

Pushing the frontiers of knowledge

Zhejiang University: Faculty of Science

ZJU Faculty of Science complex in plan

One of the oldest state-established universities in China, Zhejiang University (ZJU) can trace its origins back to the Qiushi Academy in 1897. It is one of China's most prestigious universities and maintains a world-class standing for its commitment to excellence. At the forefront of this 120-year-old university's agenda is a plan to develop its basic science programmes and continue its role in advancing global research efforts.

The ZJU Faculty of Science has roots in the university's very beginnings. The departments of mathematics, physics and chemistry were launched along with the Qiushi Academy. Having undergone several overhauls through many years of significant change in Chinese society, today's Faculty of

Science was formally established at ZJU in 2008.

The faculty now houses five schools or departments and a centre: the School of Mathematical Sciences, the School of Earth Sciences, Centre for Psychological Sciences and the departments of physics,

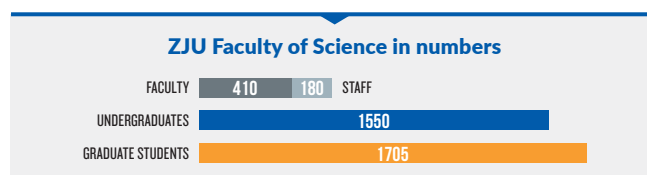
in top academic journals, but in their wide applications, ranging from the petroleum and energy industries to the digital display industry. "We aim to be at the frontier of science and emphasize the value of basic research," said Ma Shengming, dean of the ZJU Faculty of Science

laying a solid foundation for them. For graduate students, it supports and encourages their independent research capability. The faculty's remit is to educate internationally competitive science students with an ability to think critically, a comprehensive view, sound knowledge base and strong hands-on skills. Many of its alumni are already prominent scientific, industry and administrative leaders.

The key to these goals lies in a world-class faculty team. ZJU Faculty of Science applies international standards in its faculty recruitment and management and has embarked on a new journey of seeking excellence. ■

and a member of the Chinese Academy of Sciences (CAS). "Our ultimate goal is to benefit socioeconomic development and the wellbeing of mankind."

The faculty also takes a broader view of its education mission. It offers basic science instruction to undergraduate students across the university,



chemistry, and psychology and behavioural sciences. Its decent reputation for cutting-edge research is testament to the work of its 590 faculty and staff, who also nurture a large cohort of undergraduate and graduate students. The faculty's achievements are not only evident in high-quality publications





Back to basics with a bold new view

The Faculty of Science dean, Ma Shengming, and executive vice dean, Li Haoran, outline their plan to encourage original research and enhance basic science at ZJU.

What sets the faculty apart?

Ma: ZJU was renowned for its engineering strength before a merger with other three universities in Hangzhou in 1998. Now, our natural science programmes are gaining momentum as China encourages innovation and pays more attention to basic research. Government funding support is increasing and our university leadership also emphasizes the development of basic science. We have recently attracted many high-quality researchers and produced great output. With our traditional strengths in mathematics, physics, chemistry, earth science, and psychology and behavioural sciences, along with a cross-disciplinary platform for close collaboration with ZJU engineering, information and life sciences disciplines, we are empowered to drive breakthroughs in original research.

What is the development goal of the faculty?

Ma: Geared towards cutting-edge science, we aim for breakthroughs in basic and theoretical research to bring scientific advancement and technological innovation. We also hope that our research achievements may contribute to national economic and social wellbeing. Our multidimensional objective also encompasses teaching students across the university. We are striving to build a world-class research platform, to be at the centre of technology innovation, and to nurture students with strong



science literacy who will become pillars of society.

How do you plan to enhance original research?

Ma: Talent is key to driving original research. Our plan starts with bringing in quality researchers from home and abroad to boost our competitiveness. With support from the university, we are making great efforts to recruit high-profile researchers to promote our global visibility and influence. Talented

Short-listed candidates are invited for a presentation of their past research achievements and a future research plan. We are trying our best to provide new faculty members with as much support as possible. They have freedom to explore their own ideas and are encouraged to collaborate across their disciplinary boundaries. They are evaluated on the real significance of original research, rather than the impact factors of journal publications. We have also installed a tenure-track system, trying our best to be in line with international standards.

Li: Our chemistry department was among the first at ZJU to pilot the tenure-track system five years ago. An international review board assesses the performance of new faculty members within a period of three to six years. As we encourage faculty to explore both blue-sky and applied research, the evaluation will also look at contribution to industry R&D for those in the applied track. We will finally just keep the top-rated ones.

