Bridges for Fusion

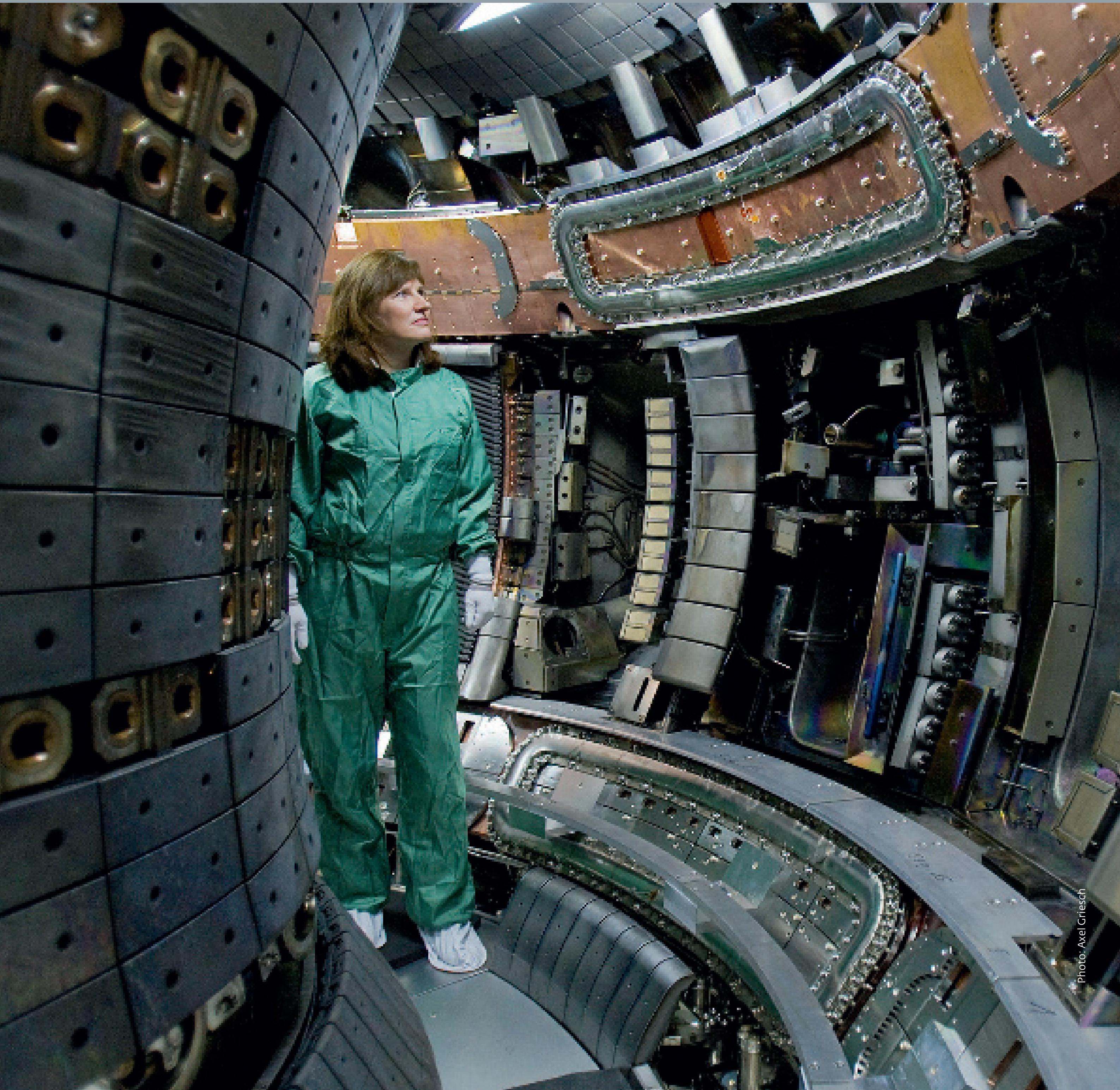
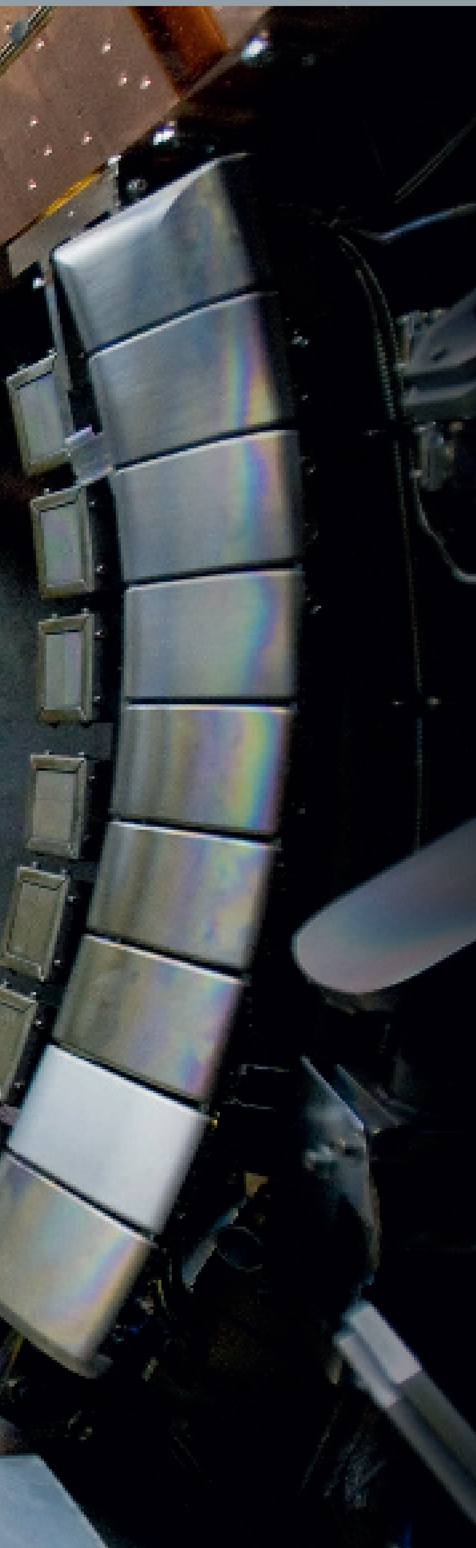


