RESEARCH
@HKUST

The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong

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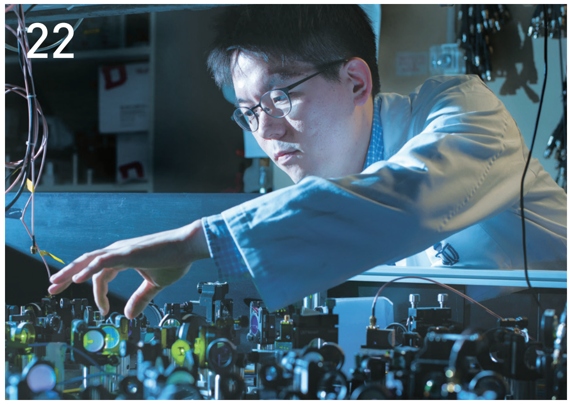

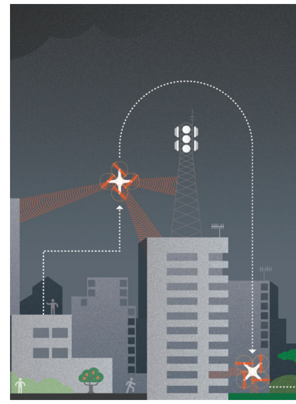

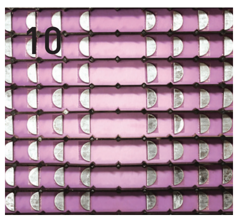

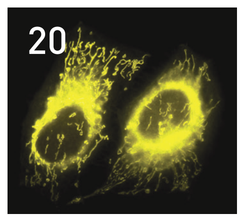

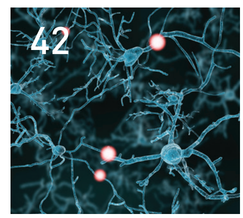

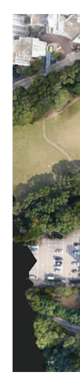

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

RESEARCH @HKUST

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President's Foreword

As we celebrate the 25th Anniversary of the Hong Kong University of Science and Technology, it gives me great pride to introduce the inaugural edition of *Research@HKUST*.

This new publication sets out to shine fresh light on the world of discovery at our University. Since establishment in 1991, HKUST has continuously sought to gather together brilliant minds on our inspiring campus to generate knowledge and significant breakthroughs locally and globally. At HKUST, blue-sky and applied research projects are conducted in a dynamic multidisciplinary environment that embraces science, engineering, business and management, and humanities and social science, based in one of Asia's most energizing cities.

Alongside our role as an innovative educator, our institution, academics and research teams have been globally recognized and awarded many prestigious accolades. We work collaboratively and in strategic partnership with the world's leading universities and on far-reaching projects with local, national and international companies. Stimulating postgraduate education and research opportunities enable graduates and fellows to contribute further creative input to the wider community as academics, hi-tech entrepreneurs, and industry and institutional dynamos. The HKUST Jockey Club Institute for Advanced Study, which draws world-leading thinkers and academic pioneers to our campus and Hong Kong, fosters the University's aspiration to be a knowledge leader and trendsetter in society.

Our research impact and global presence are reinforced through participation in prominent international leadership events, including World Economic Forum (WEF) meetings at Davos and in Mainland China. Invitations to serve as discussion leaders at WEF IdeasLab sessions that propose cutting-edge innovations and explore the challenges and opportunities in implementing these ideas are a great way to extend the footprint of our discoveries. HKUST is also honored to be one of 26 members of the Global University Leaders Forum (GULF) where subjects for discussions range from new paradigms for universities of the future to how collaborations with universities can spur innovation. At home, we frequently host eminent academic gatherings, such as the Gordon Research Conferences. Such engagement alerts more researchers and scholars to our work, encourages diversity of perspectives and future eureka moments, and foster new initiatives with other thought leaders.