As Dr Ma explained, we encourage diversity and cross-disciplinary, and try to avoid academic inbreeding in recruitment. We are also building the Centre of Psychological Sciences, which will incorporate natural sciences and social sciences.

Are there examples of industrial applications of your research?

Li: I have partnered with a local enterprise for years to advance novel techniques for synthesizing vitamins. We have developed a green synthetic approach to cogenerate vitamin A and astaxanthin, a chemical compound known for its powerful antioxidant effect, by effectively utilizing by-products of vitamin A. This technique has enabled more efficient production of a wider variety of vitamins, on a larger scale, and at a lower cost. The technique was integral in the company taking almost a third of Chinese vitamin market.

What do you see as the trend in your field of research?

Ma: For me, chemistry is more than synthesizing things and optimizing fabrication approaches. It is essential to invent original protocols to advance theories and identify new technologies. This is particularly important for China, which is relatively strong at making things and needs a paradigm shift. I hope we can do more original research at ZJU to facilitate this process. ■

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young scientists with great potential are also in our sights. We put great stock in their abilities of independent research and teaching. Interested candidates need to submit a proposal for their future research and teaching programmes, together with their academic records.

MATHEMATICS

A stabilizing influence

A breakthrough by a maths research team undermines existing stability theories and will improve measuring methods for geophysicists.

Stability analysis of inverse problems

Geophysicists keen to peer into the Earth's inner structure can potentially use measurements on its surface, thanks to a theoretical breakthrough in the stability analysis of inverse problems by Bao Gang, chair and professor of the ZJU School of Mathematical Sciences.

Inverse problems, in simple terms, calculate causes based on results arising in a diverse set of application areas, ranging from geophysics, medical imaging, acoustics, and optics to machine learning and remote sensing. One example is using the wave equation in seismic studies to calculate

wave-speed of the Earth from the measured pressure field on its surface.

For inverse problems, instability is an issue. Studying the influence of data noises on solutions has significant implications, says Bao. Existing stability theories for the inverse problem of the wave equation generally assume that the velocity field in question does not induce caustics; that there is only one shortest ray path from the boundary incidence point to the exit point. The assumption allows the use of geometric optics (GO) approximation, a key technique for stability results.

The latest study by Bao and collaborators, has weakened this assumption by showing that a velocity field with caustics can be recovered stably by scattering relations on the boundary.

This is the first stability posed for the recovery of the velocity field in the wave equation with caustics, demonstrating the inversion method's benefits by scattering relations. A novel element to Bao's approach is the use of Gaussian beam approximations, rather than the GO approximation.

Recovering velocity fields inside the medium from boundary measurements in

the wave equation model is a key question in the inverse problem, and a major one in geophysics research.

"Geophysicists can now calculate the velocity field in a stable fashion if scattering relations can be measured on the boundary," Bao says, about a possible application of their research. "Our stability study helps build their confidence." ■

Reference

Bao, G. and Zhang, H. Sensitivity analysis of an inverse problem for the wave equation with caustics. *Journal of the American Mathematical Society* **27**, 953-981 (2014).

PHYSICS

A field of good conduct

Physicists at ZJU have found superconductivity in a chromium compound, opening opportunities for studying unconventional superconductivity.

Discoveries of novel superconductors typically advance research across the whole superconductor field. The finding, in the 1980s, of the first high-temperature superconductor in quasi-two-dimensional copper oxides with strong electronic correlations revealed a new research paradigm.

The exploration of unconventional superconductivity in

quasi-two-dimensional systems with highly correlated electrons led to the 2008 finding of the iron-based high-temperature superconductor.

A group of ZJU researchers is exploring a new approach. Their question is: given the relatively simple structure of quasi-one-dimensional materials with highly correlated electrons, is it possible to observe superconductivity in such a system?

EXPERT COMMENT

Initial results have demonstrated the existence of rich physics in these materials. With improving crystal quality in the future, these superconductors can be a unique playground to explore electron-electron correlation effects and find clues for unconventional superconducting mechanism.

—Hu Jiangping

Beijing National Laboratory for Condensed Matter Physics, and Institute of Physics, CAS.

After years of study, ZJU researchers, led by Cao Guanghan from the department of physics, have found superconductivity in an alkali-metal

chromium-based arsenide, $K_2Cr_3As_3$. It was the first time it was observed under normal pressure in a chromium compound notorious for its reluctance to superconduct. The discovery adds a new realm, says Hu Jiangping from Beijing National Laboratory for Condensed Matter Physics, and Institute of Physics, CAS.

