Science Foundation of China, the nation's main research-funding body.

"The US–China conflict was a wake-up call for China," adds Mu-Ming Poo, a neuroscientist and scientific director of the Chinese Academy of Sciences' Institute of Neuroscience in Shanghai.

For example, late last year, the United States restricted exports to China of advanced microchips used in smartphones, out of concerns that the chips could be used for military purposes. The incident revealed a major bottleneck in the application of home-grown advances in basic research to fulfil China's technological needs, argues Poo.

China produces much high-quality research in the field of materials science, but those recent events revealed the need to produce useful products, too, Poo says. "The research community and industry need to be better connected to fully realize the potential of our basic-research community."

Although the latest plan indicates China's desire to become more self-reliant to avoid problems such as this, Yang says, it wants to retain strong research ties overseas.

But Huang Futao, a researcher in higher education at Hiroshima University in Japan, worries that because Western countries impose greater restrictions than normal on collaborations with Chinese scientists in sensitive areas of research, it will become more difficult for researchers to work together.

China's joint push for self-reliance and industrial collaboration will mean that fundamental science will be increasingly directed towards fields of importance to society, says Poo. Areas of focus now include artificial intelligence, quantum information, genomics and deep-space and deep-sea exploration. The plan is seeking to create a "strategic research force for the nation", adds Yang.

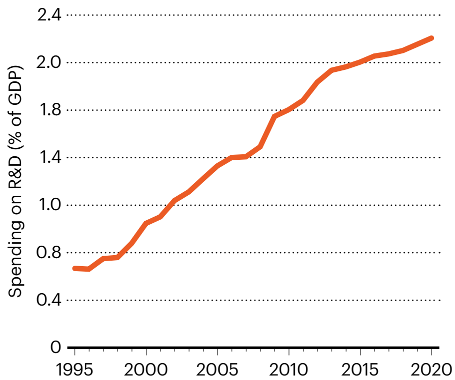
As part of the move for closer ties between research and industry, there will be incentives for the private sector to invest more in basic science through tax cuts.

This shift to closer links with industry is a change for China, says Huang. "Compared to many Western countries, China has a very short history of collaboration between academia, industry and business, because all business was originally controlled by the central government," he says.

The five-year plan's emphasis on industrial collaboration is in line with efforts over the past few years to translate basic research into science with real-world applications, say researchers. For example, in December 2019, China's Ministry of Human Resources and Social Security published rules allowing researchers to take sabbaticals of up to six years to join industry or create their own start-ups, says Zhang. Researchers who pursue this opportunity continue to receive a salary and other benefits, and their output during this time is recognized in academic evaluations and promotions.

BOOMING BUDGET FOR SCIENCE

China's spending on research and development (R&D), as a proportion of gross domestic product (GDP), has increased steadily since 1995.



SOURCE: OECD, NATIONAL BUREAU OF STATISTICS OF CHINA

To facilitate the shift to industry, China is also trying to place less emphasis on researchers publishing high numbers of papers, and to find new ways of evaluating them on the basis of the impact of their work. The focus is on "getting things done", says Zhang.

But these developments could create blind spots for ethics and research integrity, she adds. By encouraging closer collaboration with the private sector, scientists might be entering terrain where the current system of monitoring research conduct through home institutions will not have oversight.

China has made efforts to crack down on research misconduct, including cases of plagiarism and fabricated peer review, that have led to the retraction of a large number of papers, but problems remain. The lack of transparency in research conducted by industry will make it more difficult to address research integrity in collaborations between academia and industry, says Huang.

The pressure to meet societal goals and the competitive system for disseminating funding could also result in researchers cheating the system in new ways. "The tolerance for failure is going to be low," says Zhang. And with fewer scientific publications as a result of the shift to industry, Chinese scientists' work will become less visible to the world, she says. "They are pushing elite scientists into a dark room behind closed doors."

Changes in how researchers are evaluated could also make it more difficult for young scientists to access competitive funds on the basis of merit, say researchers. The government needs to clarify what indicators it will use to evaluate performance, so that researchers fully understand them, says Cong Cao, a science-policy researcher at the University of Nottingham in Ningbo, China.