Meanwhile, alumni serve as valuable ambassadors of the unique HKUST core values that underpin the University's rapid rise and achievements: leadership through excellence, integrity and academic freedom; global vision and local commitment; can-do spirit; inclusiveness, diversity and respect; and 1-HKUST campus integration. Such values reflect our honor code, character, DNA, and unique East-West outlook, and serve as our guiding aspiration alongside our mission and vision.

The University's 25th Anniversary theme – *Innovating Today, Imagining Tomorrow* – encapsulates our research goal to drive forward understanding and capabilities, and raise greater awareness of academic endeavor in shaping the future. Through *Research@HKUST*, we look forward to showing and sharing the power of innovation and imagination.

Prof Tony F Chan, JP
President

“We continue to build on our existing strengths to generate new knowledge and push forward research frontiers, to deepen our contribution and impact to society”

Top: IdeasLab, World Economic Forum (WEF), Davos, Switzerland, 2015.
Above: Prof Tony F Chan speaking to University leaders.

A Word from the Vice-President for Research and Graduate Studies

Over the past two and a half decades, we have been able to attract and nurture a committed faculty team of top international scholars and young research talents. Their global achievements and recognition, both individually and collectively, have placed HKUST among the leading universities in the world. In a major research quality exercise* carried out recently in Hong Kong and benchmarked globally through international scholar assessment panels, a remarkable 70% of HKUST submissions were ranked either "world leading" or of "international excellence".

Small is Beautiful

One key factor in our research success is the freedom and ability to interact across disciplines and borders. The cozy size of our campus and community has played a major contributing role. Talking to experts in different disciplines is easy at HKUST as they may be located down the corridor or on the next floor, or be working alongside you in the lab.

Our centralized cutting-edge research facilities – HKUST is the first in Hong Kong to embrace such a concept – are today a pillar of our research infrastructure and multidisciplinary approach.

Research institutes, established to generate cross-disciplinary initiatives, are another cornerstone of the University. The Biotechnology Research Institute, William Mong Institute of Nano Science and Technology, Institute for the Environment, Energy Institute, Institute for Emerging Market Studies, as well as the recently established Robotics Institute, Big Data Institute, and Institute for Public Policy play a pivotal role in integrating and moving the University forward in achieving its research directions.

Such carefully planned arrangement of space, facilities and equipment special to the region brings our faculty closer together, helps foster a younger generation of researchers and

** Research Assessment Exercise 2014, conducted by Hong Kong University Grants Committee* nurtures students. Together with various internal research support schemes from the University, this setting promotes and fosters the development of interdisciplinary as well as exploratory curiosity-driven research.

Unique Location

The University's location in the Special Administrative Region of Hong Kong adds another dimension to our research enterprise, with HKUST platforms in Shenzhen and Nansha and a Liaison Office in Beijing driving collaborations in Mainland China. Over the years, HKUST has actively collaborated with Mainland universities, institutions and corporations. Today, we partner two prestigious State Key Laboratories and host two Hong Kong branches of Chinese National Engineering Research Center. Internationally, our research strengths and presence are extended through strategic partnerships, east and west.

In this first issue of *Research@HKUST*, we provide an inside view of the University's research excellence. We begin with an article on our overall research vision. Features follow on sonic material advances, aggregation-induced emission and light-emitting molecules with wide-reaching applications, innovative lighting and display technologies, renewable energy breakthroughs and air quality monitoring, drone technologies, big data initiatives, neurodegeneration discoveries, social science data collection and analysis on China, and fundamental business research insights on purchasing decision-making. Statistical information about HKUST research is also included for reference.

I would like to thank my fellow Editorial Committee members, faculty, staff and Research Office team for their hard work and commitment in bringing this publication to fruition. We hope all readers will be inspired to explore the world of research further through this and future issues.

PROF JOSEPH HW LEE
Vice-President for Research and Graduate Studies

> "Research at HKUST is a thrilling, fascinating, and rewarding undertaking"

THE REACH OF RESEARCH

HKUST has acquired a sterling reputation for research excellence despite only being founded 25 years ago. What are the driving forces behind the University's achievements?