The crystalline structure of this material is quasi-one-dimensional. It contains double-walled sub-nanotubes with an outer diameter of around 0.58 nm, which are separated by alkali metal ions. The material bears significantly strong electron correlations, shown by a large electronic specific-heat coefficient. Experiments revealed that below 6.1 Kelvin (around -267.1°C), electrical resistance



Vacuum assembly is used in an X-ray diffractometer to determine the crystal structure.

drops to zero, while the external magnetic field is expelled and the specific heat jumps up.

The work has inspired many follow-up studies in China and abroad. Researchers are upbeat about the material's prospects in presenting new superconducting pairing symmetry. Also, as chromium is a transition metal element, such materials may serve as a bridge between quasi-one-dimensional and

quasi-two-dimensional unconventional superconductors, according to Hu. "They may help us solve the mystery of high-temperature superconducting mechanisms."

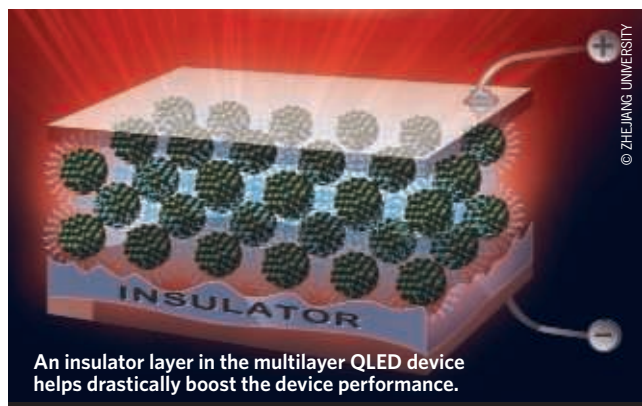
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CHEMISTRY

Joining the dots with exciting consequences

Future looks bright for next-generation display technology with an unprecedented QLED performance.



An insulator layer in the multilayer QLED device helps drastically boost the device performance.

ZJU scientists have shed light on the possibilities of quantum dot light emitting diode (QLED) as the newest generation of display technology.

The recent development of a solution-processed, multilayer LED with high performance levels, by Peng Xiaogang, a professor of chemistry at ZJU, could see the QLED replace LED as the newest generation of display technology.

Organic light emitting diode (OLED), which uses an organic compound as the semiconductor material, has stability issues,

according to Peng and his team. "QLED integrates the advantages of OLED and GaN quantum LED, and presents better performance at lower cost."

Quantum dots are inorganic semiconductor nanocrystals with unique optical and electronic properties. They can emit light with high efficiency, tunable emission wavelength, high colour purity, narrow emission spectrum and low energy consumption, making them ideal candidates of LED emitters. With the capacity for suspension in solution, quantum dots may revolutionize the

fabrication of LEDs. Production of QLEDs could be cheaper and faster compared with traditional LEDs or OLEDs, but challenges in longevity, efficiency and processing techniques must be overcome before commercialization can be a reality.

To this end, Peng was the first to propose and achieve “synthetic control of the excited state of quantum dots”. He synthesized quantum dot emitters with single decay channel, 100% radiative recombination and no fluorescence blinking.

Working with a team led by Jin Yizheng, another professor

of chemistry from ZJU, Peng pioneered a structure for a QLED device and achieved efficient and balanced injection of charge carriers. By inserting an insulating layer between the solution-processed quantum dot layer and the oxide electron-transport layer, they optimized charge balance, while preserving the superior emission properties of quantum dots. This led to a highly efficient red QLED with a lifetime of more than 100,000 hours at an initial brightness of 100 cd m⁻², with low energy consumption. “This is the

best-performing solution-processed red QLED to date,” says Peng. “Its performance is comparable to that of the most cutting-edge OLEDs produced by vacuum deposition.”

Peng’s team’s breakthrough was selected as one of China’s 10 major science and technology achievements of 2014. It attracted strong interest from the industry as well as academia. Samsung announced that it would shift from OLED to QLED technologies for its next generation TV.

Solution-processed quantum dots are also compatible

with low-cost and high-speed inkjet printing, blade-coating and other printing and coating techniques. With government approval for ZJU to lead a research and development plan focusing on the use of quantum dot technology, Peng and his colleagues are looking forward to expanding their research. ■

Reference

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EARTH SCIENCES

Melting away the mysteries of time

ZJU studies of the basalts in China’s enormous Tarim basin reveal its evolution and could unlock vast mineral resources.

A ZJU research team exploring in the Tarim basin.

