamber. This time the pictures of the palm tree and the house are used again, but instead of the baby and the telephone there are two new pictures. The birds now have to learn which disc goes with each of the new images. This process is repeated every day. After a while the birds come to recognise the two "old" patterns (palm tree and house) so well that they rarely make a mistake. But the situation with the new day's pictures is different. In the morning, the birds aren't yet familiar with these pictures and must learn by experimentation which is associated with the left disc and which with the right. Meanwhile, very fine electrodes measure the activity of individual neurons in the bird equivalent of the prefrontal cortex and hippocampus. In this way we can observe what happens at cellular level during first-time learning, recall and extinction learning.

The pigeons go through three phases each day. In the first phase they choose the disc they have al-

Graphic: Oliver Wrobel



Graphic: Lehrstuhl Biopsychologie Uni Bochum

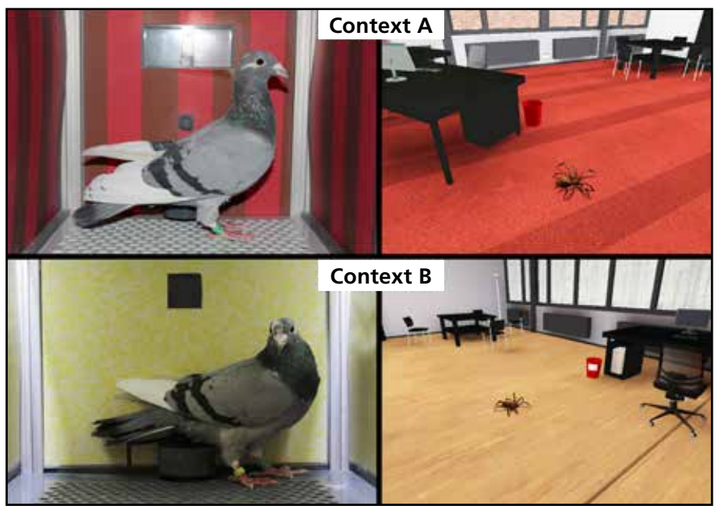
(A) Experimental design of an extinction experiment with pigeons where the birds learn that the stimulus in the middle must be associated with one of the two stimuli at the sides (the correct side is indicated by the arrows). There are two "old" stimuli that the birds have been familiar with for weeks and two new stimuli that must be learned each day. After first-time learning one of the new stimuli is suppressed and then learned a second time. (B) Schematic representation of the activity of two types of cell in a "prefrontal" brain area in pigeons during the three phases of the experiment.

ready memorised for the old pictures (palm tree and house) and learn which side the new pictures are associated with. When they can respond correctly to all four pictures, the second phase begins: extinction learning. For reactions to one of the two new pictures, no reward or punishment is given no matter which disc the animal chooses. The situation with the other three patterns remains exactly the same. Hence, the process of extinction learning begins for one of the new patterns. The third phase is second-time learning. Once extinction learning is complete for one picture, the bird is again rewarded for choosing the correct disc for all four pictures. Once again, food is offered if the pigeon makes the correct choice for the picture that previously had no reward or punishment associated with it.

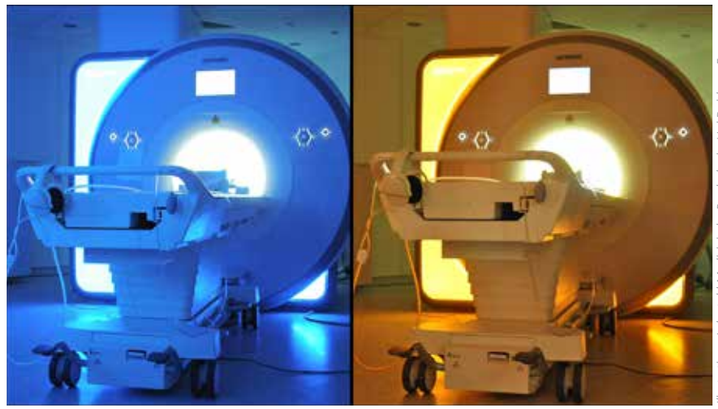
Recordings of individual neurons in the prefrontal cortex reveal the diversity of neural processes that take place during learning. Here we will only look at two types of neurons that tell us quite a lot about how extinction learning works. Type 1 shows a slow increase in activity during first-time learning, a drop to almost the starting level during extinction, and a second rise during second-time learning. These cells also encode the association between pattern and side. Interestingly, the same cell is active during both first-time and second-time learning. In other words, second-time learning does not require new neurons to be recruited; in fact, during extinction learning the cells retain their learned associations. They do not forget, but are probably inhibited.

Type 2 is a cell that only reacts during extinction learning. The activity of this neuron is triggered by the unexpected violation of a reward expectation. It is possible that type 2 is actively involved in the formation of the learned inhibition that suppresses the previous knowledge.

Investigating the effect of context on extinction learning in pigeons (left) and humans (right). In context A the pigeons learn to peck a coloured switch to get a food reward. Volunteers with a mild fear of spiders learn in context A that the appearance of a spider is associated with a weak electric shock. In context B the association is suppressed in both pigeons and human volunteers (pecking the coloured switch no longer produces a reward; spiders do not cause electric shock). Back in context A, in both pigeons and humans the behaviour eliminated in context B returns. The pigeons start pecking again in response to the colour stimulus and the human patient experiences the fear of spiders again.