Photo: Axel Griesch

To consolidate the scientific basis for a fusion reactor – this was **Sibylle Günter's** objective when she took up her post as Scientific Director of the **Max Planck Institute for Plasma Physics**. But ever since the German government renounced nuclear fission, nuclear fusion has also had a difficult time politically. Sibylle Günter must therefore demonstrate, above all, political skill to gain acceptance for this way of generating energy.



TEXT **ALEXANDER STIRN**

"Fukushima was not fair," says Sibylle Günter and laughs. It is not cynical – not condescending laughter. It sounds more like thoughtful, like self-mocking laughter. After all, the sentence that was far and away the one heard most frequently after the reactor disaster in Japan has unintentionally become the main item on Sibylle Günter's agenda: Fukushima has changed everything.

At the beginning of February, Günter had taken up her new post as Scientific Director of the Max Planck Institute for Plasma Physics in Garching. Six weeks later, a tsunami hit the nuclear power station on Japan's east coast. Since then, nothing is as it was before: nuclear fusion, the scientific heart of the institute, has suddenly become a target. The technology is designed to generate energy in a power station by fusing deuterium and tritium nuclei, two heavy isotopes of hydrogen, to form helium. It has only the first word in common with nuclear fission, which drove Fukushima into chaos, but nobody is really interested in that.

