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Cover: AG Arlinghaus

Modern fish tracking: Receiving stations are distributed underwater like a network and save signals with a time stamp. Further information on water depth and temperature can be recorded, too.

Katja Becker

Towards a New Science Diplomacy

With its worldwide networks, science is capable of contributing a great deal when it comes to overcoming global challenges – not least as an element of science diplomacy. What kind of impact can it have? And where is first-hand political and diplomatic involvement required? It's time to engage in intense dialogue on tasks and responsibilities.

Science crosses borders: it always has done, and the trend has been on the increase for many years. Its immense wealth of experience in international dialogue and its networks of researchers dedicated to global issues – some of which have become established over decades – are sources of science policy leverage that must be tapped into if the transnational challenges of our time are to be understood in their full complexity and if new, unexpected but urgently needed answers are to be found. In a nutshell: these are the instruments of science diplomacy. Their significance has never been greater than it is today. This is why it is all the more important to jointly clarify responsibilities and coordinate these between the academic community and policymakers.

Orientation is provided here initially by the existing common distinction made by the American Association for the Advancement of Science (AAAS), which names three dimensions of science diplomacy. "Science for diplomacy" involves scientific cooperation being used to expand or maintain intergovernmental relations, which is particularly important in politically difficult times. If relations are sufficiently robust, foreign policy for its part – in this case defined as "diplomacy for science" – supports concrete scientific cooperation or creates suitable framework conditions in which this can happen. In addition to these classical pillars of science diplomacy, a third dimension is "science in diplomacy". A remarkable change is currently taking place here. While this area initially included the use of scientific and country-specific knowledge for (foreign) policy advice, science in this guise is increasingly being incorporated as part of a whole new approach to foreign policy.

According to a strategy paper issued by the Federal Foreign Office (AA) in December 2020, for example, the concept of "science diplomacy" aims to expand the political mandate and the fields of political action. The prerequisite for this is first and foremost the opening of foreign and security policy issues to academic discourse. Accordingly, science diplomacy means international policy that explicitly includes academic expertise, drawing on international cooperation and deriving new potential for action in this way. The fields of activity of science are to be expanded, too: science is to be cultivated as a knowledge sphere in which socially relevant decisions can be made. This understanding of science diplomacy means nothing less than the fusion of foreign policy, science, citizen science and science communication.

This concept undoubtedly puts science in the spotlight, and the dialogue between the actors involved is of immense value. However, the concept is also thought-provoking, since it gives rise to a redefined interaction between politics and science as well as new areas of responsibility.

A current position paper published by the German Academic Exchange Service (DAAD) entitled *Mehr Verantwortung wagen in einer global vernetzten Welt* ("Venturing more responsibility in a globally interconnected world") provides clues to such definitions. It discusses ten points of contact between national requirements for action and international contexts: with regard to different partners, different systems and, in each case, different vested interests. The paper focuses in particular on challenges in the area of researcher mobility and sets out ideas as to how to shape collaborations in concrete terms.

This intensified awareness of the problem in science and politics is the starting point from which to strengthen science diplomacy on a lasting basis (materially, conceptually and institutionally). And the question to which science and politics can only find an answer together is: how can scientific autonomy and quality be maintained and promoted under the premise of intensified cooperation and in the light of global challenges?

In our country, we have a solid basis on which to expand cross-border cooperation: a highly differentiated research system based on the freedom of science as anchored in the German constitution; a dense international cooperation network of research organisations and universities; a no less dense and resilient network of agreements between the DFG and its partner funding organisations worldwide, and the resulting joint calls for proposals along with tens of thousands of project collaborations; recognised funding programmes for the exchange of researchers run by the Alexander von Humboldt Foundation and the DAAD. For their part, science organisations such as the Max Planck Society, the Leibniz Association and the Helmholtz Association draw on and intensify international research networks, bringing together the best minds in the world. This is why science diplomacy is increasingly a task for the Alliance of Science Organisations.

Coordination between science organisations and agreement on common standards are also taking place at the global level. The work of the Global Research Council (GRC) is particularly worthy of mention here: it fosters cross-border dialogue between national science organisations, thereby enabling mutual consultation while also striving to ensure the compatibility of funding systems, including the joint funding of research projects. As a global network, the GRC is of utmost importance in tapping into the potential of collaborations while at the same time epitomising science diplomacy.

An abridged version of this article first appeared in the weekly newspaper DIE ZEIT on 18 November 2021.

Illustration: DFG/Ausserhofer

However, this self-organisational capacity on the part of science is only one side of the coin. On the other side is what science cannot provide itself: the point at which the creative possibilities of science end and where scientific cooperation sometimes requires first-hand diplomatic involvement. Agreement regarding this sphere and the tasks it involves is needed in the political domain, in the ministries responsible and between politics and science.

The DFG already pointed out the urgency of a coherent overall strategy in its own impulse paper in the run-up to the federal elections, and the coalition agreement of the new federal government sends out a positive signal here, too (see article below). Established discussion formats and events organised by the AA and BMBF, for example, ought to be further intensified with a systemic and holistic orientation. They can help raise issues of academic cooperation within the classical institutions of diplomacy – such as the global network of embassies – to a level that does justice to the enormous potential of research collaboration and the challenges it faces. In this way, a uniform understanding of the tasks and limitations of an effective foreign science policy might be developed across the ministries, also involving an assessment of the roles and interfaces of the actors concerned.

Incidentally, the following triangle of goals may serve as an orientation here. According to this, politics and science have a coordinated responsibility in their respective domains: firstly towards the security of researchers (physical integrity) and their expertise (security of ideas), which together enable planning security; secondly, they have a responsibility towards the quality of interstate relations, and thirdly towards the challenges of the future. For many researchers, taking these challenges into account is a driving force in their quest for knowledge, the importance of which was recently underlined in a ruling by the Federal Constitutional Court, which warned that "opportunities for freedom must be distributed proportionately across the generations".

Ideally, such coordinated science diplomacy should be supported and developed jointly by all government agencies and Alliance organisations. Coherence is needed not only in terms of the political concept but also in the external image of Germany as a hub of science and research; only then can international cooperation be effectively initiated and secured, especially in challenging conditions. It is also against this background that the EU Commission intends to present its "Guidelines on dealing with foreign interference targeting EU research organisations and higher education institutions".

Guidelines are no substitute for continuous dialogue between politics and science, however. One of the priority tasks of the new federal government is to swiftly give this a new binding force. It must quickly achieve unity with allies in Europe on common concerns while at the same time establishing new alliances and underlining the values of liberal democracies in terms of science policy, too. Germany's presidency of the G7 for 2022 offers further favourable opportunities for this. We – politics and science – should make the most of this together. It is high time we did so.

Professor Dr. Katja Becker
is the President of the DFG.

"Strong Commitment to Free Basic Research"

The DFG welcomes the future Federal Government's plans for science and research.

Commenting on the coalition agreement between the SPD, Bündnis 90/Die Grünen and the FDP, the President of the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), Professor Dr. Katja Becker, said:

"I'm very pleased to see such a strong commitment on the part of the coalition parties to the importance of free, curiosity-driven basic research dedicated to Germany's future viability and prosperity. Not only the section on science but the entire coalition agreement reflects great confidence in the German research system and positive expectations of its potential.

In our view, it is crucial to appreciate that the science system can only meet these expectations with adequate funding. We therefore expressly welcome the agreed increase in general government spending on research and development to 3.5 percent of gross domestic product by 2025. It is also gratifying to note that the future Federal Government will continue to adhere to the Pact for Research and Innovation, thereby enabling reliable planning security for many thousands of excellent research projects, all of which embody the innovation potential of the future.

Together with all those involved in science and the research system, I am relieved that additional funds are to be specifically made available for the second funding phase of the Excellence Strategy. Given the fact that this strategy has contributed significantly to raising Germany's profile and strengthening its position as a centre of science and research, I am very pleased to know that it can now be carried forward subject to fair and competitive conditions. In addition, we welcome the coalition's commitment to increasing the DFG's programme allowance in the medium term. This is essential in order to sustainably strengthen the research and strategic capability of HEIs and ensure their competitiveness at national and international level. We hope that concrete steps will be taken in the near future in this regard.

We also take a positive view of the agreement regarding the further development of the National Research Data Infrastructure, a Research Data Act and the introduction of research clauses. Data are crucial to the quality and transparency of research, they enable follow-up opportunities for new scientific projects and provide the essential basis for translating research outcomes into innovations.

The coalition partners have put aspects of their election manifestos into practice by proposing the establishment of an Agency for Transfer and Innovation (DATI). The task will now be to develop a prudent concept for this that boosts the transfer and innovation potential of all the relevant actors while optimising the interfaces with basic research.

The future coalition can also count on the DFG's support in developing a strategy to reduce experimentation on animals. What is more, we will make our contribution to society-wide debate in promoting the opportunities offered by biotechnology, something for which the coalition partners put forward a strong plea in their agreement.

Download: www.spd.de/koalitionsvertrag2021

In view of the coronavirus pandemic and based on the experience gained in the work of the DFG Commission for Pandemic Research over the past year and a half, I also personally welcome the proposed establishment of an interdisciplinary pandemic advisory council at the Federal Ministry of Health. International academic cooperation is essential in overcoming crises – both now and in the future. DFG funding recipients already work with partners in more than 120 countries worldwide based on numerous bilateral and multilateral agreements between the DFG and its partner organisation. The proposed strengthening of cross-disciplinary science diplomacy will have a significant impact, too.