Illustrations: Lehrstuhl Biopsychologie Uni Bochum



Illustrations: Lehrstuhl Medizinische Psychologie, Uni Duisburg-Essen

Changing the colour of the room during an experiment changes the context in which the subject learns pictures. A change into the old context can reawaken old behaviour patterns.

Extinction learning always involves learning the context at the same time. This is very useful, because we often have to modify a piece of knowledge (such as "My train to work leaves at 07:43") depending on the context ("In the summer timetable this train doesn't leave until 07:58"). By integrating the context into the learned knowledge we can follow one rule or the other as context dictates.

But context-dependent extinction learning creates an immense problem in psychotherapy: the elimination of pathological phobias always takes place in a particular context, for example a psychiatrist's office. No matter how much success is achieved in this setting, in everyday life the patient may be exposed to the same fears again because these fears have not been forgotten, only inhibited in a specific context. This problem is exacerbated by the fact that phobia patients are strongly aware of the critical context but at the same time have problems with learning extinction. These unfavourable factors probably contribute to the development of normal anxieties into pathological phobias.

The researchers' investigations in both pigeons and humans reveal the significant influence of context during extinction learning on the rate of relapse into old behavioural patterns. To analyse this more closely, in some image-based investigations the room is illuminated in different colours to generate changes in context. These studies demonstrate that the degree of activity in the hippocampus during extinction learning correlates with the extent of relapse into original behaviour patterns. All these studies tell us more about how extinction learning works. To help phobia patients conquer their fear in all areas of life, we need a comprehensive research approach such as this that investigates the mechanisms of extinction learning from single neuron to patient.

Illustration: Lehrstuhl Klinische Psychologie Uni Bochum

Phobias, for example a fear of spiders, respond well to psychotherapy in the form of extinction learning. However, a return to the context of the home may sometimes result in a relapse into old fears.

Prof. Dr. Dr. h.c. Onur Güntürkün
is Professor of Biopsychology at the University of Bochum. He received the Gottfried Wilhelm Leibniz Prize in 2013 and the Communicator Award in 2014.

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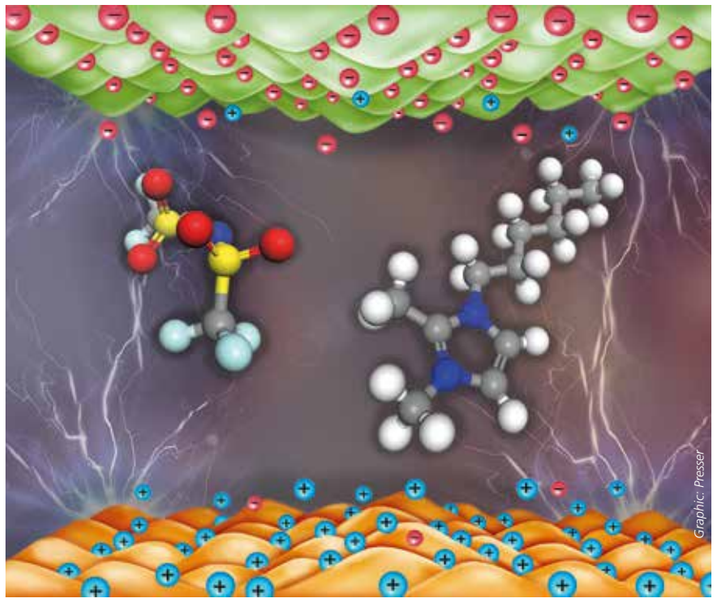
Rembert Unterstell

High Energy Density

Volker Presser, a Heinz Maier-Leibnitz awardee, researches and develops functional nanomaterials for electrochemical applications to make energy storage more efficient and sustainable.

A key element to the success of the German "energy transition" is to find new solutions for the old problem of energy storage. For a long time now, the problems surrounding energy storage have been familiar to the initiated yet non-scientific public: how can green energy from inconsistent and discontinuous solar and wind power be stored? How can it be safely held ready for use at a moment's notice? And how can green technology be developed to pave the way to the energy mix of the future? It is not by chance that storage technology has become a focus of interdisciplinary energy research.

Dr. Volker Presser is looking to find pioneering answers through materials science. The 33-year-old is head of the "Energy Materials" Junior Investigator Group at the INM – Leibniz Institute for New Materials in Saarbrücken, and since spring 2013, Assistant Professor at Saarland University. His fundamental contributions to improving electrochemical energy storage were honoured with the Heinz Maier-Leibnitz Prize, awarded by the DFG in 2013, and were considered to have such promising potential for application that he was also presented with the "Early Excellence in Science Award" by Bayer AG.



"Ion electrosorption" occurs at electrically charged solid-fluid interfaces. It makes the process highly reversible and fast.

There are high expectations of alternative energy storage, which bears little resemblance to the batteries and accumulators currently in common use: it should be cheap to manufacture and environmentally friendly, be able to store a lot of energy in as small a space as possible, and last but not least, charge quickly. Presser's work focusses on electrochemical systems and on the innovative use of the electrical double-layer.

The "electrical double-layer"? In our interview in his office, Presser explains the mechanism underlying electrochemical energy storage clearly, comprehensively and eloquently. The way he expresses himself is mirrored in the visitor's impression of his office with its desk, roll-top cabinets and meeting area – uncluttered, meticulously organised, with attention to detail. Presser is no stranger to presentation nor to self-presentation. He is drawn to visibility and visualisation, both at work and in his hobby as a photographer ("I am passionate about photography"). He has put together images to aid understanding of his research area. An example is a schematic figure to explain the electrical double-layer (see graphic on the left) which is the basis of his work.