According to the five-year plan, China intends to increase spending on research and development (R&D) by more than 7% annually (see 'Booming budget for science'). Li said that central-government spending on basic research would also increase, by 10.6% in 2021, which Cong says is higher than the average annual increase over the past five years. And the plan proposes raising the overall share of basic research in R&D spending from 6% to more than 8%. Although that increase is welcome, it would still be only half the proportion of R&D spending of many countries, says Cong.

More details on China's science funding are scheduled to emerge later this year.

EVIDENCE OF ELUSIVE MAJORANA PARTICLE DIES WITH RETRACTION

But search for exotic states lives on, despite setback for Microsoft's approach to quantum computing.

By Davide Castelvecchi

A study that was once trumpeted as evidence for the existence of an exotic quantum state that could revolutionize computing has turned out to be anything but. A 2018 *Nature* paper[1], based on work led by researchers at a Microsoft laboratory in the Netherlands, has now been officially retracted[2] owing to what the authors call "insufficient scientific rigour" in the original data analysis.

The retraction is a setback for this approach to quantum computing, but scientists say that it should still be possible to create and study the exotic states, known as Majorana fermions, that were the subject of the research. And researchers at Microsoft and elsewhere are still optimistic about the company's plans to make use of the phenomenon in a future quantum computer.

Topological states have become one of the hottest areas of basic research in physics and materials science in the past decade.

Theoretical physicists have predicted that, in certain materials, the collective behaviour of electrons can display the properties of Majorana fermions, hypothetical elementary particles that could simultaneously be matter and antimatter.

The theory says that these collective quantum states would be topological, meaning that they would 'remember' how they moved around with respect to one another, in the same way that strings in a braid 'remember' how they were intertwined. This should make the Majorana states robust carriers of information, suitable for building a quantum computer.

In practice, it has been devilishly difficult to build actual devices that can enable Majorana fermions to form. Researchers have tried various approaches, and Microsoft decided to bet heavily on one that had been pioneered by Leo Kouwenhoven, a physicist at Delft University of Technology in the Netherlands. In 2016, the company hired Kouwenhoven — among other stars in the field — and tasked him with founding a Microsoft lab on the Delft campus.

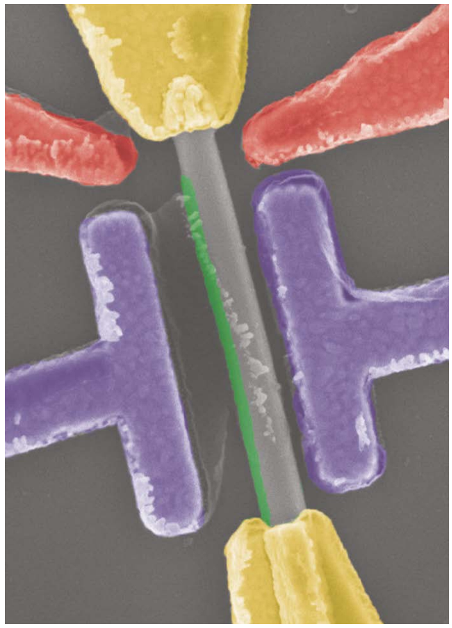
Kouwenhoven's approach involves trying to create Majorana fermions inside 'hybrid' nanowires, which combine a layer of a semiconductor material with a superconducting one laid on top of it. Theory predicted that at very low temperatures, thermal vibrations in the superconductor — which enable electrons to travel through such materials without any heat losses — also 'leaked' an effect on the semiconductor underneath. Under certain conditions, such as the application of a magnetic field, a pair of Majorana fermions, one at each end of the nanowire, should spontaneously form in the semiconductor.

No one yet knows how to detect Majorana fermions directly, but to at least prove they exist, Kouwenhoven and his collaborators looked for an effect that was considered a 'smoking gun': the electrical conductance of the nanowires' tips should have a sudden peak as researchers apply a voltage and then dial it down to 0. This was the signature that the team reported in *Nature*. (*Nature*'s news team is editorially independent of its journal team.)