Photo by Prof Wei Shyy

The role of educator is still the one most frequently associated with universities in the eyes of the public and many potential students. Yet in today's hotly contested academic arena and swiftly evolving internationalized society, capabilities as a transmitter of knowledge alone are generally no longer enough to secure a higher education institution's standing or relevance. HKUST, established in 1991, was built with such a development already in mind. Through the foresight of the University's founders, the generation of knowledge has always been a core activity, alongside education, through original research with global impact.

Importance of New Knowledge

"At HKUST, the value of research is viewed as manifold," said Executive Vice-President and Provost, Prof Wei Shyy. "Research impact entails moving the boundary of knowledge forward. It means deepening understanding or creating a new capability in substantial ways. It helps us to fulfil our social responsibility to improve on what we know."

"But we are not solely a basic research hub," he said. "At HKUST, research also involves how to apply that knowledge, how to solve existing problems and drive development. It encompasses how such insight and approaches to enquiry can be integrated with our teaching mission to serve undergraduates and postgraduates in exploring their own potential and capabilities."

From Discovery to Market

While HKUST is relatively small with a focused concentration on certain fields in line with its designation as a science and technology university, careful planning has accommodated a holistic research vision.

The University's broad areas of Science, Engineering, Business and Management and Humanities and Social Science operate as both independent powerhouses of enquiry as well as an interlocking whole in which interdisciplinary insights can enhance questions asked and answered. The quality of research work is set by the recruitment of faculty who are among the most eminent international researchers in their fields, along with the brightest young minds of the future to work alongside them. Adding to such motivation, the launch of the HKUST Jockey Club Institute for Advanced Study in 2006 has helped to draw Nobel laureates and other prominent thinkers from around the world to visit and work with the University community. This allows a wide range of state-of-the-art knowledge and developments to continually percolate throughout the campus, the wider society in Hong Kong, and beyond.

To move research out of the lab or published journal and into use in society, the University has a well-established knowledge transfer infrastructure handling patent applications and its IP portfolio, licensing proof-of-concept support, and contract research and consultancies. Research collaborations with local, national and overseas institutions are encouraged as are strategic industrial partnerships with major companies around the world. The University's own start-up culture among faculty and students is fostered through a dynamic Entrepreneurship Center and incubation support under the HKUST Entrepreneurship Program, among other initiatives.

How Students Benefit

A "research-enriched" environment is seen as a great platform for students to learn in ways that add value to a traditional university experience. The popular Undergraduate Research Opportunities Program is one example, providing "live" experience of research team life ahead of graduation. Research postgraduates benefit not only from the rich academic insights and networks of HKUST's senior faculty, but also from a Professional Development initiative, driven by the Office of the Vice-President for Research and Graduate Studies. Courses encompass a broad range of skills, from writing proposals and ethical behavior to entrepreneurship, to build a strong foundation as well as analytical and practical competencies.

"The aim is to provide a more comprehensive education, equip students with a wider range of professional competencies beyond the usual mentor-student research-focused relationship," said Prof Joseph HW Lee, Vice-President for Research and Graduate Studies. "Such self-development increases their exposure and, from that, confidence and self-respect. This in turn widens the future prospects of our postgraduates."

Ready for the Future

To keep moving at the frontiers of the vastly expanded realm of knowledge created by advancement in science and technology in many fields and explore the fresh possibilities arising, HKUST is currently building on its established strengths to broaden its research across Schools. This is being encouraged through cross-disciplinary faculty cluster hiring in areas identified as highly significant for future social development. The pinpointing of data science, sustainability, autonomous systems and robotics, public policy, and design thinking and entrepreneurship took place through a demanding consultative process involving all 20 of the University's departments and divisions together with senior research management.