This is the question at the heart of his research: How can higher energy density, that is, storage capacity, be achieved for double-layer capacitors? Presser works with nanoporous carbon and hybrid materials to precisely change the structure and composition of the material for the electrodes. The challenge is to optimise the porosity and the pore size distribution of nanopores for the fast transport of ions. Many questions remain unanswered, particularly concerning processes at the fluid-solid interface. However, the direction is clear: "Our idea is to include 'a little bit of battery technology' in the double-layer capacitor," says Presser.

Illustration: Unterstell

Volker Presser was born in Immenstadt in Oberallgäu, Bavaria, in 1982. Although a materials scientist, he has a background in mineralogy. "Ever since I had pockets to fill, I've collected minerals. I've always found their structure fascinating and intriguing." He studied mineralogy with a focus on materials science in Tübingen. At 24, he was awarded his diploma and he obtained his doctorate at age 27. His diploma thesis on silicon carbide ceramics won him the DFG's Rendel Prize, and he received an award from the Faculty of Earth Sciences at Eberhard Karls University in Tübingen for his outstanding doctoral dissertation on the wet wear of silicon carbide. It offered accurate insights into the chemistry and science of material wear and benefited from the application and complementary use of different analytical methods. It also showed Presser in hindsight that "interfaces are more important than was previously thought".

In 2010 he moved to the Nanomaterials Group at Drexel University in Philadelphia as a Feodor Lynen Fellow, then later as an Assistant Research Professor, where he enjoyed an inspiring postdoctoral period, came into contact with issues of energy storage and learned to reinterpret the potential of carbon-based materials. In 2014, he published the textbook "Carbon Nanomaterials" with his former US mentor Yury Gogotsi.

He decided to return to Germany with the prospect of building up and leading an independent Research Unit funded by the German Federal Ministry of Education and Research (BMBF). He has been head of a team of twelve which investigates the nanotechnology of energy materials since the summer of 2013.

What is the secret of the success of this early career researcher? He emphasises that he did not grow up "with a silver spoon in his mouth", which makes his awards even more gratifying. His prize certificates hang in neat wooden frames over his desk. He speaks of "passion" and "vocation", of "stamina" and "a bit of obsession".

And the luck of working in a productive research field might also help. Besides energy storage, the electrical double-layer can be used for capacitive deionisation, a particularly energy-efficient way of treating water (such as converting brackish water into drinking water) with the added advantage of being "really green technology".

Presser is compiling a yearbook for his expanding group, a collection of words and images under the title "explore – create – apply". For materials science, this is the triple jump of innovation. He adds, however, that it often takes years, if not decades before it can be established whether an innovation is really viable. Nevertheless, the foundations for the energy revolution of tomorrow and for the energy supplies for day after tomorrow must be laid today.

Dr. Rembert Unterstell
is Publishing Executive Editor of *german research*.

Andreas K. Hüttel

Illustration: Schupp / Götz

Strong, Conductive and Defect-Free

Carbon nanotubes are a fascinating material. In experiments at ultra-low temperatures, physicists make their different properties interact with one another – and in so doing find answers to fundamental questions.

Carbon is everywhere. All forms of life are made of organic carbon compounds, and even in its purest natural forms of diamond and graphite we encounter this chemical element in everyday life. Two other carbon modifications have also become well-known outside scientific circles: the fullerenes, the "football-shaped" carbon molecules, and the perfectly flat, two-dimensional material graphene. Graphene became famous in 2010, when Andre Geim and Konstantin Novoselov received the Nobel Prize in Physics for their work on this material.

However, most people are unaware that there is another modification: tube-shaped carbon macromolecules. Scientists have known about them since the 1960s from the results of transmission electron microscopy; in 1993, Sumio Iijima and Donald S. Bethune discovered single-wall carbon nanotubes, where a single layer of graphene forms a quasi-one-dimensional self-contained tube.

Left: With the aid of electron-beam lithography, structures are "written" on the surface of the chips. Right: Electron microscope image of a freely suspended carbon nanotube; the light metal electrodes and the trenches etched between them are clearly visible. Below: A model nanotube.