The coalition partners have put forward an ambitious plan seeking to set the agenda for many crucial aspects of science policy that are currently necessary in order to ensure the German research system is equipped to tackle the challenges that lie ahead."

www.dfg.de/en/service/press/press_releases/2021/press_release_no_49

Illustration: DFG

Community Prize: Six Concepts Receive Award for International Research Marketing

New competition format under the BMBF initiative "Research in Germany" with an online vote for the first time / Approximately 350 people voted

As a partner organisation of the "Research in Germany" initiative, the DFG awards the newly established Community Prize for international research marketing to six project ideas. The Leuphana University of Lüneburg, the Leibniz Institute for Photonic Technology (IPHT), the Max Delbrück Center for Molecular Medicine (MDC), the TU Dresden in cooperation with the University of Würzburg, the University of Jena and the University of Leipzig each receive €20,000 prize money for the implementation of their research marketing concepts. An award ceremony will be held this year; details will be provided at a later date.

The Community Prize is a new competition format under the BMBF initiative "Research in Germany" that combines competition and cooperation. People involved in academic administration and research at HEIs and non-HEIs in Germany can apply for prize money to fund project ideas in the area of international research marketing and take part in an online vote to select the best ideas put forward by other institutions. The aim of the competition is to enhance the international visibility and networking of German universities and research institutions.

In last year's first round of the Community Prize, all competition entries were presented in the form of short video clips on a digital voting platform. The most innovative and impressive ideas were selected by the community by means of an online vote. In this case, the community consisted of almost 500 individuals at German higher education and research institutions who had registered on the platform based on the fact that their work is relates to internationalisation or international research marketing. Around 350 people from this group took part in the vote.

www.dfg.de/en/service/press/press_releases/2021/press_release_no_55

In Support of Democratic Values

Transatlantic online debates / Cooperation between the American Academy of Arts and Sciences, the DFG, the HRK and the Thomas Mann House

The political responsibility of science and research for democratic culture was the topic of a transatlantic online symposium hosted by the American Academy of Arts and Sciences, the DFG, the HRK and the Thomas Mann House in mid-October 2021. Participants reflected on the role of universities and the academic community in view of illiberal populism and growing scepticism towards democratic values and institutions. In her virtual contribution, Professor Dr. Julika Griem, Vice President of the DFG, emphasised the global dimension in particular: "Defending knowledge-driven research against the notion that science is all about an immediate 'return on investment' is becoming increasingly difficult in the US as it is in Germany. But we shouldn't limit ourselves to a transatlantic perspective here: attacks on research freedom and the dismantling of democracy are taking place worldwide and are a global problem."

Illustration: Shutterstock

www.dfg.de/en/service/press/press_releases/2021/press_release_no_44

Seibold Prize

Last award ceremony

Online ceremony: in the anniversary year marking "160 Years of German-Japanese Relations", the DFG celebrated the winners of the Eugen and Ilse Seibold Prize 2020 together with the Japanese ambassador in Berlin, Hidenao Yanagi, and the German ambassador in Tokyo, Dr. Clemens von Goetze: chemist Professor Dr. Shigeyoshi Inoue of the Technical University of Munich, Japanologist Professor Dr. Regine Mathias of the University of Bochum, materials physicist Professor Dr. Hidenori Takagi of the Max Planck Institute for Solid State Research in Stuttgart and law professor Dr. Kanako Takayama of Kyoto University. Following the last award ceremony, DFG Secretary General Dr. Heide Ahrens and Dr. Ingrid Krüßmann, Head of the DFG Office Japan and Deputy Head of the International Cooperation Group, talked to the award winners about the opportunities and challenges of international cooperation in times of the "new normal". The consensus emerged that although online communication offered new possibilities in terms of supporting international discourse, in-person meetings and dialogue were definitely still desirable. For this reason, the statements and discussions also included suggestions and ideas as to how on-site collaboration could be resumed.

Screenshot: https://youtu.be/1d0kEFNCz8w

www.dfg.de/en/dfg_profile/head_office/dfg_abroad/japan/reports/2021/211123_seibold_ceremony

Rembert Unterstell

Illustration: dpa/ POOL New

"Vaccination is the Most Important Remedy – and the Only Remedy"

Germany in the fourth wave of the coronavirus pandemic: infectious diseases and lung specialist Susanne Herold, member of the DFG Commission for Pandemic Research, on the "pandemic of the unvaccinated", "vaccine mandate for all", current SARS-CoV-2 studies and lessons learned in health communication

german research: *Professor Herold, we're conducting this interview in the second week of December, in the middle of the dramatic fourth wave of the pandemic. What is the situation in the intensive care units at Gießen University Hospital?*

Herold: We're doing comparatively well in that the rate of infection in the district of Gießen is currently below 200. Nevertheless, we're working to full capacity and under strain in the intensive care units (ICU) because the clinical situation is different from that of the second or third wave. We now have fewer COVID-19 patients to look after – but we're not able to take on more because we've been up to 25 percent short of intensive care staff at the hospital in some cases. As in many intensive care units, we're working at the limit.

What changes have you been seeing with the Delta variant in terms of the age of your COVID-19 patients and the progress of the disease?
The patients are getting younger – not because Delta is causing a substantially different disease but because more older people are vaccinated. We're now mainly treating middle-aged people who are not vaccinated. We rarely have children, unless they have pre-existing conditions. We can now influence the progression of the disease somewhat more effectively by means of monoclonal antibody therapies, but these are still not ideal.

Is the impression deceptive that at the beginning of the pandemic the life-threatening lung problems associated with severe COVID-19 progressions were predominant, but that other consequences of the disease are now more prevalent – affecting the brain, the vascular system and the psyche?
Nothing has changed in terms of the clinical pattern of the disease. But we do now have more data regarding the Long Covid symptom complex. SARS-CoV-2 is primarily a viral disease of the lungs, but other organ systems can also be affected. It is particularly striking that COVID-19 infections differ from other virus-induced lung infections such as influenza. We're only just beginning to understand the molecular mechanisms involved here.

You've led the Clinical Research Unit "Virus-Induced Lung Failure" since 2017: have you come up with any findings with regard to SARS-CoV-2 that have surprised you?
We've not only been conducting research into coronaviruses since the beginning of the pandemic. What has surprised us in the current Clinical Research Unit is that there are specific signatures in SARS-CoV-2 (i.e. a specific inflammatory profile in infected cells, but also in the organism as a whole – editor's note): the impact of these on the symptoms of the disease and its severity are still unclear. We're seeing that the excessive immune responses to COVID-19 differ from those associated with influenza. This is also where the macrophages (i.e. phagocytes and leukocytes in the immune system – editor's note) come into play: as a researcher, these have long been among my favourites. In the Research Unit, we've also extended some questions and projects to include SARS-CoV-2 and are working on translational approaches – such as preliminary studies for an immunomodulatory drug – and we're also conducting a number of phase 2 clinical trials aimed at improving the macrophage-based immune response and promoting organ repair after lung injury.

How do you assess the risk potential of Omicron as an immune escape variant?
There seem to be more than 30 mutations in the spike protein where the targets for the antibodies are located; this means there's a significant probability that the antibodies acquired through vaccination or infection do not work well, so we have to assume limited immunity. To put it simply, the antibody response is not the only key factor in our immune system: T cell immunity is vital, too. The significance of this in terms of the rate of infection is a matter of speculation and requires further data. But this is something many scientists are already concerned about. The main thing now is to slow the spread of Omicron by means of vaccination and boosting, while hoping that an adapted vaccine will be available soon.

From your clinical point of view, can we speak of a "pandemic of the unvaccinated"?
Yes, at the moment that is absolutely the case.

The lagging peak for ICU is expected in January. Will it still be possible to slow down the hospitalisation rate by means of the vaccination and booster campaigns combined with contact restrictions?

Dr. med. Susanne Herold, Ph.D., …

… heads the Department for Infectious Diseases of the Lung at the University Hospital Gießen and Marburg. She has also been Professor of Infectious Diseases of the Lung since 2018. Her research focuses on influenza viruses, pneumonia and coronaviruses. She is deputy chair of the German Society for Infectious Diseases, a member of the scientific advisory board of the Robert Koch Institute, and a member of the DFG Commission for Pandemic Research. Since 2016, she has also coordinated the DFG-funded Clinical Research Unit "Virus-induced Lung Failure – Pathobiology and New Therapeutic Strategies".
www.kfo309.de

We're actually expecting an increase in new infections as a result of contacts over the holidays. The number of severely ill COVID-19 patients and those requiring intensive care lags behind the infection rate. But one thing we are seeing – and this is said too rarely – is that most people do stick to the rules. In my social environment, I'm seeing that people have become much more cautious again in view of the frightening infection and fatality rates. Together with 2G rules and an increase in second vaccinations and booster jabs, this will hopefully lead to an easing of the situation and we'll at least enter a sustained plateau phase in terms of hospitalisation figures.

What is important now?
There are a number of interrelated factors, also at the regional level: it will be crucial to increase the vaccination rate quickly; whether the planned 30 million vaccinations can be achieved by the end of the year remains to be seen. In retrospect, I believe it was wrong to close the vaccination centres from the summer onwards and not to drive the vaccination campaigns earlier and more consistently when we realised that vaccination rates were stagnating below 70 percent. Vaccination is the most important remedy – and the only remedy – that will enable us to bring the pandemic situation to an end, and of course the day-to-day hygiene rules must continue to be observed even as vaccination rates rise. But ultimately, as always, it'll come down to each individual's insight and common sense.