"Tackling many of the most challenging research topics of today involves solution-building across different fields, not only one," Prof Shyy noted. "This is not an easy task. But we see it as highly important and timely to foster such an environment. When you put the right capabilities and expertise together, the results can be remarkable. We could be making game-changing contributions, a trendsetter of a domain."

Providing the environment to inspire the younger generation to recognize the significance and thrill of discovery in a research career is also an on-going endeavor. The pure joy that can be generated by research is something both Prof Shyy and Prof Lee, as world-renowned specialists in their respective fields of aerospace engineering and environmental engineering know all about. "You collaborate, yes. You have partners, yes. But, in the end, it is really up to you to unlock whatever mystery you are trying to figure out or the invention you are seeking to develop," Prof Shyy said. "It is you versus the unknown."

WAVES OF THE FUTURE

Futuristic possibilities are being brought forward to today through curiosity-driven research into metamaterials

Profiles of hybrid resonators are shown in color. Incident acoustic energy flux lines are delineated in white. They are completely absorbed by the impedance-matched resonators.

**The important thing is not to stop questioning.
Curiosity has its own reason for existing.**

ALBERT EINSTEIN

Curiosity… without it, the world of today would not exist and the world of tomorrow will not come about. It is the prime force in the very human quest for knowledge.

In the academic arena, it is the driving force for basic research and the foundation for all advances in science and technologies. There would likely be no television, radar, or mobile phones, without the theories and experiments on electromagnetic waves by 19th-century Scottish physicist James Clerk Maxwell, who did not make any actual product himself but simply wanted an explanation as to why certain phenomena occurred.

Such blue-sky research has been a core element of HKUST since its establishment in 1991, enabling exploration into the extraordinary, and helping to bring answers to many previous unknowns.

The fascinating realm of wave functional materials is one such area, where investigation at HKUST is laying the groundwork for exciting realizations that previously might have been categorized as science fiction. In some cases, applications may not be realized in our lifetime. In others, this fresh understanding has already led to commercialized technologies.

Wave functional materials offer revolutionary possibilities in the control and manipulation of light (electromagnetic) and acoustic waves. World-leading research has been on-going in this area at the University since global advances in theory and fabrication technology pointed the way to such smart man-made materials in the 1990s.

These materials possess properties that "go beyond" ("meta" in Greek) those found in Nature, opening up fresh areas of scientific investigation. Invisibility, the "perfect lens", and the silencing of low-frequency noise have now been brought from the far reaches of the imagination into the realms of reality. HKUST has pioneered the development of fundamental concepts in photonic quasi-crystals, negative dynamic mass, acoustic metamaterials, remote cloaking, illusion optics, optical pulling, zero-index materials and topological acoustics. Prof Che Ting Chan and Prof Ping Sheng of HKUST's Physics Department are founders and leaders of wave functional materials research in Hong Kong.

The research groups they head have nurtured many top researchers in Hong Kong and Mainland China. Globally, in 2013, Prof Chan, Prof Sheng and Physics colleague Prof Jason Yang received the inaugural Brillouin Medal from the International Phononics Society for their discovery of locally resonant acoustic/elastic metamaterials.

"When something is said to be impossible, there are two points for researchers to initially clarify: whether it really is forbidden by the laws of Nature; or whether it is simply that no material that currently exists in Nature can do that"

PROF CHE TING CHAN
Daniel CK Yu Professor of Science, Executive Director, HKUST Jockey Club Institute for Advanced Study

LIGHT **FANTASTIC**

Originally an electronic physicist working at Ames Laboratory in the US, Prof Che Ting Chan moved into exploration of materials with unusual light and sound functionalities when he joined HKUST in the mid-1990s. It was the perfect area for a scientist who had spent his childhood pondering such questions as why the sun appeared white at noon yet red in the evening and how the ocean can be green or grey while water itself is colorless.