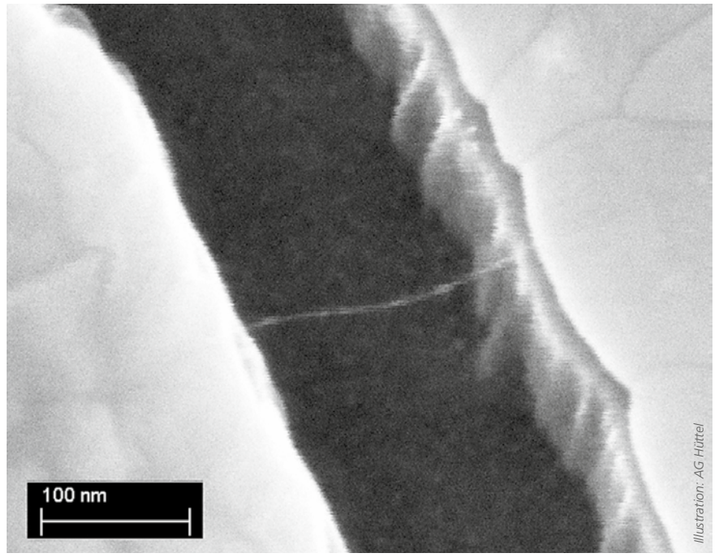
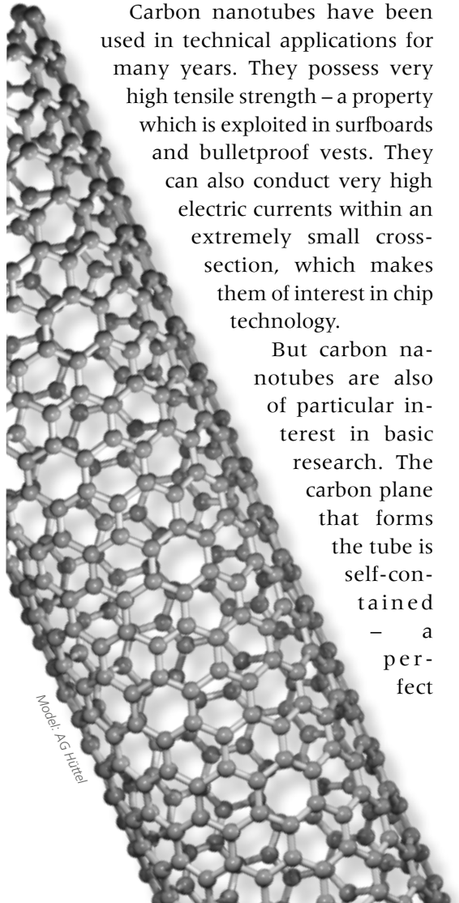


Illustration: AG Hüttel



Model: AG Hüttel

Carbon nanotubes have been used in technical applications for many years. They possess very high tensile strength – a property which is exploited in surfboards and bulletproof vests. They can also conduct very high electric currents within an extremely small cross-section, which makes them of interest in chip technology.

But carbon nanotubes are also of particular interest in basic research. The carbon plane that forms the tube is self-contained – a perfect shape with no uneven, undefined edges to interfere with its electronic or mechanical properties. And if a clean nanotube is allowed to grow across a trench on a chip so that it is freely suspended, it is possible to prevent perturbations caused by contact with the chip surface – creating a system in which the quantum mechanical properties of the nanotube can be observed in high detail.

This particular system is the topic of a DFG-funded Emmy Noether working group at the Institute of Experimental and Applied Physics at the University of Regensburg. Since 2010 the research group has been combining nanoelectronics and nanomechanics at very low temperatures with the aim of realising electronic spectroscopy of carbon nanotubes and demonstrating interactions between the mechanical movement of a vibrating nanotube and the electrons flowing through it as electric charge carriers.

The institute offers the ideal environment for this type of research, with excellent facilities from clean-room chip fabrication to a helium liquefier as well as close collaboration with other working groups. Researchers at Regensburg also have extensive previous experience with nanotubes. The Emmy Noether group takes advantage of both factors to focus on a fabrication process that maximises the visibility of the nanotube properties.

First, metal electrodes are constructed on a chip and trenches are formed between them. Nanotubes are then allowed to grow chemically over the trenches. The nanotubes then cover the electrodes, bridging the approximately 1 micrometre wide space between them. This technique keeps the macromolecules absolutely clean and undamaged; no further fabrication steps can introduce defects or contamination.

If the chip is then cooled to a temperature of a few hundredths

of a degree above absolute zero, the thermal energy of the environment is so low that it is insufficient to charge the nanotubes with a single electron, the smallest unit of electrical charge. The electrons already captured on the nanotube form quantised states similar to the shell of an atom, which is why these systems are also known as quantum dots or "artificial atoms". By applying a gate voltage, the number of trapped electrons can be externally influenced; current will only flow through the nanotube if the number of captured charges can change, through "single electron tunnelling", the passage of one single electron after another.

Quantum dots are found in many semiconductor materials. What is special about carbon nanotubes is the fact that they are free from defects and have a clearly defined geometry. With a tube diameter of around one thousandth of a micrometre, the electrons can be aligned as if strung out on a line, in a perfect lattice of carbon atoms repeated along the entire length of the freely suspended nanotube. If this system is gradually charged with one electron after another, the development of the spectrum of this captured charge system can be tracked using electrical measurements starting from the first electron – from the ground and excited states of an individual particle to complex multi-particle effects.

Concentration required in the laboratory: Physicists Daniel Schmid and Stefan Blien prepare the low-temperature apparatus for further measurements.