We will keep you posted about the impact the coronavirus pandemic has on the DFG's work and about all measures taken to date and in the future on our website www.dfg.de and via Twitter: @dfg_public.

Why were you one of the co-signatories of an urgent letter sent to politicians by 35 scientists in mid-November?
There were clear scientific predictions about how the pandemic would develop, which were then fulfilled almost 1:1. It was obvious that we had to achieve a significantly higher vaccination rate. More preparations should have been made, a forward-looking pandemic policy should have been pursued – but this didn't happen because it didn't seem opportune.

A young, intubated COVID-19 patient being attended by a nurse in the ICU at the University Hospital of Gießen. Doctors and nursing staff are having to fight the virus as well as coping with staff shortages and permanent exhaustion.

Illustration: dpa | Boris Roessler

Political observers suspect that since the summer of 2021 there has been a denial of reality and a sense of unconcerned wishful thinking among political leaders (the notion of "Freedom Day") – combined with an unwillingness to take unpopular pandemic measures during an election campaign and before the government was formed …
Yes, that's how I see it too. That was why I signed the letter. After almost two years, people are tired, worn down and long for normality – if you proclaim the end of the pandemic, it's a message that's bound to fall on fertile ground.

What is your personal position on the much-debated vaccine mandate?
I never imagined that we'd have such difficulties in achieving high vaccination rates in Germany. We received the first vaccine doses delivered to Gießen Hospital on 26 December 2020 – we were so grateful and happy to be able to start vaccinating right away. Since that time, the perception of vaccination has changed considerably. Yes, I do believe we need a vaccine mandate now – not only for specific workers in hospitals and care facilities but for everyone.

As a member of the DFG Commission on Pandemic Research, you contributed to the dossier "Know more, make informed decisions" published in January 2021. In the face of the unnerving debate on vaccines and vaccinations, does educational health communication need to be approached differently, or indeed entirely reconceived?
A new approach has to be taken to communication at very different levels. One lesson we've learned is that public and media communication has failed to some extent. It's not just about conveying facts – it has a lot to do with psychology, too. We need to study how communication can be improved. By now we might assume that almost every citizen is aware of the important facts about vaccination. Far from it! Besides those who are genuinely opposed to vaccination and the relevant government regulations, there are many people who simply don't use television, newspapers or social media and are completely out of reach due to cultural and linguistic barriers. On ward rounds and when asking unvaccinated COVID-19 patients at their bedside, I hear again and again: "I didn't know all that – if someone had explained it to me like that I would have got vaccinated!"

Illustration: Shutterstock

According to current studies, the new virus mutation B.1.1.529 is considered to be particularly contagious; immunity acquired through vaccination or infection is reduced.

Looking ahead to 2022, what is the lesson from the pandemic that you would like to focus on?
In medicine, we need better research infrastructures that can make third-party funds available for longer periods of time – longer than the one-year horizon – so as to be able to act more swiftly in basic research and translation. Short-term new and renewal proposals cost a lot of energy and time – and pose a major problem for clinical trials. And we must continue to invest in targeted basic research. The mRNA vaccines would not have been possible without decades of fundamental work.

What is your wish for the New Year in relation to the pandemic?
(laughs) I have several! My wish as a clinician and for the people is, of course, to take the chance now to get vaccinated promptly before we run into a new wave of Omicron. My wish for the funding institutions is make plannable funds available so as to be able to combine basic research and translational research on a lasting basis. And finally, I'd like to see policy makers listen to scientists and clinical practitioners more closely and make better use of what they say – not least with a view to an evidence-based pandemic policy.

Thank you very much for taking the time for this interview!

Interview: Dr. Rembert Unterstell,
Publishing Executive Editor of *german research*.

Illustration: Jenny Otto

Modern times: for the international pandemic conference in the midst of a pandemic, the Norbert Elias Hall at the DFG Head Office in Bonn was transformed into a broadcast studio for one day. One of those participating via video link and introduced from here was Sir Jeremy James Farrar, Director of Wellcome, London, with his highly acclaimed keynote address …

In Search of Solutions for the Future

„Preparedness for Future Pandemics from a Global Perspective": an international conference on pandemic research organised by the DFG enabled some 300 researchers from funded projects to engage in virtual dialogue.

What influence does air quality have on the spread of virus-transmitted infections? What statistical models are needed to assess potential treatment effects in COVID-19 observational studies? How can societies prepare for pandemics, and how has this "preparedness" worked since the 1990s? What statements and messages about COVID-19 and protective measures have governments and health institutions communicated to the public, and what has the role of the media been?

Thousands of researchers in Germany are working on these and many other questions relating to the coronavirus pandemic. All of them wish to contribute to finding ways out of the current crisis and be as well prepared as possible for future pandemics. The DFG funds numerous pandemic-related projects through its regular funding procedures and has further strengthened research relating to the coronavirus via special calls for proposals since March 2020. In mid-November, researchers working on more than a hundred of these projects engaged in dialogue and networked with each other for the first time ever. Under the title "Preparedness for Future Pandemics from a Global Perspective", around 300 participants gathered on a virtual event platform at the invitation of the DFG and its Commission for Pandemic Research. In eight thematically clustered conference rooms, researchers discussed perspectives on the issue from the point of view of medicine and virology, sociology, economics, politics, health science and other fields, outlining their findings to date.

"This conference is an excellent opportunity to jointly explore the further potential of pandemic research, but above all it gives us the chance to examine the many issues from the full range of research perspectives," said DFG President Professor Dr. Katja Becker in her welcome address. "The more we know about pandemics, the more challenging the methodological search becomes. So our aim is to contribute to pandemic preparedness from a methodological point of view."

The conference not only focused on the pandemics of the future, however: it also adopted a deliberately global perspective. Pandemics cannot be contained within national borders, nor can they be researched solely from a national perspective – what is needed is cross-border cooperation and exchange.

It was precisely this perspective that was put forward by keynote speaker Professor Dr. Sir Jeremy James Farrar, Director of the UK's Wellcome – one of the largest health research foundations in the world. He focused on the question of what research is needed for science and society to be better prepared for global crises such as epidemics and pandemics, but also to tackle challenges in areas such as climate, energy, adequate food supply and many more besides.

Illustration: Jenny Otto

… likewise DFG President Katja Becker at the opening of the conference (with moderator Anne Brüggemann of the DFG Head Office) …

The key point for Farrar: in a pandemic situation, science relies on the infrastructures, partnerships and trust that have been built up in advance. Establishing these is not something that can start during the pandemic – it has to be done beforehand: "You rely so much on what you have before the crisis! If you are trying to build any partnerships and collaboration in the midst of a crisis, you will either fail or you will be too slow to make a difference. What you have before a crisis in human capacity, infrastructure, scientific endeavour, trust, will largely determine your ability to respond in a very fast, dynamic crisis – which is likely to be the sorts of problems we will face in the 21st century."

In the further course of the conference, a panel discussion directed the focus from the global perspective back to the situation in Germany. One particular area of interest: the interplay between the scientists, the media and policymakers and the research findings in this regard.

Ralf Heyder, head of the coordination office of the University Medicine Network based at the Charité Berlin, highlighted the "unprecedented presence of science in the media and also in political decision-making". This was only natural, he said, because in an existential crisis such as this, policy makers "turn to people who have the answers to solve the problems". "But," Heyder went on, "can this approach be easily transferred to other political decision-making processes, to other crisis situations? I really don't know!"

With regard to political communication, however, science can learn from the crisis, he said; for example: "When it comes to separating good evidence from bad more quickly, and also translating this knowledge into information that the general public and decision-makers can readily understand. There is definitely room for improvement here!".

Professor Dr. Cornelia Betsch, psychologist and expert on health communication at the University of

… Marylyn Addo, Cordula Artelt, Cornelia Betsch and Ralf Heyder taking part in the digital panel discussion (above, with DFG Press Spokesperson Marco Finetti as moderator), and DFG Vice President Britta Siegmund making her closing summary (below).

Illustrations: Jenny Otto

Erfurt, saw one of the challenges facing scientists during the pandemic as being able to clearly distinguish opinion from fact and making this difference known to the public. She also criticised the way many media outlets treat scientists: "At the beginning of the pandemic, many researchers thought: what can I contribute? And then it appeared that the selection process of who was heard by politics or was asked by the media, was quite a random process and it appeared that actually the media did some kind of a preselection for the political process."

For the future, Betsch would like to see more interaction between science and politics. "We have to learn to talk to each other and listen to each other. And we scientists need to understand how the processes work – because we never knew how policy making functioned in this crisis. That's something we definitely have to improve on next time!", said Betsch.

The Director of the Leibniz Institute for Educational Trajectories in Bamberg, Professor Dr. Cordula Artelt, added that although the logic of science and the media are fundamentally distinct, science couldn't simply sit back and insist that good research takes time. Instead, she said, science had to face up to the question of how to better formulate political communication and political advice in the future.

But infectiologist Professor Dr. Marylyn Addo of the University Hospital Hamburg-Eppendorf also noted the importance of scientists in filtering information – especially in the era of the preprint. "It's not helpful if scientific data is suddenly picked up on social media that has neither undergone peer review nor is classified in any way." Addo also called for young researchers to be better trained to engage in dialogue with the media.