The Quest to Know

Starting from functionality, for example, a material that can absorb light more efficiently, Prof Chan and his team first explore the theory behind what they seek to achieve. At the material design stage, the team uses mainly numerical computation to design samples. Then comes fabrication. Prof Chan's experimental physics colleagues, including Prof WY Tam, Prof KS Wong and Prof HB Chan, make actual samples of the new materials, utilizing the advanced equipment in the University's central Materials Characterization & Preparation Facility and Nanosystem Fabrication Facility, including electron-beam lithography and focused ion-beam lithography. Characterization, which can probe, measure, and analyze a material's structure and properties, may involve use of electron microscopes as well as the construction of innovative in-house equipment, not commercially available. An integrated Metamaterials Lab opened in 2016.

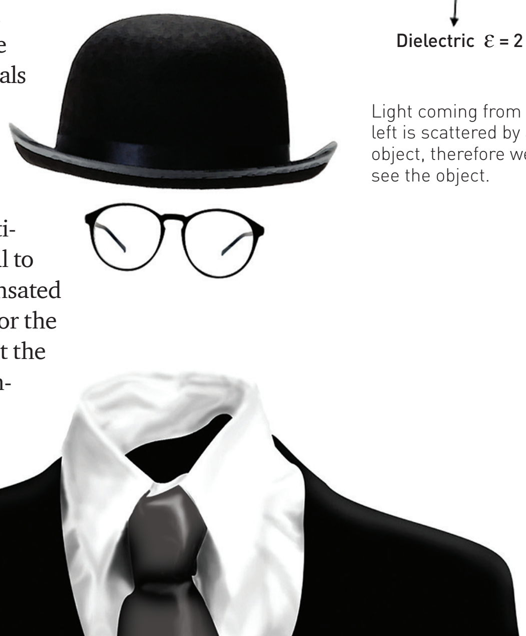
Setting the Pace

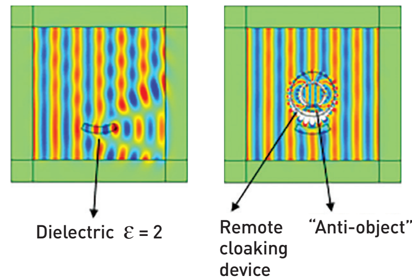
The groundbreaking research in new materials has been supported by a large-scale Collaborative Research Fund grant from Hong Kong Research Grants Council (RGC) since early 2000. Such exciting, cutting-edge discovery has encouraged a stream of outstanding research students and post-doctoral researchers from Mainland China to take the plunge and move into the new research area. In 2013, Prof Chan received an Area of Excellence grant of HK$46.5 million from the RGC to lead exploration into novel wave functional materials for manipulating light and sound in collaboration with several other universities in Hong Kong.

Some of the key discoveries that HKUST research has produced are featured in the following pages.

Cloaking Device

In science fiction, such as HG Wells' *The Invisible Man*, a person could become invisible by drinking a chemical. In reality, no such substance has been made. How about wrapping a material around an object to make it invisible to the human eye? Yes, theoretically, now it could be done, thanks to advanced physics techniques that change the path of light, not the object. In 2006, UK scientists designed man-made materials ("metamaterials") that could provide invisibility by guiding light around an object, and the concept was soon proved experimentally in the US. Instead of creating a cloak to hide an object embedded inside, Prof Chan's group has designed metamaterials with optical properties that are the exact opposite of the material to be cloaked so that light scattered by an object is compensated by the cloak. An observer thus sees neither the object nor the cloak. This method of invisibility has the advantage that the hidden objects can still see the outside world. In conventional cloaks, the objects are blinded because no light enters the cloaked region. Such "remote cloaking" currently works for a narrow band of frequencies. Whether such cloaking strategies can work for a broad range of frequencies remains an open question.





Light coming from the left is scattered by an object, therefore we see the object.