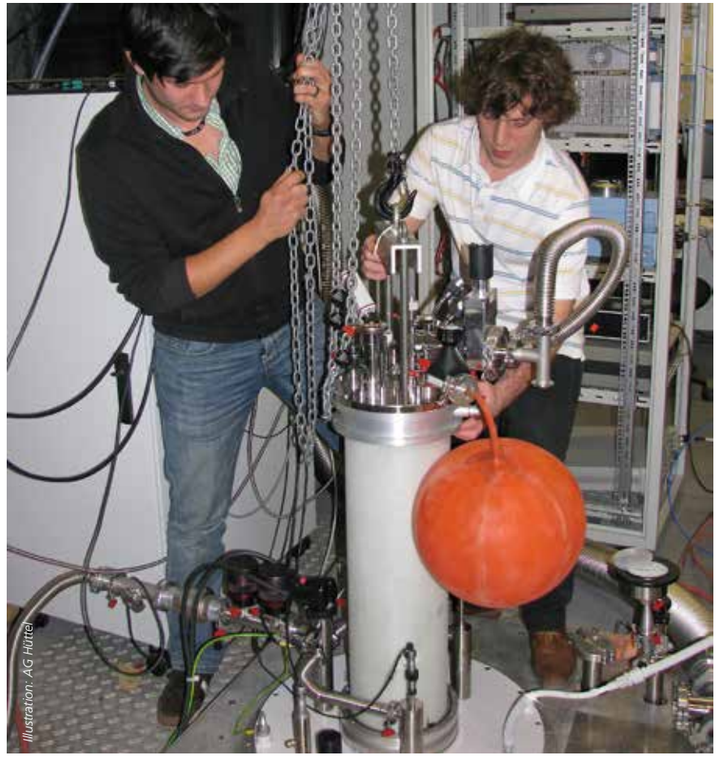
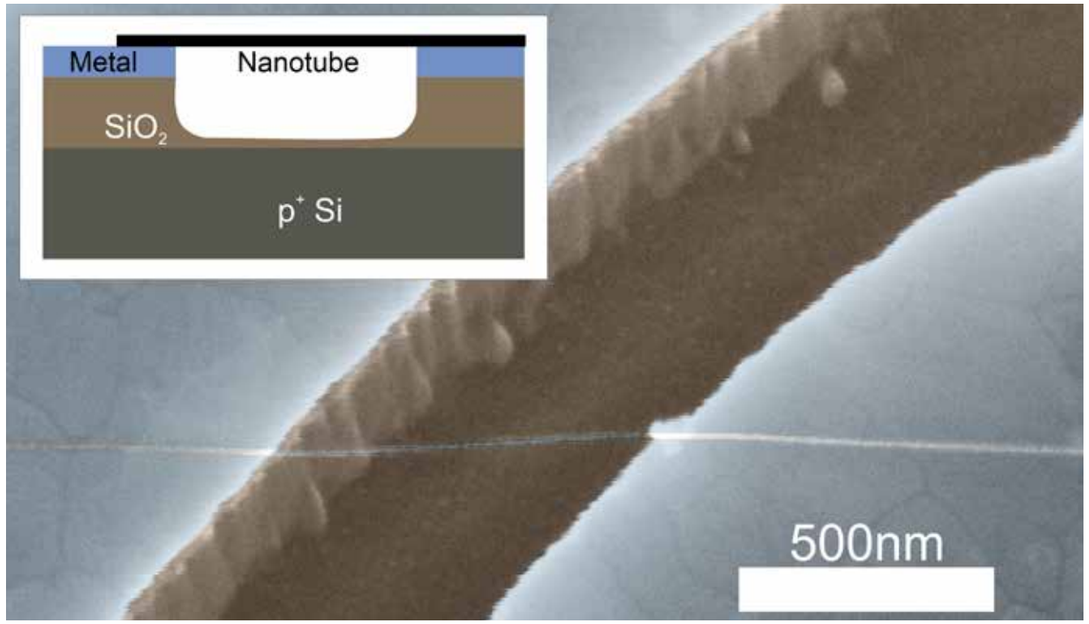


Illustration: AG Hüttel

When a freely suspended nanotube is viewed in a scanning electron microscope, the picture instantly reminds you of a guitar or piano string, or, in the case without mechanical tension, a skipping rope. Just like these everyday objects, and in addition to its electronic properties, a carbon nanotube can mechanically vibrate. Particularly at very low temperatures such as are used by the Emmy Noether group in the experiments in Regensburg, this vibration is almost free of mechanical damping. If a piano string had similarly low damping, a note would continue to sound for several minutes after the key was struck! If a direct current is applied to the nanotube, spontaneous self-excitation can occur; the nanotube starts to vibrate without being periodically driven. This effect is so marked that it sometimes interferes with electronic spectroscopy measurements as mentioned above.

But the electronic properties also influence vibration – particularly when we remember that current is carried by individual electrons with discrete charge. Researchers at the Technical University of Delft and elsewhere have demonstrated that electrons can also "transport" vibration energy directly out of the nanotube. The team in Regensburg has discovered that even a relatively small magnetic field causes eddy currents and therefore a damping of the movement – what could be



A delicate carbon nanotube bridges a trench etched on the chip. The graphic model can be seen top left.

called the world's smallest eddy current brake!

So why is all this so interesting to researchers? For one thing, there are still many unanswered fundamental questions relating to purely electronic systems. What effect does the detailed rolling-up of the graphene-like carbon plane to form a nanotube have on the electron states? Can we identify the exact type of the nanotube by examining the available measurement data? How do the electrons interact as the charge on the nanotube is increased? Other intriguing questions and research approaches emerge when carbon nanotubes are combined with ferromagnetic or superconducting materials. For example, researchers are seeking to control the electron spin, i.e. the intrinsic angular momentum of electrons, which is responsible for many magnetic effects and interactions. One objective of this field of research – known as spintronics – is information processing based on magnetism and not just electrical charges as in conventional computer systems.

Finally, in terms of mechanical effects, the transition from classical physics to quantum mechanics is an extremely topical area of research. To approach this transition requires a very high vibration frequency, which presents no problem for carbon nanotubes with their combination of high tensile strength and low mass. In addition, a very low temperature is required to prevent thermal excitation. Detecting and controlling the mechanical vibration of such a system without using a powerful external drive signal and therefore causing it to heat up is another challenge currently being tackled by a number of research groups throughout the world.

Dr. Andreas K. Hüttel
is a research assistant at the Institute of Experimental and Applied Physics at the University of Regensburg and the leader of the Emmy Noether group "Carbon Nanotubes as Electronic and Nano-electromechanical Hybrid Systems in the Quantum Limit".