At the end of the conference, DFG Vice President Professor Dr. Britta Siegmund summarised key insights for the future of pandemic research from the day's discussions: "Curiosity-driven research that taps into different disciplines – i.e. multidisciplinary work in the best sense of the word – provides the most effective answers during a pandemic and beyond. Only in this way will we be able to achieve a higher level of preparedness. In order to be able to combat global societal challenges such as pandemics and the climate crisis, we need powerful global research infrastructures. For this reason, the call for cross-border academic cooperation has never been more urgent."

Benedikt Bastong
is a Press Officer at DFG Press and Public Relations.

Further information:
For DFG President Katja Becker's welcome address in its entirety, see:
https://youtu.be/rGUi1nr2QaE

For the entire keynote speech, see:
https://youtu.be/a50xzTUWHis

Video recording of the panel discussion:
https://youtu.be/zxqJ8jzHmbs

Future Prize for Vaccine Developer

DFG congratulates Uğur Şahin's team / Important preliminary work done in DFG-funded projects

To the incomprehension of many observers, they were left empty-handed when this year's Nobel Prizes were awarded in October. But in mid-November, Professor Dr. Uğur Şahin, Dr. Özlem Türeci, Professor Katalin Karikó, PhD, and Professor Dr. Christoph Huber (see picture, from left to right) of the Mainz-based company BioNTech received the German Future Prize 2021. Federal President Frank-Walter Steinmeier presented the €250,000 award at a ceremony in Berlin.

The four-member BioNTech team was awarded the Future Prize for its COVID-19 vaccine, developed jointly with the US pharmaceutical company Pfizer, which has been used worldwide since the beginning of the year to combat the coronavirus pandemic. The vaccine developers were also able to draw

Illustration: www.deutscher-zukunftspreis.de

on preliminary work funded by the DFG from 2006 to 2008 as part of a Collaborative Research Centre (SFB) on cancer research at the University of Mainz. The research into fundamental immunological questions carried out at that time became one of the main foundations for the so-called mRNA platform used for the COVID-19 vaccine more than a decade later.

DFG President Professor Dr. Katja Becker congratulated Sahin's team, saying: "Your outstanding work is a fine example of the long-term benefits of knowledge-driven basic research. It also shows how such insights can to some extent be transferred to areas that suddenly confront us with completely new challenges that require swift action."

www.dfg.de/en/service/press/press_releases/2021/press_release_no_47

„Greater Objectivity in Crisis Situations"

Alliance of Science Organisations in Germany on coronavirus reporting by the newspaper BILD

Together with the other members of the Alliance of Science Organisations in Germany, the DFG issued a statement at the beginning of December clearly criticising the reporting of the newspaper BILD in connection with the coronavirus pandemic and calling for "greater objectivity in crisis situations".

The reason for the statement was a BILD article dated 4 December. In it, three individual scientists were held responsible for the coronavirus protection measures over the Christmas period with large-format portrait photos and the headline "The Lockdown Makers – Trio of Experts Give Us Frustration for Christmas".

This was a case of personal defamation, the Alliance noted in its statement. "Moreover, it can easily contribute to a climate of opinion that has already led to scientists elsewhere being exposed to or threatened with physical or psychological violence.

Such forms of confrontation are in no way acceptable in the view of the Alliance and go against the fundamental rules of a free and open society as well as the underlying principles of our democracy. In crisis situations in particular and when dealing with an already highly emotionally charged subject, objectivity in discussion and reporting is particularly necessary and far more effective.

Science provides substantial support for policymakers and society at large, and not only during pandemic crises. For this reason, scientists must be able to freely contribute their expertise," says the statement, which has received much attention in the academic community, the media, the public and social networks.

www.dfg.de/download/pdf/presse/20211206_stellungnahme_allianz.pdf

Robert Arlinghaus

Illustration: Adobe Stock/Kletr

Where Do the Fish Go?

Fish often react surprisingly to environmental factors such as angling. Fish tracking uses modern technologies to show why this is the case – and provides important insights in terms of the behavioural biology of fish populations and fisheries management.

There has long been a desire to be able to conduct behavioural research on carp, pike and perch under natural conditions in lakes and rivers involving the precise measurement of the behaviour of fish populations, yet it still poses considerable challenges. While satellite-controlled remote sensing has revolutionised the analysis of the terrestrial environment, there are no such high-resolution methods for use underwater. Unfortunately, GPS technology does not penetrate water, while echo sounding and video tracking can only be applied on a localised basis: these methods simply do not allow detailed tracking of the behaviour of mobile fish in a river or lake, let alone in the ocean. Early technologies for locating fish such as radio telemetry were either very labour-intensive or only worked in freshwater because the salt water blocked the radio waves.

The alternative ultrasound technique allows detection in salt water, but this was limited to "presence-absence" analyses: after all, it is practically impossible to set up a sufficient number of underwater receiving stations in the oceans to allow the life of the fish to be observed in high resolution. By contrast, smaller lakes do offer the possibility of mapping fish life at the ecosystem level using modern ultrasound detection. The principle is based on the retrospective analysis of detections at as many receiving stations as possible. The fish wears an active ultrasound transmitter that emits ultrasound signals (e.g. at a frequency of 76 kHz) at a high pulse rate (e.g. every 5–10 seconds) over a period of several months (or even years, depending on battery size).

Receiving stations (hydrophones) are distributed throughout the lake like a network and save the relevant signals with a time stamp. If the signal carries further information – such as the water depth of the fish or water temperature during signal transmission – this information is also stored. The ultrasonic signal is received by hydrophones further away just milliseconds later. The exact position of the fish can then be calculated in very high resolu-

Big fish: two pikes (Esox lucius) *under water.*

Illustration: AG Arlinghaus

For the purpose of tracking, the fish wears an active ultrasound transmitter that emits ultrasound signals (e.g. at a frequency of 76 kHz) at a high pulse rate (e.g. every 5–10 seconds) over a period of several months (or even years, depending on battery size).

tion based on these minimal time differences of signal arrival at precisely calibrated hydrophones. Considerable effort is required to install, maintain and calibrate such a system, so research waters where complete recording of fish behaviour can be carried are still rare worldwide. As far as we know there are currently a maximum of five active projects.

The Berlin working group led by fisheries scientist Robert Arlinghaus installed a system of this kind in a lake in Brandenburg back in 2009, transforming the lake into an open-air aquarium so as to better understand the behaviour of the fish at the level of an entire ecosystem and in particular at a higher resolution. Every few months the data was downloaded, processed on the computer and converted into fish positions with a very high spatio-temporal resolution. A treasure trove of data!

The research team, funded by the German Ministry of Education and Research in this case, was also able to use a comparable technology in coastal areas off Majorca. As compared to conventional telemetry methods, where each fish had to be located manually requiring a huge amount of effort, the workload was by no means reduced on this project, however: it was simply shifted from the field to the computer. This is because it draws on Big Data, with several million detections in short periods of time – a volume of data that takes some handling. In particular, location errors have to be eliminated, and if a fish swims into aquatic plants or coral reefs, its signal disappears, too – these data gaps have to be dealt with constructively. Nevertheless, the new technology allows unprecedented insights and revolutionises our understanding of life under water.

The aim of research in the Working Group for Integrative Fisheries Management (IFishMan) at the Humboldt-Universität zu Berlin and the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB) is to answer both fundamental research questions about fish behavioural biology in field conditions in natural waters and also pursue application-oriented questions for practical fisheries management, such as how fish behave in response to environmental factors. One of these environmental factors is fishing, specifically angling, which has interested the working group for 20 years.

In Germany, there are 3–4 million anglers who set out to catch fish in their free time. Most lakes and rivers in this country are used by anglers. Many fish make acquaintance with a fishing hook in the course of their lifetime, such as when they are caught as young, immature fish and then put back in the water again. Not all fish are equally catchable, however, even within one species. Angling involves the selection of certain size classes and behavioural types of fish, and the animals learn from their experience to avoid fishing hooks in the future. But how does this process work exactly?

For many waters, there is no reliable information on how many fish are caught and taken away for consumption. Yet this knowledge is important so as to be able to derive recommendations for sustainable management. Here, modern fish detection technology allows unprecedented insights into previously hidden behaviour that offer (mostly) surprising findings.

For example, the winter biology of most native fish species is poorly understood and modern fish detection has enabled a number of commonly held beliefs to be revised. For example, it became evident that carp actively swam around in shoals during the day in winter. Until now, it was assumed that as warmth-loving fish, carp go into a kind of hibernation in the cold months. One study proved that the pike, a predatory fish, does not move to the deeper and therefore warmer areas of the water in winter but instead prefers shallow waters as its habitat.

In all the fish species studied – carp, catfish, pike, perch – the working group was able to identify persistent behavioural differences, i.e. specific individuals differed consistently throughout the year based on characteristics such

Receiving stations are distributed underwater like a network and save signals with a time stamp. Further information on water depth and temperature can be recorded, too.

Illustration: AG Arlinghaus

as activity or exploration, despite all the seasonal adaptations to changing temperatures over the course of the year. This provided clear evidence for the existence of behavioural types ("personalities") in fish in the field.

New insights are gained when behavioural data are combined with other individual data, for example in relation to the fish's diet or reproductive success. Here, the research team makes use of stable isotope methods or genetic methods. This revealed that perch who are consistently more active even during adolescence also show different feeding patterns as compared to adults, and that there is a close correlation between behavioural traits, growth, life history and diet.