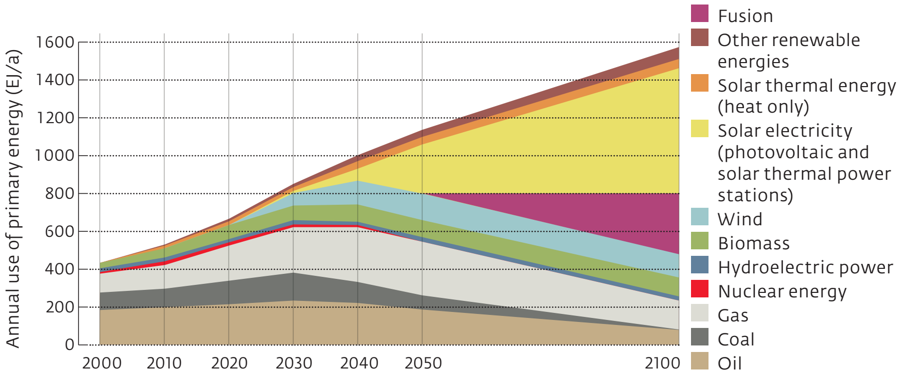
Ever since, instead of providing scientific momentum as planned, instead of moving the institute forward, instead of conducting research herself, Sibylle Günter has been involved in damage limitation exercises. The important thing is to market her own research field – and to build bridges: between politics and science, between fusion and renewable energies. "I want to put the aspects they share at the focus of the discussion," says Sibylle Günter.

This is the motto of her time in office, one could say, because it is not only in politics that gulfs must be overcome. The Rostock-born scientist also wants to build a bridge between theory and experimental physics, between children and career, east and west, man and woman.

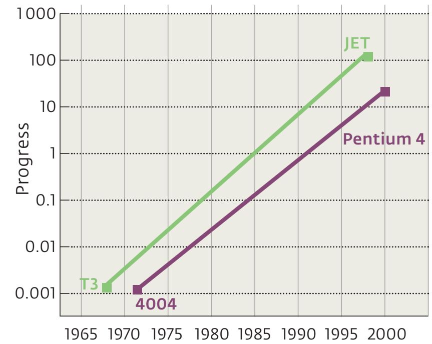
At the moment, however, it is clear that top priority must be given to efforts to persuade key figures on the political level. Last week, she had a visit from the Federal Minister of Economics. He was followed by the leadership of the Green party in the European parliament. This week, the President of the Federation of German Industry (BDI) announced that he wanted to visit. And the energy experts of the CDU and CSU parliamentary coalition group would also like Günter to give them a tour of the institute. They all are motivated by the question of how safe nuclear fusion is, how reliably it will one day be able to generate energy, and primarily, why it is still needed at all – now, where the expansion of renewable energies is as good as decided and all problems appear to be solved. >

The future of energy in her sights: Sibylle Günter, Scientific Director of the Max Planck Institute for Plasma Physics (IPP), puts her faith in fusion – but she also sees the importance of renewable energies.

Forecast of the German Advisory Council on Global Change



Progress in nuclear fusion and computer technology



Global energy demand is expected to increase to four times today's figure by 2100. The illustration on the left (source: Bundesverband Solarwirtschaft) shows the future trend. In about 40 years, the contribution from nuclear power will be missing, and oil and gas reserves will have been depleted. Sibylle Günter wants to compensate for the loss with fusion. In recent years, its technology has developed at a similar rate to that of microprocessors, whose power depends on the number of transistors that are integrated. The progress that fusion has made is measured by the so-called fusion product, from the values of the plasma density, temperature and energy confinement time that have been achieved.

Graphic left: Bundesverband Solarwirtschaft; graphic right: designergold, based on original material from the MPI for Plasma Physics

"Unfortunately, the discussions in Germany are very emotional at present," says Sibylle Günter. "Quite a few politicians would like to have a simple solution, but simple solutions are usually wrong." For politicians, simple means: We put as much money as possible into regenerative energies. There is then nothing left for different solutions, not even for nuclear fusion.

SOLAR THERMAL ENERGY CAN BE ONLY PART OF THE SOLUTION

"There's no question about it, renewable energies are important," says Günter. "But we should not fight each other. Quite the opposite, we should be glad to have different options afterwards."

Options, alternatives, possibilities: no matter what the topic is, Sibylle Günter always comes back to one of these terms. But the plasma physicist does not stop at slogans – she also has the relevant arguments up her sleeve: global energy demands will spiral to four times the current figure by 2100, and the demand for electricity could even climb to six times its current value. This is due mainly to countries that that are on the threshold of rapid change, such as India. "We won't be able to tell the people in India that they must conserve energy and use only renewable energies just because that is what we do," says Sibylle Günter. The consequence: without alternatives, the emerging nations will stick to nuclear fission or continue to burn coal – thus making the climate problem even worse.