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Andreas Ostendorf and Karsten König

Miniaturisation is the Name of the Game

Nanostructuring and ultra-short laser pulses allow extremely small structures to be manufactured more cheaply and easily. This technology has promising applications in microelectronics and biomedicine.

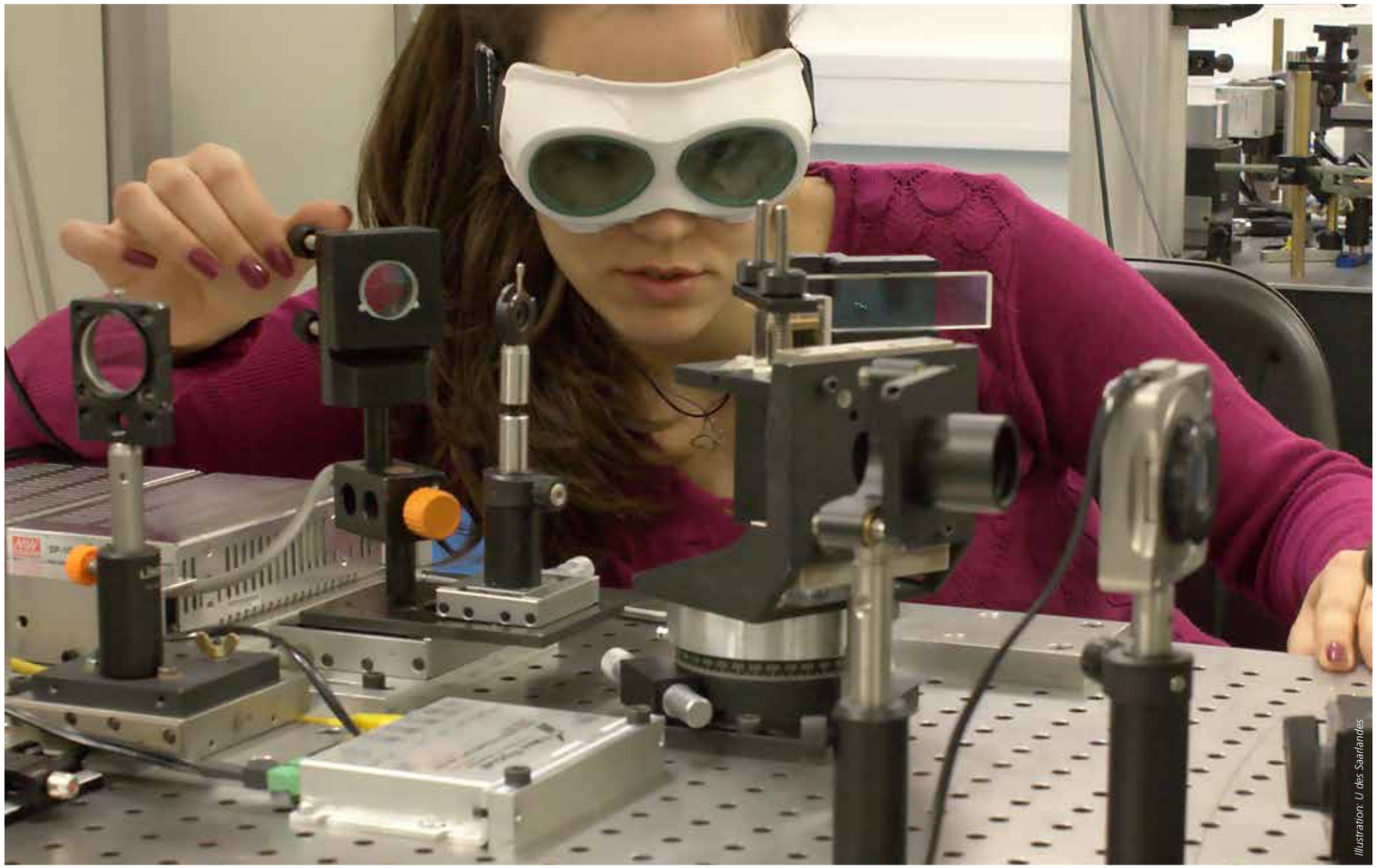


Illustration: U des Saarlandes

Adjusting an ultra-short pulse laser, used to manufacture nanostructures in ultra-thin organic layers.

It was a game-changing idea in microelectronics: the integrated circuit (IC) of various components on a single semiconductor. ICs were invented by Robert Noyce, co-founder of Intel and AMD, and Jack Kilby, who won the Nobel Prize for Physics in 2000 for his work at Texas Instruments. Nowadays, integrated circuits are made from millions of transistors on a tiny semiconductor plate measuring just a few square millimetres. For some time now these structures have also been manufactured using nanotechnology.

Nowadays, in order to build highly integrated electronic circuits for computer processors or memory chips, you need semiconductor lithography. The transistor circuits, designed on a computer, are transferred on to a "mask". The mask is shrunk by an optical system using ultraviolet light and projected on to the semiconductor surface, to which a very thin layer of photoresist has already been applied. Once the resist has been chemically treated, the areas exposed to light – or unexposed, depending on the technique used – are left behind. Thanks to perfected optical systems, projection systems of this type – also known as wafer steppers – can now be used for the large-scale production of structures as small as 20 nm wide. That's 1/100 of the diameter of a red blood cell!

But as the structures get smaller, the costs of the optical system rocket, with the result that only a few companies with enormous financial resources can afford to develop and operate this type of technology. There are also many limitations in terms of materials and geometries, which means that the technology is almost exclusively used for high-performance silicon-based ICs.