Climate change, evolution, and the formation of Earth’s oil, gas and mineral resources may all be associated with large igneous provinces (LIPs). The impact of these vital forces was modelled by ZJU scientists whose work highlighted the joint forces of lithospheric and mantle plume melting in LIP evolution.

LIPs are extremely large deposits of igneous rocks, usually arising from large scale volcanic

eruptions within a short geological timeframe, which may cover an area greater than 100,000 square kilometres. “The formation and evolution of LIPs, along with the changes they brought to our natural environment are questions of central concern in earth sciences,” said Chen Hanlin, dean of the School of Earth Sciences at ZJU.

The Tarim basin, in northwest China, is the country’s largest and considered a potential

reservoir of resources, rich in petroleum and natural gas. In collaboration with PetroChina, a research group in the School of Earth Sciences at ZJU, led by Yang Shufeng, CAS academician, has been exploring the Tarim basin since the early 1990s. Through surveys and data collected from seismic exploration and oil drilling, the team identified an LIP covering more than 250,000 km² in the Tarim basin. Dated around 290 million years

ago, this is the second Permian LIP identified in China.

In the past 20 years, Yang’s team has learned much about the genesis and magmatic evolution of the Tarim LIP. Their studies showed that the basalts in this LIP were produced by lithospheric melting in its early stage, while the melting of the mantle plume contributed to the formation of most late-stage intrusive rocks. Their Tarim LIP model also contributed to the

explanation of the formation of the Wajilitag Fe-Ti-V oxide ore deposit in the basin.

Yang's work has received worldwide attention from geologists and was selected by the Large Igneous Provinces Commission as the Large Igneous Province of the Month in

June, 2006, for its contribution to enriching LIP formation theories. "We have also provided an important theoretical basis for the exploration and development of large oil and gas fields, as well as Fe-Ti-V oxide ore in the Tarim basin," added Chen, who also

contributed to the research.

The team's exploration of Tarim basin goes on. They are planning further studies on the various types of igneous rocks for a more thorough understanding of plume-lithosphere interactions. "There are still many unknowns on the

magmatic evolution of Tarim LIP," said Chen.

Reference

Yang, S.F. *et al.* Early permian tarim large igneous province in north-west China. *Science China Earth Sciences* **56**, 2015–2026 (2013).

PSYCHOLOGY

Out of sight, out of mind

Research revealing the dynamic processing of working memory sheds light on the design of intelligent systems.

The importance of visual information in allowing us to get through the day, is the focus of research by ZJU scientists.

Information is stored in the brain as memory, which is categorized by its varying functions. Working memory (WM) is the part that stores information briefly and manipulates it for the purpose of accomplishing complex cognitive tasks.

"If we say the core issue in cognitive psychology is the processing of information, then WM is the key," said Shen Mowei, head of the department of psychology and behavioural sciences at ZJU.

Visual information is the most important source for WM. We rely on visual WM to carry out daily activities, often without realizing it. Current studies mainly focus on the passive storage of information in WM, which does not differ much from the traditional study on short-term memory, said Shen.

Yet, the crux of WM — the dynamic processing of information, is often ignored. Shen



A driving simulator was used to look at the impact of visual working memory on driving ability.

led a team which systematically investigated how information is encoded and stored/processed in visual WM. They established a novel model depicting the interaction between visual perception and WM. The central thrust of their findings is that visual WM not only stores the outcome, but actively helps visual processing by providing temporary storage.

Shen and colleagues also showed that visual WM and visual perception share similar organization principles for visual inputs. For example, Gestalt principles — by which visual elements are grouped together perceptually — describe

information processing in the visual WM as well.

Visual WM also rehearses information in a similar manner as visual perception, demonstrated by the fact that object-based attention plays a key role in feature binding during visual processing. As with visual perception, visual WM requires the engagement of mirror neurons when storing biological motion information.

Better understanding of the mechanism of visual WM instructs the development of self-learning and interface design for intelligent systems. Shen's results also provide clues for the diagnosis and treatment

of illnesses, such as Alzheimer's disease and schizophrenia.

Their work also won the team the 2012 New Investigator Award from the American Psychological Association, the first time the award was given to researchers based in mainland China.

"We are now exploring applying our research to developing cognitive exercises for the elderly to prevent neural diseases," Shen said.

Specialized in industrial psychology, the ZJU psychology department aims to improve work performances by applying psychological principles, and to improve understanding of the underlying mechanisms.

"To achieve this, we need to enhance our exploration of the cognitive processes," said Shen.

Reference

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