Günter thinks it is an illusion that wind and solar energy alone can satisfy future demand. Even huge solar thermal energy projects like the ones now being planned in the – currently politically unstable – countries of North Africa, can be only part of the solution," says the physicist. "It is the same situation as with shares: a broad portfolio decreases the risk and the dependencies."

The Director fetches her laptop and starts a computer presentation. The illustration, actually intended for the BDI president, shows how the demand for energy will change in the coming decades. It comes from the Bundesverband Solarwirtschaft, the interest group of the solar power industry. Günter does not want to give people any grounds for accusing her of using only data that suits her purposes.

The yellow area on her diagram, which stands for solar energy, becomes wider and wider. One click and a pink wedge moves into the dominant yellow. It represents fusion energy – at least from Günter's point of view. From 2050 onwards, the wedge will compensate the deficit that will result from the renouncement of nuclear power and the slow depletion of oil and gas reserves.

"We need to campaign for politicians to put their faith not only in wind and sun," says Günter. It sounds self-assured – and quite egoistic: "The nice thing about my job is that I am also fighting for my own specialist field all the time."

There was not much time to prepare for everything, to understand the tricks and dodges of politics, or to learn how to lobby. Günter learned that she was to become the Scientific Director in October last year. She moved into her office in February. Fukushima was in March. She had been able to accompany her predecessor, Günther Hasinger, on political visits a few times, giving her a crash course in diplomacy. Then she was in at the deep end. "There are no seminars for this kind of thing. One simply has to look and see how things work," says Günter tersely.

It certainly helped a little that fusion researchers have never had the easiest of positions. A scornful phrase that is often bandied about is that nuclear fusion is always 40 years away. Cynics call it a fusion constant, a time period decreed by nature. "I know all the jokes," says Günter and calls up a second diagram – a kind of defense against all the malice. It shows how the mathematical product of density, temperature and energy confinement time has developed over the years. The value is considered to be the most important parameter for the success of fusion research. It shows how close the scientists are to igniting the solar fire on Earth.

The curve on Günter's laptop increases steeply. Directly next to it she has drawn the same graph for Moore's law – the empirical formula that states

Politics meets science: On August 19 this year, Sibylle Günter provided the Federal Economics Minister, Philipp Rösler, with first-hand information about the progress being made in fusion research.

Photo: MPI for Plasma Physics – Tino Schulz

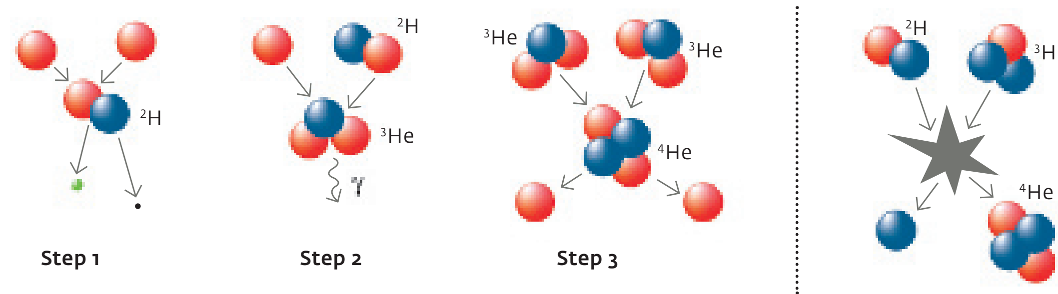
that the number of transistors on a computer chip doubles every 18 months. The two lines hardly deviate from each other at all. “Nobody would argue that the computer industry has not made rapid progress,” says the plasma physicist. “Our success parameter has increased just as fast.”

FUSION STILL HAS AN ENERGY PROBLEM

This may all be reasonable and scientifically correct, but Günter is realistic enough to know that the only thing that counts in politics is the result, and fusion is still inputting significantly more energy into its experiments than is being output afterwards.

This is not going to change very quickly, either: ITER, the largest test reactor for nuclear fusion to date, is currently being built in Cadarache in the South of France. Its purpose is to show that the reaction will provide more energy than is needed to maintain the high ignition temperature. The reactor should be completed in 2020, and the crucial experiment is planned for 2027 – if the scientists can obtain the 15 billion euros that ITER is now expected to cost.