Another study, likewise application-oriented in approach, looked into the controversial issue of fish feeding by anglers. Many anglers who pursue peaceful fish such as bream or carp use feed to improve their chances of success. The aim is to attract the fish to the fishing spot. Using the automated telemetry system at the Brandenburg research lake, it was shown that both carp and other bottom-oriented species such as tench accepted the new bait very quickly and subsequently showed up regularly at the feeding points – a kind of feed-induced taming occurred.

However, parallel fishing experiments indicated that at the same time there was a rapid decrease in fishability. The carp apparently learn very quickly to evade anglers' attempts to lure them – a phenomenon which the working group calls "angling-induced

Fishing is generally regarded as a relaxing, contemplative pastime, but when researching fish behaviour, hands-on action is required: here, preparations for installing an underwater measuring station.

Illustration: AG Arlinghaus

Screenshot: DFG bewegt! / www.youtube.com/watch?v=zfiRTURfkj7c

Diverse media and channels can be useful in gaining insights into the living environment of fish. Communicator Award winner Robert Arlinghaus often draws on the benefits of visual methods, depending on the target group.

shyness syndrome". Accompanying laboratory work identified the same mechanism: the carp learned to distinguish between baits with and without hooks and simply spat out the baits with hooks. Telemetry work in the field also showed that the fish did not shun the feeding grounds, however, as many anglers believe. They continued to stay at the feeding sites with particularly abundant food, but avoided being caught.

The field of fish behaviour research has developed dynamically in recent years. It is a good example of how interdisciplinary collaboration between researchers in fish biology and fisheries ecology, data analysis and network research, statistics and electrical engineering can lead to huge leaps in knowledge in terms of what is happening underwater. The close connection between basic and application-oriented research has a major role to play here. This combination is not least important when it comes to putting findings swiftly into practical application.

International cooperation is also of great importance to both past and future projects. Many projects now have diverse groups in different countries working together (e.g. European Tracking Network, Lake Telemetry Network) to collate data from different lakes for appropriate replication. Only then are the results generalisable.

With regard to research funding, it would be desirable if there were more programmes to establish and maintain the necessary research infrastructure since it is hardly possible to build and sustain the complex technology in the long term based on project cycles of only three years. After all, it is only by supporting the work with technicians and making sometimes considerable investments in equipment that it is possible to generate extensive data sets, eradicate errors and make the data usable for research. Fisheries research could benefit from this in the long term.

Professor Dr. Robert Arlinghaus
conducts research at the Leibniz Institute of Freshwater Ecology and Inland Fisheries and is Professor of Integrative Fisheries Management at HU Berlin. He was the winner of the 2020 Communicator Award presented by the DFG and the Stifterverband für die deutsche Wissenschaft.

Contact: Leibniz-Institut für Gewässerökologie und Binnenfischerei, Abteilung für Biologie und Ökologie der Fische, Müggelseedamm 310, 12587 Berlin, Germany

www.ifishman.de/en

Ullrich Pfeiffer

Before the Next Stage

People get a new smartphone every 34 months on average, and a new generation of mobile phones comes out every ten years. The commercial roll-out of 6G technology is planned for 2030: basic and applied research in this field is long underway. Numerous questions still remain unanswered – a look at high-frequency technology.

In retrospect, mankind has become the ruler of the world over the course of evolution. One key factor that has made this triumph possible is Homo sapiens' outstanding capacity for dialogue and communication. The smoke signals once used by the indigenous tribes of North America and the drumming of the native peoples of Africa were the simplest forms of early communication: indispensable as they were, they were also formative for life and survival.

In the 21st century, sign-based communication has long since shifted into the digital realm, too. One example of this is communication via mobile phone, which faces constantly growing demands. While the first and second smartphone generations (1G/2G) were focused mainly on voice services, 3G/4G literally put mobile broadband internet in everyone's pocket. 5G/6G is expected to drive global growth and productivity, create new business models and transform many aspects of society. The vision of 6G is to cognitively connect every device, every process and every person to a global information grid, putting us on the brink of an information revolution.

Illustration: Shutterstock

According to studies, new mobile phone generations emerge every ten years and new value chains every 20 years. This means that the commercial launch of new 6G technologies should happen in 2030 – basic and application-oriented research is long underway. Digitised society in the 6G era of the future requires a redefinition of how we want to use network resources, data and services for communication and sensor technology. The traditional business models and ecosystem roles of digital service providers will change, and the market will open up to new 6G-era players such as digital service operators, cloud operators and resource brokers. What is more, sustainable development is a highly complex field that will require major changes in industrialised society in the long term.

Achievement of the United Nations Sustainable Development Goals (SDG) and the commercial launch of 6G communication systems are both scheduled for 2030. The SDG aim to make the planet a better place to live in by 2030 by eradicating poverty, advancing gender equality, combating climate change and enabling the development of smart cities. The relationship between these potentially mutually enhancing forces is still unclear, however. Building on the 6G vision, studies are currently being conducted to assess how mobile communication relates to the SDG. 6G could potentially have a vital role to play here: firstly as a service provider supporting municipalities and countries in implementing the goals; secondly as a measurement tool for data collection and indicator reporting; and finally by strengthening new ecosystems based on 6G technology.

What is different about 6G technology? The main aim is to continue the trend towards higher data rates so as to be able to distribute digital data (bits) instantly. In the 2030s, the required peak data rates are expected to approach terabits per second for indoor applications: examples here might include 360-degree 16K videos with a refresh rate of 240 hertz or holographic displays. However, much of the data also consists of small-scale, time-critical measurement or movement-dependent data that has to be reliably distributed in connection with numerous industrial, automotive and health applications. Industrial processes, tactile applications and future multi-stream holographic applications require accurate time synchronisation to the nearest microsecond.

This will require ultra-high data rates. Digital data transmission is always about the rapid sending and receiving of bits. Like a switch, a bit can either be switched on or off, i.e. it can assume the state 1 or 0. This information has to be transmitted by mobile means or wirelessly. With their smoke signals, the indigenous tribes of North America achieved a rate of 1 bit per second at best. Things have to move much faster

Well equipped: a radio mast with the latest technology near the A9 motorway in Garching.

Illustration: dpa/Sebastian Gabriel

these days. But what are the limits when it comes to modulating the electromagnetic field? With one oscillation (1 hertz) of the electromagnetic field, two states (1 bit) can be transmitted relatively easily. Similar to a rope oscillation, a high deflection amplitude can be understood as 1 and a small deflection amplitude as 0. In this way, the digital state (1 or 0) is transported on the back of analogue electromagnetic signals. Here we are talking about a spectral efficiency of 1 bit per hertz.

If electromagnetic oscillations with a high bandwidth are used, a much larger number of bits can be superimposed simultaneously – in parallel so to speak. Complex modulation techniques also encode amplitude and phase, achieving spectral efficiencies of 4, 8, 16 or more bits per hertz. Higher spectral efficiencies require more signal-to-noise ratio (SNR), however, and cannot be increased arbitrarily. So ultra-high data rates will clearly require enormous analogue bandwidths and high spectral efficiencies with as much SNR as possible.

Technologically speaking, the situation is as follows: the radiated electromagnetic field of an antenna can be generated and modulated in its form (amplitude and phase) by moving charges (the antenna current). A distinction is drawn here between two technologically different approaches: either the fastest transistors are used as part of cutting-edge micro- or nanotechnologies in an electronic circuit with high switching speeds and sufficient amplification, or the desired antenna current is generated by absorbing light in semiconductors. Unlike electronic systems, the latter are referred to as photonic systems.

In both cases, mobile systems need to be extremely efficient to ensure high ranges and extended battery runtimes. There are two DFG Priority Programmes in which basic research is being conducted in each of these two areas (SPP 1655 and SPP 2111), while innovative system integrations are the subject of research in the DFG Priority Programme “Integrated Terahertz Systems Enabling Novel Functionality” (SPP 2314). Cross-site technology pools are available for the use of state-of-the-art micro- and nanotechnologies (Research Fab Microelectronics Germany, FMD).

The fundamental principle is as follows: if the transmission frequency is doubled, the size of the antenna is halved. So from the lower terahertz range, inconvenient antennas can be integrated on the surface of a chip. This makes it possible to create antenna systems that are compact but have a directional

Bits are transported in purely analogue form: the 6G transmitter module transmits ultra-high data rates (100 Gbit/s) with huge analogue bandwidths.