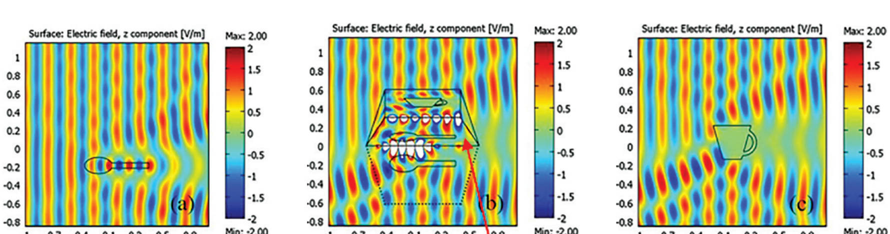
A "remote cloaking" device (the circle) is put next to the object. The device is designed to cancel the light scattering by the object so that the light wave passes through as if nothing is there.

Both the cloaking device and the object become invisible to outside observers. The principle behind is to use a metamaterial "anti-object" to cancel the light scattering by the object you want to hide.

Physical Review Letters, 093901 (2009)

Illusion Optics

Platform 9¾ at King's Cross Station where students travel to Hogwarts in the world of Harry Potter appears to the eye to be a wall. In the fictional story, it is actually an open channel that the body can pass through. Using the novel notion of "illusion optics", HKUST researchers have demonstrated for the first time that such a phenomenon is possible and, in principle, an apple can be made to look like an orange, or a spoon like a cup. This is achieved by changing the light-scattering pattern of an object to that of another object, making it appear like the second object, with the assistance of "negative index" metamaterials specially designed at HKUST. The illusion device requires very complex man-made materials. Prof Chan's team is now working to realize such novel effects with less complex materials.



A dielectric spoon

Illusion device

A metallic cup

Left and far left: Light-scattering patterns of a cup and a spoon. The scattering patterns are different, and the different patterns allow our eyes to detect different objects.

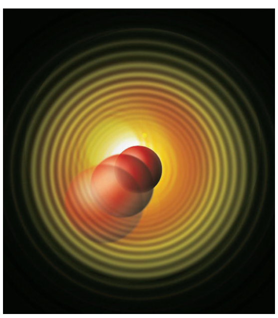
Center: By using a negative index metamaterial, the scattering pattern of a spoon can be changed to that of the cup. An observer in the far field will see a cup, although the object is actually a spoon.

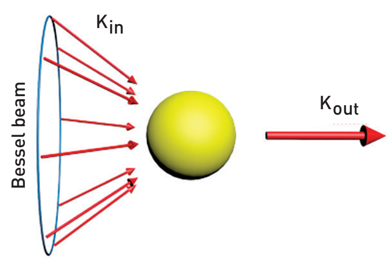
Physical Review Letters, 102, 253902 (2009)

Tractor Beam

It is commonly believed that light carries momentum and as such, light always pushes objects away. "Tractor beams" of light that pull objects toward them only exist in movies and science fiction. However, in 2011, Prof Chan and his collaborators solved the problem of making light attract an object, finally bringing the futuristic possibilities envisioned in the popular 1960s television series *Star Trek* closer to reality. The "tractor beam" breakthrough was published as a cover story in *Nature Photonics* journal and drew substantial media interest. Prof Chan and his student showed subsequently in an article in *Nature Communications* how light could push an object sideways. The tractor beam concept is different from the so-called "optical tweezers" commonly used to manipulate small particles. Optical tweezers, relatively easy to realize with today's technology, act to grab a particle while the tractor beam pulls a particle, offering the possibility of manipulation with zero contamination. The tractor beam is very selective in the properties of the particles it pulls, so it can be useful for the optical sorting of micro-particles in an inexpensive device.

The Starship Enterprise using its tractor beam to pull an object without touching it in an episode of *Star Trek: The Next Generation.*





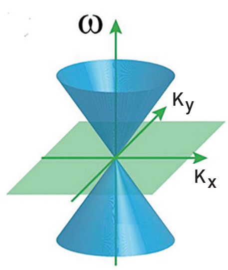
Left: In some special optical beams, the projection of the photon momentum on the beam axis is less than the total momentum. Some particles can have multiple excitations that can interfere to form a forward directed beam. Under such circumstances, the scattered light can have more momentum on the beam axis than the incoming light, allowing for light to "pull" without violating the conservation of momentum.