Alternative techniques for creating structures less than 100 nm wide have not yet been fully developed; they use complex techniques like electron and ion beams. So researchers are working to develop new nanostructuring techniques, firstly to expand the range of materials and applications, and secondly to reduce the costs compared with lithography systems by several orders of magnitude.

As well as microelectronics, the structuring of technical surfaces is extremely important as the science of miniaturisation advances. Examples include special filters in biology and reactive surfaces in chemistry. Nanostructures enlarge the surface area on which chemical reactions can take place, which can make surfaces much more efficient. Other applications include optical structures that reduce reflection losses, bioactive sensors in materials research, implant surfaces to improve tissue integration, and structures that could reduce friction and wear on tools subject to harsh use. An important argument in favour of nanostructured surfaces is the fact that robust manufacturing techniques would be available.

A little explanation is in order. In semiconductor lithography, the absorption of the laser radiation in the resist depends primarily on the wavelength used. This effect can be physically described by linear absorption equations. According to the law of optical resolution formulated by Ernst Abbe in 1873, resolution is proportional to the wavelength of light used. This is why increasingly shorter-wavelength laser radiation is being developed with appropriate optical systems down to the low ultraviolet range.

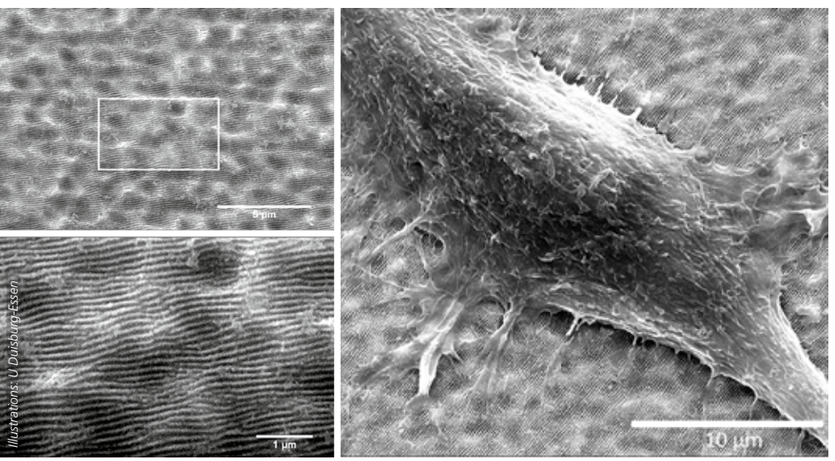
Non-linear absorption processes, on the other hand, are mechanisms

where the absorption of radiation depends not only on wavelength but also on the radiation intensity. Absorption mechanisms of this type, which are mainly used with non-metallic materials, can help to create nanostructures. Instead of complex and expensive UV laser projection technology, compact laser systems can be used that emit radiation in the visible or near-infrared region. Another advantage is that the radiation intensities allow nearly all materials to be efficiently structured.

Usable non-linear absorption values are achieved with high intensities, which can be generated with ultra-short laser pulses. (The pulse durations of femtosecond lasers are in the range of 10^{-13} seconds. This is only enough time for light to move across the width of a human hair.) Today it is possible to build compact and robust ultra-short pulse lasers, which are used in many applications, including eyesight correction in ophthalmology.

Non-linear absorption also has a noticeable threshold behaviour. This means that below a certain intensity, which varies according to the material, the material absorbs almost no radiation and the light simply passes through. Above this intensity level, non-linear absorption increases dramatically. If the parameters for the pulse are set accordingly, the laser energy can be introduced exactly as required. By moving the focal spot along the desired contour, it is possible to create complex structures with maximum precision. The aim of Priority Programme 1327, "Optically Induced sub-100 nm Structures for Biomedical and Technical Applications", is to investigate and develop much simpler nanostructuring techniques with the help of non-linear absorption processes in 16 interdisciplinary projects.

Left: A ripple structure on silicon, generated by treating the material with a femtosecond laser. The picture below shows an enlarged detail. Right: Striking HeLa cell, cultivated on a ripple structure on silicon that was previously coated with calcium phosphate nanoparticles.