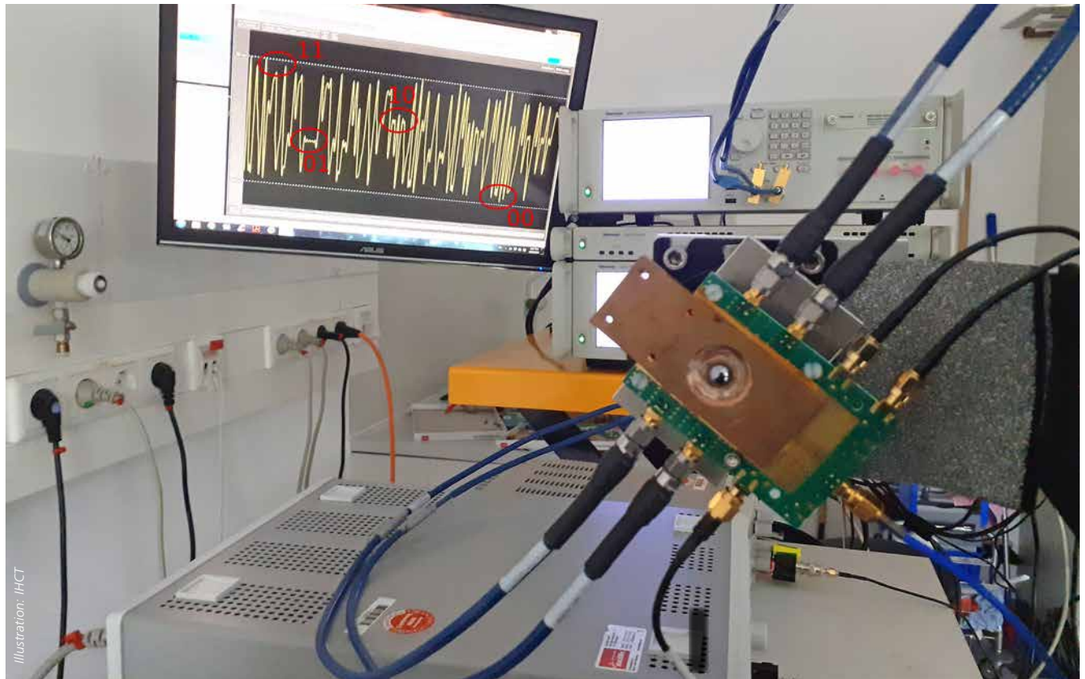
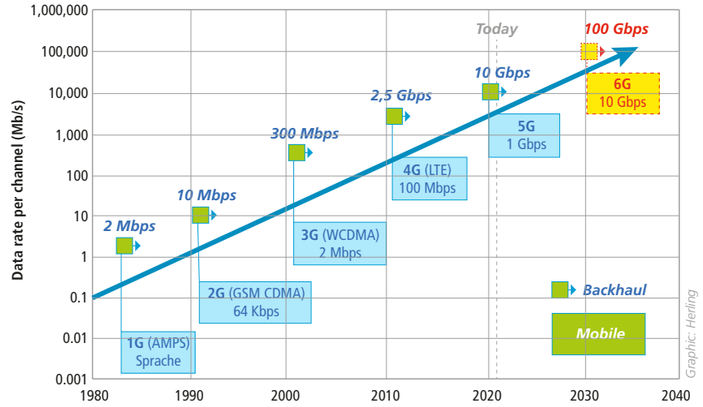
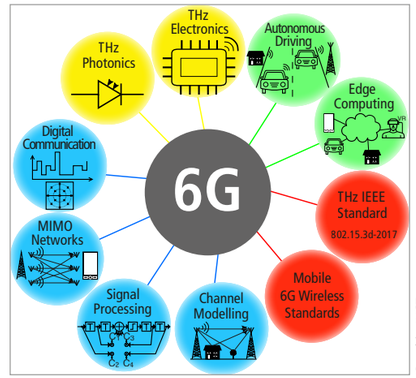


Illustration: IHCT



Graphic: Herling



Graphic: IHCT

Left: Rapid development of mobile phone generations – a quantum leap in data transmission rates every ten years. Right: 6G technology requires close cooperation between different disciplines: electronic and photonic hardware development (yellow), system sciences (blue), application development (green) and standardisation organisations (red).

emittance and have to be precisely aligned with receivers like a laser pointer. This trend goes against the idea of a 6G network, where devices network in a global information grid. Intelligent antenna systems are to remedy this by acting dynamically, with the capacity to align and network themselves instantly. The testing of such devices is a central focus of research being conducted under the DFG’s major instrumentation initiative “Measurement systems for ultra-high data rates for communication technologies of the future”.

There are fears that 6G radiation might be dangerous. But in fact electromagnetic radiation can best be described as light. By visible light, we mean the part of the electromagnetic spectrum that evokes sensations of brightness and colour in the human eye. This is quite high in the frequency range at about 385-789 terahertz, between UV radiation and infrared radiation. So ultimately, antennas are nothing more than torches that emit electromagnetic radiation in a part of the electromagnetic spectrum that is invisible to our eyes. The antenna light is typically in the frequency range of only about 0.001 to 0.3 terahertz. What difference does this make?

Light or electromagnetic radiation consists of a multitude of tiny light particles (or light quanta) known as photons. The photon is an elementary particle without mass, but with energy, linear momentum and angular momentum. It is important to note that the energy of a single photon is proportional to its frequency. As such, 6G antennas emit photons that are between a thousand and a million times weaker or less harmful than photons from visible torches. However, the more photons that hit a surface, the higher the radiation intensity of the source. The radiation intensity of the midday sun in the visible range in Central Europe is quite high, at around 700-900 watts/m². Antennas for 6G applications only manage a few watts/m² at best, being more comparable to weak torches in terms of their biological impact.

Looking at the results obtained to date, considerable efforts are still required before 6G can become a success story. The fascinating point here is that at its lowest level, what we like to call the digital transformation of society actually happens in purely analogue form. Terabits per second require huge analogue bandwidths, which are only available in the terahertz range of the electromagnetic spectrum.

Illustration: UniService Transfer

Professor Dr. Ullrich Pfeiffer
is Head of the Institute for High Frequency & Communication Technology at the University of Wuppertal.

Contact: Fakultät für Elektrotechnik, Informationstechnik und Medientechnik der Universität Wuppertal, Lehrstuhl für Hochfrequenzsysteme in der Kommunikationstechnik, Rainer-Gruenter-Straße 21, 42119 Wuppertal, Germany

https://ihct.uni-wuppertal.de/en/news

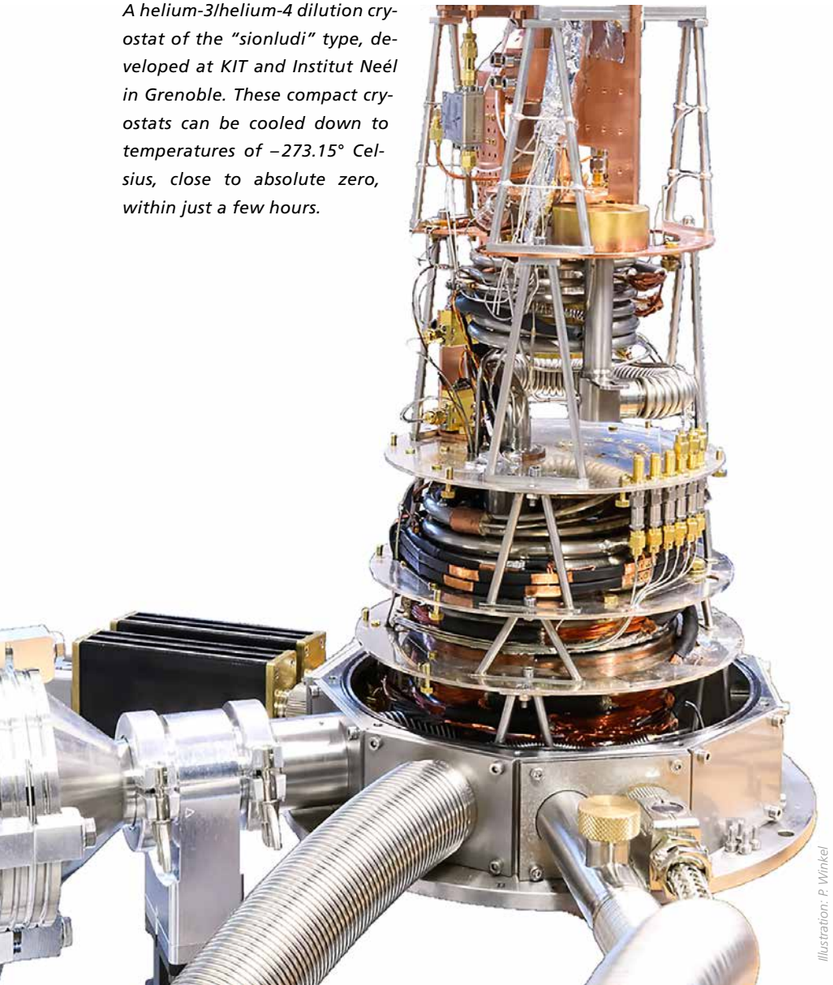
Wolfgang Wernsdorfer and Philip Willke

A Quantum Faster

They are supposed to solve problems that are impossible for conventional supercomputers: for a long time, quantum computers were regarded as a pipe dream and their underlying mechanisms as being virtually impossible to realise. But several approaches have since emerged that could make them more feasible after all. An overview.

I think I can safely say that no one understands quantum mechanics." This is how, more than 50 years ago, US physicist and 1965 Nobel Prize winner Richard Feynman succinctly assessed the theory that describes our world on the nanometre scale. In this world – where everything revolves around atoms and electrons, molecules and light particles – the laws of physics are very different from what we are used to in our day-to-day lives.

Yet it is this very quantum physics, although difficult to understand, that has allowed new technologies to be developed – providing its laws are rigorously adhered to. This paved the way for the development of transistors, lasers and subsequently computers, mobile phones and the internet. Today, almost 100 years after the discovery of quantum mechanics, scientists are able to use quantum mechanical effects with even greater depth and control. This so-called "second quantum revolution" enables the extraordinary effects of quantum physics to help drive forward new technologies in the fields of information processing, sensor technology and communication.



A helium-3/helium-4 dilution cryostat of the "sionludi" type, developed at KIT and Institut Neél in Grenoble. These compact cryostats can be cooled down to temperatures of –273.15° Celsius, close to absolute zero, within just a few hours.