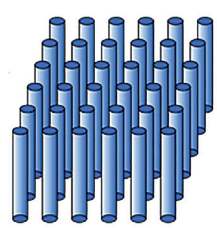
Far left: A schematic picture showing a beam of light pulling a spherical particle toward the light source.

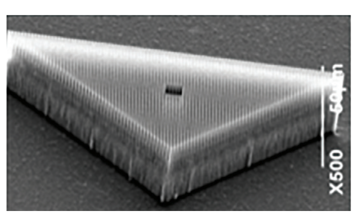
Nature Photonics 5, 531 (2011)

Zero Refractive Index

Physics textbooks teach that a vacuum has a refractive index of one. Since a vacuum is already "empty space", does it mean its refractive index cannot be less than one? The amazing versatility of man-made materials means that some artificial materials can, in principle, have refractive indices of less than one. Prof Chan's team recently designed and made photonic crystals with a refractive index approaching zero, which is optically emptier than a vacuum. Such zero index materials have unusual and interesting properties, including an infinite phase velocity. In addition, light travels inside such materials without any phase change, as if space does not exist. Interestingly, Prof Chan discovered a hidden mathematical relationship between the "Dirac cone physics" in graphene (a new electronic material) and a metamaterial with a zero refractive index.







Top left: Some photonic crystals can be specifically designed so that they have a conical frequency-momentum relationship called a "Dirac cone". Theory shows that these photonic crystals behave as if the effective refractive index is zero at some specific frequency.

Top right: A "photonic crystal" composed of an ordered array of dielectric (e.g. Si) cylinders.

Bottom: A prism of "zero index" photonic crystals, made experimentally in Prof WY Tam's laboratory as a realization of the blueprint shown in the top right diagram.

Nature Materials, 10, 582 (2011)

> If something is truly new, it may not be easy to gain acceptance for it

PROF PING SHENG
Dr William MW Mong
Professor of Nanoscience

NOW YOU HEAR IT, **NOW YOU DON'T**

Envision a quiet construction site. An air-conditioner without any hum. The elimination of the roar of traffic in an apartment building located near a highway. It is no longer so fantastical. Such everyday noise pollution could now be consigned to history, given pace-setting research carried out at HKUST into acoustic metamaterials.

From Curiosity to Commercialization

It has been a long road of more than 15 years' continuous enquiry and experimentation, challenges and rejection in the world beyond for HKUST researchers. However, the promise and premise of acoustic metamaterials, artificial materials designed to control or manipulate sound waves, are now being widely acknowledged in both academia and industry. A whole new field has emerged. In addition, far-reaching applications and practical sound absorbency products that could "silence" pernicious low-frequency noise, such as fans, turbines, and cabin noise, now appear set to move on to the "can-do" list.

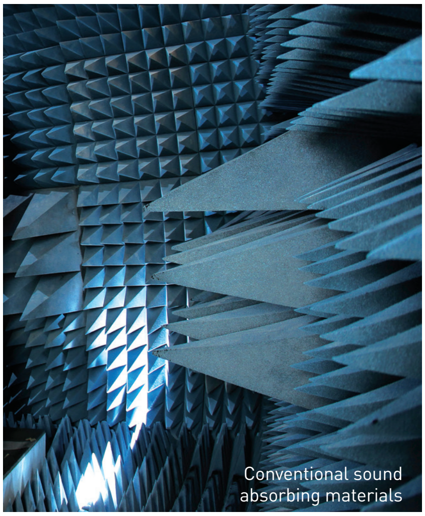
Prof Ping Sheng, Chair Professor of Physics, together with Prof Che Ting Chan and Prof Jason Yang, are among HKUST's key inventors of locally sonic resonant materials, which can break the mass density law in providing protection from such noise. "We started out knowing nothing about acoustics and noise. It was purely curiosity-driven," Prof Sheng said. "Initially a lot of people thought we were crazy. Anything with acoustics and sound had already been done 50 years ago and it was deemed that nothing new could occur. Everything that can be known was already known."