“The taxpayer has a right that we say: That’s enough, ITER must not cost any more,” says Sibylle Günter. “But it must not be the case that there is then no money left for research into other aspects of nuclear fusion.” The Institute Director again has the appropriate fig-



The solar fire on Earth: In the interior of the star, two protons (red) first convert into a deuterium nucleus (^2H), whereby one proton becomes a neutron (blue), and one positron (green) and one neutrino (black) are released. In a second step, the deuterium nucleus fuses with a further proton, emitting a quantum of gamma radiation and forming a helium-3 nucleus (^3He). This finally fuses with another helium-3 nucleus to form helium-4 (^4He), releasing two protons in the process. In the Earth's fusion reactor (right), helium-4 is obtained by fusing one deuterium nucleus (^2H) with one tritium nucleus (^3H), and one neutron is released in this process.

ures to hand to support her arguments: Only two percent of the income from the Renewable Energy Act goes into research. The growth rates in energy research are still significantly below those of research into health issues. Not to mention the coal subsidies ... the plasma physicist can only shake her head. "I don't want to say that the funding for fusion must be a bottomless pit, but one must see things in proportion," says Günter, the bridge builder. Fusion power stations are expensive, of course, but coal power stations are expensive as well.

Still, with the latter it is certain that energy will be generated afterwards. Günter does not accept this argument. "We have good reason to assume that ITER will generate ten times the energy we put in," says the physicist. "But this is science, and this is precisely why our work every day is directed at improving this."

And, indeed, the IPP is not a Max Planck Institute like many others. Everything plays second fiddle to the overriding task of operating a fusion power station efficiently. This is why huge machines are built, why the researchers concentrate on studying magnetically confined plasmas.

When Sibylle Günter came to Garching 15 years ago, it was a completely new world for her. "A dictionary would have been useful," says the 47-year-old physicist, and smiles. She studied in her hometown of Rostock from 1982 until 1987: physics, because the disciplines mathematics and physics had been particularly interesting at school; plasma physics, because it was one of the highlights at the University of Rostock; theoretical plasma physics, because it was no fun being an experimental physicist in East Germany, and there was hardly anything to do research on. "They had to collect parts for their instruments from scrap heaps, and this did not appeal to me," says Günter. Pencil and paper became her tools.

COURAGEOUS CHANGE OF DISCIPLINE AFTER TEN YEARS

She wrote her doctoral thesis on dense plasmas – a topic that has nothing to do with magnetic nuclear fusion at all. She became pregnant. In December 1989, as East Germany was going through monumental changes, Sibylle Günter handed in her doctoral thesis. Six months later, now a young mother, she defended her thesis. The baby was ill and she was ill, but the defense was nevertheless successful. "It was not easy to obtain my doctorate with a small child, of course," says Günter today. "But really, there is never a reasonable time to have children. If you want children, you simply have to go ahead and have them."

After the fall of the Berlin Wall, science in Eastern Germany changed. Computers opened up new possibilities; the gulf between theory and experiment started to close. And Sibylle Günter was bang in the middle. The scientific child of reunification, with a new doctorate under her belt, was confronted with a problem: nearly all the interesting positions in Eastern Germany were already taken; there was no job in sight for the foreseeable future.

Sibylle Günter decided to take the plunge: In 1996, after ten years in the field of dense plasmas and directly after obtaining her post-doctoral lecturing qualification, she moved to Garching – into fusion research. "I felt like a student again," she said. "I went to specialist conferences, where I didn't know anybody and didn't understand a word." It was a challenge, but also a motivation. Günter, the theoretical physicist, linked up with the experimental physicists in Garching. She had them explain the discipline to her, and had to listen to stupid jokes, but she convinced her colleagues by predicting the result of the experiments.

Today, more than ten years later, theory and experiment are closely interwoven in plasma physics. There is hardly a talk that makes do without equations, without theoretical background knowledge. Mainframe computers have helped to successfully simulate experiments. The researchers have also been helped by a willingness to research the fundamental questions of the discipline, rather than just chasing after the ultimate goal of making fusion work. "We want to understand details, not just turn knobs," says Günter. "The good interplay between theo-

Graphic: MPG.

ry and experiment has become the hallmark of the Max Planck Institute for Plasma Physics."