Illustration: P. Winkel

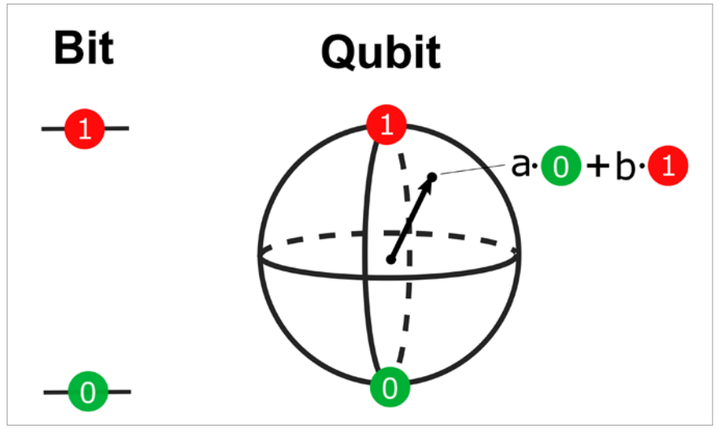
In the field of information processing in particular, quantum computers are something experts have long dreamt of creating. Unlike a conventional computer, it would be based on the laws of quantum mechanics and make clever use of them. The operating principle of a quantum computer is based on qubits (short for quantum bits) rather than bits. While a bit in an ordinary computer can only assume two states (0 and 1, off and on), a qubit can be in both states simultaneously, with different probabilities.

This is based on the quantum phenomenon of superposition. Furthermore, qubits can be entangled with each other. The phenomenon of entanglement, which Albert Einstein dubbed "spooky action at a distance", describes a process in which two qubits are "coupled" together. According to this, they are no longer independent of each other – rather like a long-married couple – and the attempt to measure one automatically influences the other. Superposition and entanglement are two of the basic ingredients of a quantum computer. Superposition enables calculation with several input values and allows several solutions to be tested simultaneously. This quantum parallelism works because, in addition, clever algorithms reinforce correct solutions and erase incorrect ones.

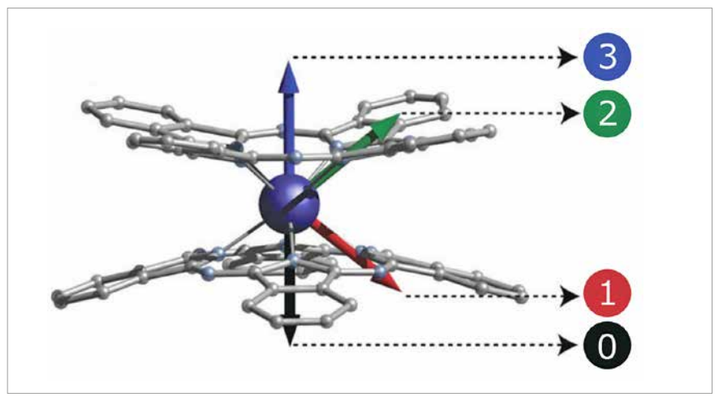
Theoretically, algorithms for a quantum computer have existed for at least two decades. But what makes it so challenging to build a computer of this kind? Firstly, quantum states are very unstable and short-lived. This phenomenon is known as decoherence. It results from every smallest interaction of the qubits with their environment, which can destroy or disrupt the quantum states. Secondly, manipulating, reading out and entangling qubits is technically demanding, since the quantum state must not be disrupted in the process either.

Despite these difficulties, a few platforms have emerged in recent years that could help put a quantum computer into practice. Probably the best-known platform here is based on superconducting (resistance-free) current loops – so-called superconducting qubits. These are already being sold commercially by companies such as IBM and the Canadian company D-Wave. Even if both the number of qubits (currently around 50) and their connectivity are still in their infancy, these computers can already serve as testing tools for initial applications. In fact, Google solved a problem with a quantum computer in 2019 that would have been impossible for a normal supercomputer to manage within a realistic period of time. However, the problem was more or less specially designed for a quantum computer – without any practical relevance.

So it could be some time before a quantum computer is able to solve relevant, real-life problems. Although quantum computers will probably not be used in our day-to-day lives, they promise to be significantly faster than conventional computers when it comes to solving very specific and complex problems. Probable applications here include optimisation problems, such as for the purpose of route planning. But they could also be used in the development of new medicines and functional materials. The key factor here is that these systems are themselves based on quantum mechanics, so it is more natural to simulate them using a quantum computer than a conventional one – according to the principle of "like with like".



Top: Bit and qubit: while a bit can only assume two discrete states, qubits allow a continuous superposition of the quantum states "0" and "1" with adjustable amplitudes a and b and phase relationship to each other. Bottom: Structure of a terbium-bisphthalocyanine molecule. The central atom is terbium, which belongs to the rare earth class and has magnetic properties. The arrows show the four possible orientations of the terbium nuclear spin.



Graphics: AG Wernsdorfer

In addition to superconducting qubits, however, other concepts for a quantum computer exist as well – for example based on atomic defects in semiconductors or ion traps in which individual ionised atoms are "captured" by electrical traps and serve as qubits. The competition between different technologies can be understood by recalling the very beginnings of the computer age. Initially, electromagnetic relays or electron tubes were used, before later being replaced by transistors and microchips. In the same way, existing quantum technologies could also end up in a dead end in spite of everything, for example because they are too big and bulky, or are simply too slow.

This is why it is currently very important to explore which platforms provide the best qubits in the long term that can be scaled to large numbers. For this reason, our research group is looking into alternative qubit concepts based on single molecules. In these, quantum states are encoded in their magnetic orientation – the so-called spin. In order to protect the spin state of these molecules from decoherence as described above, the experiments are carried out at very low temperatures close to absolute zero (–273.15° Celsius).

This protects the quantum states from interaction with the environment caused by thermal excitations. In order to achieve this, cryostats we develop ourselves are used to rapidly cool the molecules down to these ultra-low temperatures. With the aim of further reducing the interaction of the molecular magnetic states with the outside world, they are decoupled in several stages. The actual qubits are formed by the nuclear spins in a central magnetic atom of the molecule. These are then read out indirectly via two electron spins. A useful image here is that of nested Matryoshka dolls, where the innermost doll is protected from the surroundings by the others. As a result, these magnetic qubits are very durable and can be kept alive for several minutes. As things currently stand, that is an impressive age as compared to other qubits.

Qubits based on single molecules offer several other advantages over established systems. Firstly, their size: at about one square nanometre per qubit, they are significantly smaller than qubits based on superconducting circuits, for example. Secondly, it is frequently possible to use more than two states with one nuclear spin. Up to now it has been possible to control up to four spin states

A copper waveguide with three superconducting circuits that can serve as qubits. Studies are being conducted at the Karlsruhe Institute of Technology in which the attempt is being made to couple these with single-molecule magnets.

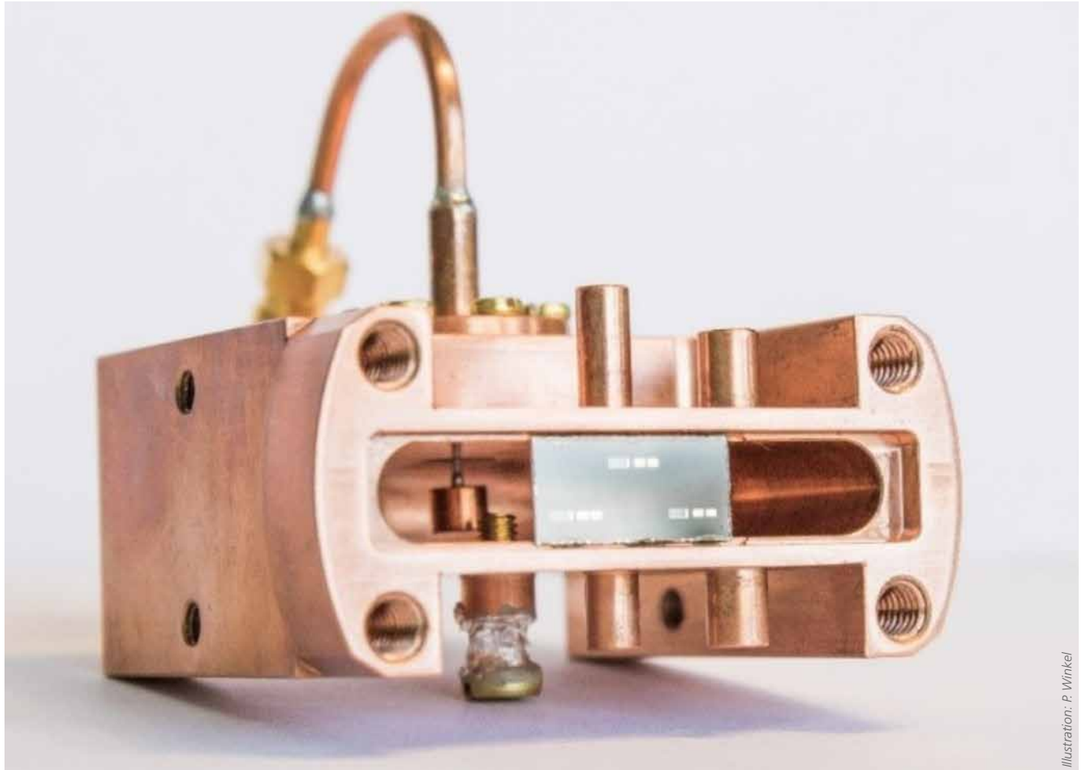


Illustration: P. Winkel

Illustration: AG Wernsdorfer

Optical structure of a laser system. This is used to read out quantum states based on imperfections in diamond.

in a molecule. This does not seem much more than the usual number of two, but when several of these higher-dimensional qubits are entangled, this results in faster exponential growth.