"This paper was considered a big deal," says Sergey Frolov, a physicist at the University of Pittsburgh in Pennsylvania, whose subsequent work helped to trigger the retraction. "It was taken widely as, if not the ultimate proof, the strongest proof to date" for the existence of Majorana fermions, he says.

Conflicting data

Based in part on his own attempt to measure the effect in his lab, Frolov suspected that the evidence presented in the 2018 paper did not tell the whole story. He points in particular to a study[3] led in 2014 by physicist Silvano De Franceschi, another former member of Kouwenhoven's team. De Franceschi and his collaborators had found that a separate,



H. ZHANG *ET AL.*/NATURE

A nanowire (green) that was used to try to create Majorana fermions.

non-topological quantum phenomenon called Andreev states can, under certain conditions, mimic the experimental signatures that are expected in Majorana states. "Andreev states can explain a number of grand claims" made by several research groups over the years, says De Franceschi, who is now at the University of Grenoble Alpes in France.

To be sure that they have created a Majorana state, experimenters should repeat their measurement many times while slightly changing the experimental conditions, such as the strength of the magnetic field, Frolov says. In a paper published in *Nature Physics* in January[4], Frolov and his collaborators describe an experiment that produced what looks like the coveted Majorana signature, but contradicts it when the conditions change slightly.

"This approach is beautiful and elegant from the theoretical physics point of view. It may still succeed."

Frolov says that, in November 2019, he obtained an extended set of data from one of the *Nature* paper's authors. When he plotted these data, he found evidence that directly contradicted the central claim of the paper. Frolov and Vincent Mourik, another former Delft colleague who is now at the University of New South Wales in Sydney, Australia, then wrote to *Nature* to express their concerns about the paper, and in April 2020 the journal issued an editorial expression of concern.

In a preprint posted in January[5], and in their 8 March retraction note, the authors say that, when the inconsistencies were pointed out to them, they re-analysed all the existing raw data from their original measurements and repeated the experiments with updated settings. When they did this, they found that there wasn't the evidence to support their previous conclusion. "When the data are replotted over the full parameter range, including ranges that were not made available earlier, points are outside the 2-sigma [95%] error bars. We can therefore no longer claim the observation of a quantized Majorana conductance," they wrote in the retraction notice. "We apologize to the community for insufficient scientific rigour in our original manuscript."

Kouwenhoven and Hao Zhang, the other corresponding author of the retracted paper, who is now at Tsinghua University in Beijing, did not respond to requests for comment on Frolov's analysis of their results.

Ongoing investigation

How the problems with the original paper came about is still not fully understood. In May 2020, Delft University of Technology announced that their research-integrity committee was investigating "whether the research, data analysis and writing of the publication were executed in accordance with the applicable guidelines". The committee appointed a panel of four external experts to review the experimental data and the paper. Their report, released on 8 March, said that the researchers had interpreted their data over-optimistically. "We found no evidence of fabrication: all data in the publication seem to be genuine results of measurements," the report says. "However, the research program the authors set out on is particularly vulnerable to self-deception, and the authors did not guard against this."

The broader investigation is ongoing, says Lieven Vandersypen, the director of research at the university's quantum-technology institute. He says that staff members have had a broader discussion on the lessons to learn from this incident. "Science always means being critical, doubting your results and discussing them."

Microsoft is still committed to the topological approach to quantum computing. It remains to be seen whether Majorana states exist, and whether they can eventually beat other approaches that are much further advanced, researchers say. "This approach is particularly beautiful and elegant from the theoretical physics and mathematical point of view," says Yasser Omar, a physicist at the University of Lisbon. "And it may still succeed."

1. Zhang, H. *et al Nature* **556**, 74–79 (2018).
2. Zhang, H. *et al. Nature* https://doi.org/10.1038/s41586-021-03373-x (2021).
3. Lee, E. J. H. *et al. Nature Nanotechnol.* **9**, 79–84 (2014).
4. Yu, P. *et al. Nature Phys.* https://doi.org/10.1038/s41567-020-01107-w (2021).
5. Zhang, H. *et al.* Preprint at https://arxiv.org/abs/2101.11456 (2021).