THEORETICAL MODELS REVIVE THE STELLARATOR ANEW

Wendelstein 7-X, an experiment the institute is setting up in Greifswald, is such a child of theory. Its concept, where the plasma is confined with the aid of three-dimensional solenoids, was already dead. Too complicated, not manageable enough. The theoretical models of the Max Planck researchers revived the stellarator, as this type of reactor is known. In the experiment, it now has to prove that it provides an alternative to tokamak reactors, to which ITER also belongs.

For Günter, this means that she has to build bridges between the old-established institute in Garching and the new part on the Baltic. The sub-institute in Greifswald was established in 1994, a classic child of German reunification: a project to improve the regional structure. Today, the Greifswald institute is one of the largest employers in the region. If something interesting happens there, it is in all the local newspapers. On the Garching campus, by contrast, the IPP is just one institute among many.

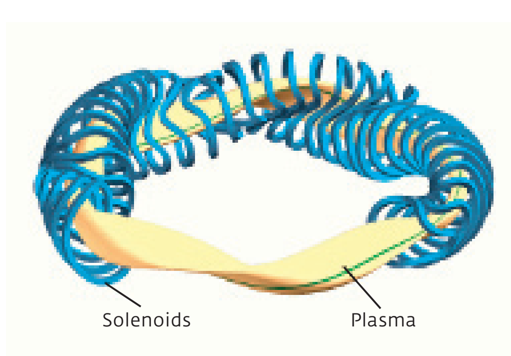
That is not the only difference: Garching does research, while Greifswald is building a huge machine. "If you are separated by 800 kilometers, and if one part of the institute has completely different problems, you grow apart," says Sibylle Günter. "We need to actively do something to prevent this, so that it remains a joint institute." She is in the process of intensifying the scientific contacts and initiating joint research projects. Günter was born in the state of Mecklenburg and travels back to her home state at least once a month. At the moment, it is more like once a week – to accommodate leading politicians such as Messrs. Rösler, Bütikofer & co. who want to have a tour through the Eastern German institute.

"When I talk to taxi drivers in Greifswald, they are extremely interested in our work. They have a positive at-

Dialog in the corridor: Sibylle Günter in a discussion with colleague Matthias Hölzl.

left: With the stellarator, such as the Wendelstein 7-X device, the magnetic cage is generated by a single system of solenoids – without a longitudinal current in the plasma and without a transformer.

right: A tokamak requires three superimposing magnetic fields to generate the magnetic field: One forms the plasma (yellow) into a ring; another one is induced by a transformer coil (in the center), with the field lines inside running helically and confining the plasma; a third, vertical field fixes the position of the plasma.



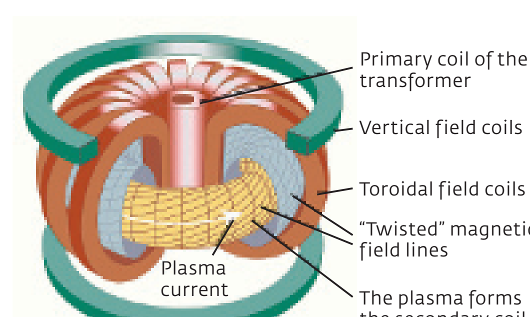
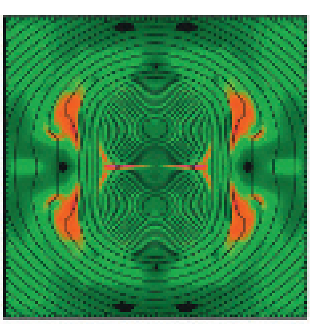
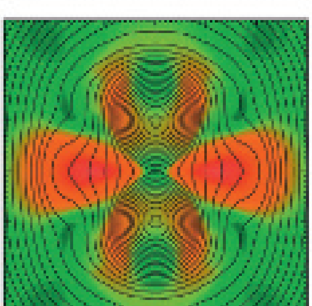


Photo: Axel Griesch (top); graphics: MPG

top: Sibylle Günter is in charge of 1,100 staff. When she was appointed to the management team of the IPP in 2000, she was 36 – and the youngest female to ever be appointed a Max Planck Director.

bottom: Basic research for fusion: The images show simulations of fast reconnection, which is also important in astrophysical plasmas.





titude, but unfortunately, without any real knowledge," explains Sibylle Günter. This is the general problem with nuclear fusion: there is a lack of knowledge in Germany – and therefore also a lack of acceptance. "Anyone who has ever visited the institute is quite impressed afterwards," says Günter. "But this is only a small number of interested people, of course."