In principle, the scaling of molecular spin qubits is not a problem. Our colleagues in the field of chemistry are already at a very advanced stage here: they are able to produce much larger qubit systems and tailor them to specific needs. However, one problem here is that these quantum processors are so small that it is an enormous challenge to control and read out several spins individually. A whole range of methods are combined with the molecular quantum processors in order to achieve this, including other qubit systems. In these hybrid systems, the individual magnetic molecules can be coupled with other qubit systems and read out.

These include the superconducting qubits mentioned above, but also atomic impurities in diamond, which, among other things, allow optical read-out, i.e. using a laser. Another hybrid technology uses scanning tunnelling microscopes. These make it possible to "see" molecules and atoms directly with an atomically sharp metal tip and change their quantum states at the same time. Firstly, hybrid coupling can be used as an amplifier to efficiently determine the spin states of the molecule, thereby minimising their interaction with the environment. Secondly, different types of qubits can be entangled with each other so as to be able to investigate new effects inherent to hybrid systems.

Regardless of which qubit system ultimately wins the race in the development of a functioning quantum computer, it will take some time. In the meantime, we will probably already encounter quantum technologies in our day-to-day lives in other areas such as new, more sensitive sensors or quantum clocks. What is certain is that application-oriented basic research gives us a better understanding of the underlying physics and quantum mechanics, right down to the atomic scale. In the long run, there is no reason why Richard Feynman's sceptical view should be proven right.

Professor Dr. Wolfgang Wernsdorfer
is an experimental solid-state physicist. He researches and teaches at the Karlsruhe Institute of Technology (KIT); he was awarded an Alexander von Humboldt Professorship in 2016 and the DFG's Gottfried Wilhelm Leibniz Prize in 2019.

Dr. Philip Willke
is also an experimental solid-state physicist at KIT. He has headed an Emmy Noether Junior Research Group there since 2020.

Contact: Physikalisches Institut, Fakultät für Physik, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

www.phi.kit.edu/wernsdorfer.php
www.atomholics.de

Boris Schiffer

Illustration: Adobe Stock

Antisocial for an Entire Lifetime

What goes wrong in the minds of people who, from childhood onwards, completely lack empathy and have no scruples about harming others when it serves to satisfy their own needs? Current studies are trying to gain a better understanding of the neurobiological background to this personality disorder and this type of offender.

Affecting about 5 percent of the male population and less than 1 percent of the female population, antisocial personality disorder – or ASPD – is characterised by a persistent pattern of disregard for or violation of the rights of others. A low moral sensitivity or conscience is often evident, as is a criminal history and impulsive-aggressive behaviour. People with this personality disorder take advantage of others for their own benefit or pleasure. They manipulate and deceive, sometimes concealing this with wit and a façade of superficial charm or using intimidation and violence to achieve their goals.

Antisocial personality disorder includes aggressive and impulsive behaviour, irresponsibility and a lack of empathy. It is diagnosed in adulthood but is visible during childhood and adolescence.

They lack remorse and often have a callous attitude towards those they have harmed. Irresponsibility is another core feature of this disorder: this is why the individuals concerned often have considerable difficulties in maintaining stable employment and meeting existing social and financial obligations – which also explains the exploitative or parasitic lifestyles of such individuals.

Like all personality disorders, antisocial personality disorder is not diagnosed until adulthood but has to be traced back to adolescence. Unlike in the case of other personality disorders, the criteria of the internationally authoritative "Diagnostic and Statistical Manual of Mental Disorders", DSM-5, explicitly require that in order to diagnose ASPD, a conduct disorder must have been recognisable before the age of 15. This disorder, found in about 10 percent of boys and about 4 percent of girls, often shows some parallels to the characteristics of ASPD, such as impulsive and aggressive behaviour as well as insensitivity. The children repeatedly engage in petty crimes such as theft or vandalism or frequently get into fights with other children and adults. Of those adolescents who exhibit this kind of behavioural disorder – among whom attention deficit hyperactivity disorder (ADHD) and the abuse of addictive substances are also widespread, incidentally – some 25 to 40 percent are diagnosed with ASPD in adulthood.

If this type of personality development continues into adulthood, the prognosis is very unfavourable and they are predestined for a life of crime. This is why the term "life-course persistent offender" is often used in this context. ASPD is considered one of the most difficult personality disorders to treat. Due to their very limited or complete lack of capacity for remorse, individuals with ASPD are often insufficiently motivated and disregard the cost

Forensic psychiatry treats mentally ill offenders. Cell at the psychiatric hospital in Herne where the author of this article works.

Illustration: www.lwl-forensik-herne.de

of antisocial acts. For this reason, they do not usually take up treatment voluntarily but only in connection with a conviction, i.e. when they are required to so by court order.

There is some research into the treatment of ASPD that suggests positive outcomes from therapeutic interventions. Rather than attempting to have such individuals develop a conscience – which is extremely difficult given the nature of the condition – successful therapeutic techniques focus on rational and utilitarian views arguing against the repetition of past mistakes and the tangible, material value of pro-social behaviour. The impulsive and aggressive nature of people with this disorder can hinder effectiveness, however, whereby medication can be used as a means of support. There are no specific or approved drugs for the treatment of ASPD, however.

Personality disorders are generally thought to be caused by a combination of genetic and environmental influences. Research into genetic dispositions in connection with antisocial personality disorder suggests that ASPD may have a certain genetic basis or could even be heavily rooted in genetic make-up. In particular with regard to the MAO-A gene, which codes for monoamine oxidase A and is responsible for the expression of neurotransmitters such as serotonin and noradrenaline, various studies have been able to show that variants of this gene that lead to less MAO-A being produced are associated with aggressive behaviour in men. This is especially true of those who have had negative or traumatic childhood experiences.

In search of structural change and dysfunction in the brains of people with antisocial personality disorder: studies using imaging techniques aim to help elucidate neuronal patterns and mechanisms.

In addition, there is evidence of structural and functional changes in the brains of offenders of ASPD sufferers, such as reduced activity in the prefrontal cortex, which is involved in many executive functions such as behavioural inhibition, planning ahead and anticipating the consequences of actions.

The social and home environment seems to contribute to the development of antisocial behaviour. It has been shown that the parents of such children often show antisocial behaviour themselves, so in this respect model learning could also be involved, at least to some extent. A lack of parental stimulation and affection during early development leads to sensitisation of the child's stress response systems. This in turn impacts negatively on the development of the brain, altering emotion and stress regulation, the ability to bond with other people and the so-called social-cognitive functions overall. The latter include the ability to infer other people's thoughts or actions ("theory of mind"), interpret other people's emotions correctly ("cognitive empathy"), feel their emotions oneself ("emotional empathy") and feel compassion.

There is still a lack of clarity regarding the causative and perpetuating conditions of ASPD and of the "life-course persistent offender" type in whom it is frequently found. The Bochum research group is pursuing the goal of investigating and gaining a better understanding of the underlying neurobiological causes and processes of this personality disorder and this type of offender.

One study showed that unlike non-offenders, antisocial perpetrators of violence use different cognitive-emotional strategies to understand and correctly assess the emotional state of the other person. The neuronal activation patterns show that when perceiving mental or emotional states, non-offending individuals appear to make much more use of those brain areas associated with emotional-empathic reactions (such as the amygdala in the limbic system of the brain) than antisocial violent offenders. In these, the cortical areas associated with cognitive processes (such as the use of learned or experiential knowledge) are more strongly activated.

The focus of a current study – which also includes endocrinological and (epi-)genetic analyses relating to brain structure – is to elucidate the functional brain processes underlying the apparent dysfunctions in social-cognitive processes. For this purpose, a new paradigm was developed: the so-called Bochum Affective and Cognitive Empathy Test (BACET). This test enables social-cognitive processing to be comprehensively recorded and analysed in a differentiated manner with regard to the perpetrator versus victim perspective.

Another particular feature of the study is that it compares the offender group with two control groups to control for the influence of two moderating factors that make previous studies less revealing. Controlling for the factor of substance dependence or abuse, which also has a negative impact on social-cognitive functions, is countered by comparing the offender group not only with a healthy and non-offending control group but also with a group that has a similar history of harmful use or dependence on alcohol and/or drugs.

Since people with ASPD have an IQ that is on average about 10 points lower than the norm, the two control groups were also paralleled with the group of violent offenders in terms of their intellectual capacity. This offers an unprecedented opportunity to analyse social-cognitive functions relatively free of the effects of intelligence and addiction and also to relate any dysfunctions directly to the offender type or ASPD. Recruiting these three groups was a protracted and complex undertaking.

In assessing the benefits of their work, the Bochum researchers assume that the knowledge gained will not be able to be used directly for the development of more efficient treatment measures. However, it might help make any therapeutically triggered changes measurable so that the insights gained can be used for risk assessment purposes. After all, changes would only become permanently established in the behavioural repertoire of the individuals if they are neurobiologically verifiable.

Professor Dr. Boris Schiffer
is Director of the Research Department of Forensic Psychiatry and Psychotherapy at LWL University Hospital Bochum and LWL Psychiatric Hospital Herne.

Contact: LWL-Universitätsklinikum Bochum, c/o LWL-Maßregelvollzugsklinik Herne, Wilhelmstr. 120, 44649 Herne, Germany

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