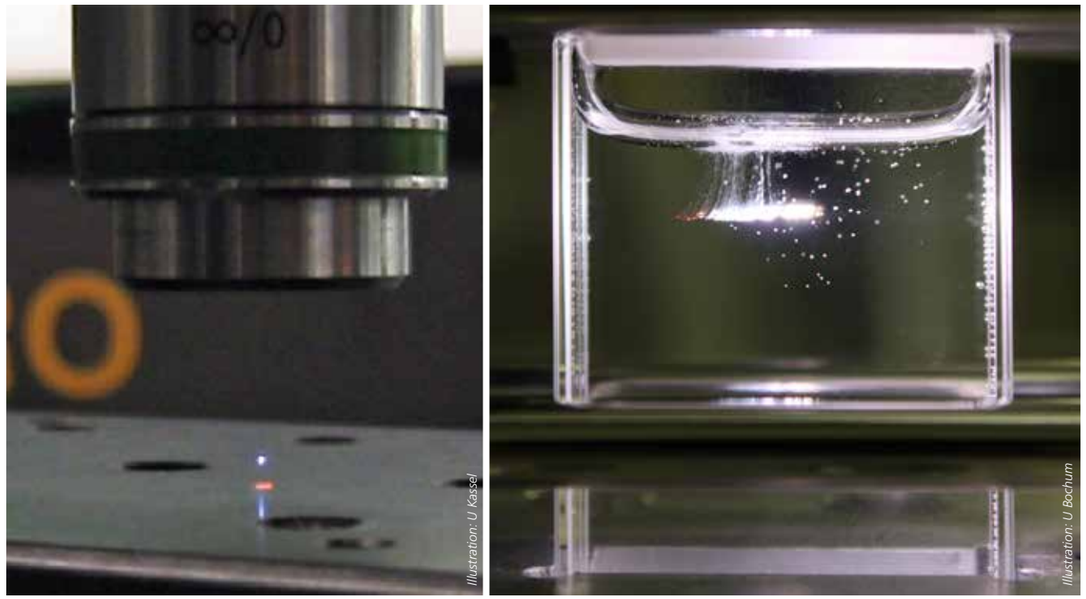


Illustrations: U Duisburg-Essen

One way of manufacturing structures with dimensions of less than 100 nm is to make small holes by removing material. By way of comparison, with a laser wavelength of 800 nm, Abbe's optical resolution limit allows a minimum structure size of around 400 nm. Intensity-dependent non-linear absorption, on the other hand, allows much smaller structures to be created. Producing holes of sufficient quality demands further optimisations. Depending on the material, a series of laser pulses may be used instead of a single pulse. These can be adjusted in a number of ways. If the laser parameters and material are optimally adapted, it is possible to achieve structures significantly smaller than 100 nm.

The use of polarised laser pulses near the processing threshold creates another fascinating effect. A limited parameter range results in plane, high-frequency periodic grooves called "ripples" with dimensions of around 100 nm, ten times smaller than the wavelength of the laser beam. This effect can be observed in metals, semiconductors and polymers and is being studied in the context of various applications in the Priority Programme.

Ripples have friction and wear properties which are of practical interest, especially in machine tool construction or for nanostructured stamps. The structures can then be copied by stamping them into a softer material. Alternatively, biofunctionalised nanoparticles can be arranged in a single layer in the grooves and then "stamped" on to polymer surfaces for implant research; this can significantly improve tissue integration. There is really no other way of achieving single-layer nanoparticle coatings.



Left: A femtosecond laser pulse is focussed in air as a plasma forms. Right: When ultra-short laser pulses are focussed in liquid media, the energy can be almost fully deposited below the surface. Absorption is associated with distinctive plasma formation. The laser beam itself is invisible in the photo because it is in an infrared wavelength.

These methods are not limited to creating nanostructured surfaces. A behaviour similar to ripple formation can be observed when ultra-short laser pulses are focussed in the volume of a glass substrate. Non-linear absorption causes the energy of the laser pulse to be concentrated below the glass surface. The structures thus formed have ripple characteristics and resemble an optical grid. These nanostructures can be used for high-resolution applications in 3D microscopy, for example.

Three-dimensional structures (in a range smaller than 10 nm) can also be manufactured using a laser-based polymerisation process. If ultra-short laser pulses are focussed in the volume of a liquid photosensitive resin, exactly at the focal point a process known as photopolymerisation occurs: the linking of the molecules in a chain. This method makes it possible to create any structure, like the much talked-about 3D printing. It could have promising applications in artificial matrix structures for tissue replacement in regenerative medicine.

There are many potential uses for nanostructures in biomedical research. One example is "cell transfection", which is used to alter the genetic characteristics of a cell by introducing foreign DNA into the cell. This requires the cell membrane to be briefly opened, which can be done safely with ultra-short laser pulses. A wide range of techniques and areas of application are conceivable. These reveal the large, as yet far from exhausted potential of laser technology in nanostructuring. This technology will become more important as time goes on.

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The Deutsche Forschungsgemeinschaft

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The *Excellence Initiative* aims to promote top-level research and improve the quality of German universities and research institutions in the long term. Funding is provided for graduate schools, clusters of excellence and institutional strategies.

The DFG also funds and initiates measures to promote scientific libraries, equips computer centres with computing hardware, provides instrumentation for research purposes and conducts peer reviews on proposals for scientific instrumentation. On an international level, the DFG has assumed the role of Scientific Representative to international organisations, coordinates and funds the German contribution towards large-scale international research programmes, and supports international scientific relations.

Another important role of the DFG is to provide policy advice to parliaments and public authorities on scientific issues. A large number of expert commissions and committees provide the scientific background for the passing of new legislation, primarily in the areas of environmental protection and health care.

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Young German researchers have enjoyed success in Europe with the support of the DFG. No less than five recipients of the Europa-Preis presented by the DFG also won awards at the 2015 European Union Contest for Young Scientists, held in mid-September in Milan. One of the three €7,000 prizes was awarded to Lukas Stockner from Altötting (2nd from left in photo with Peter Dröll from the European Commission, former prizewinner Lina Tomasella and former Italian Prime Minister Mario Monti), who as a special prize also attended the Nobel Prize award ceremonies in Stockholm in December 2015. Anselm von Wangenheim from Kassel was presented with one of the three third prizes (€3,500) and a special prize from the European Space Agency (ESA) entitling him to visit ESA's facility in the Netherlands. Jakob Dichgans, Daniel Riesterer and Lumen Haendler from Überlingen received a special prize that will allow them to visit the Intel International Science and Engineering Fair (Intel ISEF) 2016 in the USA. Following their success in the national science competition "Jugend forscht", as part of the DFG's Europa-Preis the young researchers were assigned mentors who coached them for their presentations in Milan. Congratulations to them all!