A FEMALE SCIENTIST SHOULD BE A ROLE MODEL FOR GIRLS

The Director prefers to talk with multipliers, with politicians, with journalists. In Greifswald, the Max Planck researchers recently started a project to train teachers. "Since fusion is still quite a way off, an advertising campaign is pointless. Education is the ideal solution," says Sibylle Günter, who is now unstoppable: "The problem in Germany is simply that science education is in an extremely bad way. We need to change this in the long term. It cannot be done by the day after tomorrow."

Female teachers, in particular, have a duty here, according to Günter's point of view. They need to encourage girls, who are still greatly underrepresented in the natural sciences. They should be role models for them. Günter herself has done her part. When she was appointed to the management team of the IPP in 2000, she was the youngest female to ever become a Max Planck Director. "It is very important for girls – even for those from high schools who visit us – to see that women can do such things."

She was only partly successful here with her own daughter, Stefanie, of all people. The baby whose illness once almost prevented her from defending her doctoral thesis is now 21 – and studying medicine. Really. For a long time, physics was also on her short list, but then she decided against science and for patients. But, in a way, the daughter is following in the footsteps of the mother. In the early 1980s, Sibylle Günter couldn't make up her mind between medicine and physics, either. "But then I decided that I'm too lazy for medicine," says Günter and laughs.

There is not a trace of laziness these days, though: her working day is well planned. Sibylle Günter starts it in the imposing Director's office. There, on the top floor of the administration building, in front of the wall unit and beneath the colorful picture of a forest, she manages the issues of the institute with its 1,100 or so staff. After lunch she goes down to her old researcher's office – it has no air conditioning, but it is filled with books and articles. Günt-

Photos: Axel Griesch (top); MPI for Plasma Physics (bottom, 2) er supervises degree students, doctoral students and post-docs, discusses with colleagues, engrosses herself in science. “The people in the administration think this is somewhat strange,” says Günter. “But I want to be where my science is happening.”

In recent months, Günter has had hardly any time for this. Too often she was travelling, too often politics required her involvement. After all, Fukushima changed everything. There was no possibility of her taking a holiday. One sailing trip with colleagues in Greifswald is all she has been able to manage.

Sibylle Günter is convinced that these exceptional circumstances will last until the end of the year. Her hope is that, sometime next year, they, too, will be a thing of the past. “Greater rationality will return to the discussion when the switch to sustainable energy has to be put into practice, if not before,” says the Director. And then her work will calm down as well. Sibylle Günter, at least, is confident that she can convince the politicians of the purpose and success of nuclear fusion – so confident, in fact, that she has already booked her skiing holiday for next February. ◂

GLOSSARY

Nuclear fusion
A fusion power station aims to produce energy by fusing deuterium and tritium nuclei, two heavy hydrogen isotopes, to form helium. The fusion reaction ignites in a hot plasma of more than 100 million degrees Celsius. Since the plasma will cool down immediately if it comes into contact with a material, it is confined in a magnetic field without coming into contact with the wall. The challenges of fusion research include confining a stable plasma, developing suitable materials for the high loads in the reactor, and proving that more energy is produced by the fusion reactions than is required to generate the plasma.

Stellarator
A type of reactor that generates the twisted magnetic field that is required to maintain a stable fusion plasma with the help of solenoids that are twisted like a Möbius strip. This type is more demanding than a tokamak in terms of construction, but theoretical investigations show its operation should be easier to manage.

Tokamak
This is the name of the fusion reactor on which most research has been done so far. Solenoids arranged in a circle generate a toroidal magnetic field. This must be twisted like a spiral so that the plasma inside remains stable. The twisting results when a current flows through the plasma. The generation of the plasma current causes operational problems that do not occur in the stellarator, the alternative type of reactor.