Blocking Low Frequency Sound

The question that set the HKUST team on its way was: is it possible to find an acoustic material with properties that enabled it to shield any kind of sound wave, including the difficult low frequency ranges of 400Hz and below? Metal was known to play a special role in manipulating low frequency electromagnetic waves. But no such class of materials existed for acoustics.

Low frequency noise is stubbornly hard to shield from due to its long wavelength, which gives it greater penetration than high frequency noise. Using conventional mass density laws, this means that it takes four times the mass to screen out a low frequency sound of 200Hz than to attenuate an 800Hz noise to the same degree.

Now think of trying to block a noise. To stop noise going from one area to another, several materials would usually be combined to reflect or absorb different frequencies. However, using conventional methods (reflection-based solid materials), it would take five centimeters of materials (aluminum, mass density 2,700kg/m) to attenuate 100Hz by 40dB. Such methods would thus require materials too thick to be practical for low-frequency applications. To absorb low frequency sound would require structure as shown to the right. They are bulky and not practical for everyday applications.



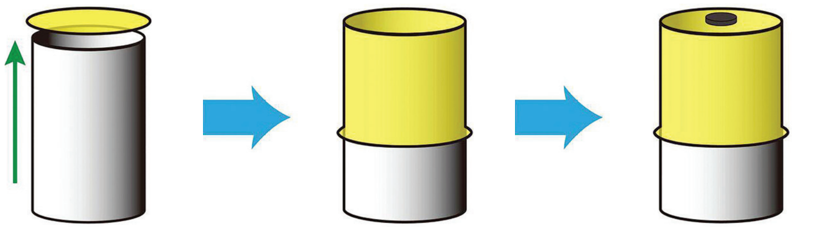
Conventional sound absorbing materials

Stage One: Wave Reflection

The HKUST team came at these problems by employing the physics law of local resonance and trialing rudimentary novel materials that might have the same impact on sound waves. Eventually, they created an exciting new composite that did just that.

The first HKUST publication on the findings appeared in *Science* in 2000. It was met with acclaim by the media. But not so readily accepted by those in the acoustics field. “Many people thought we were wrong: ‘How can someone come from nowhere and think of something new’,” Prof Sheng said. Despite the skepticism of some in the acoustics world, the HKUST team continued their studies and experimentation. Gradually, through continuous research, major strides were achieved.

In place of a wall of extremely heavy material to bounce back sound, the researchers created a thin, lightweight membrane-type acoustic metamaterial, capable of breaking the mass density law for frequencies of 150Hz to 1,000Hz by around 200 times. While it seemed counterintuitive to think of stopping low frequency sound with a thin membrane, it was in fact due to the membrane’s “flimsiness” that this could be achieved at low frequencies. Even in a small finite sample with boundaries defined by a rigid grid, there could be low-frequency oscillation patterns. With the addition of a small mass, or “button”, at the center of the membrane sample, the vibrational eigenfrequencies could be tuned, and at the frequency between two eigenmodes where the vibration amplitude was zero, the result was almost complete reflection.



Push the tube against the membrane

Membrane tightened

Circular mass is attached to center of membrane

Locally resonant sonic materials, designed to reflect sound waves at pre-specified frequencies by local resonance.

Each resonant unit has a low frequency resonance of 400Hz and some higher resonance frequencies.

Resonant units assembled as a sonic crystal – for example, a cubic structure, as shown. Sonic transmission exhibits a sonic gap at 400Hz.

These sonic materials demonstrated they were tunable when different materials, sizes and geometry of the basic unit were used. They could screen out specific frequencies over a range of 150Hz to 1,000Hz.

The thickness of materials could also be reduced. Acoustic metamaterial units are a factor of 10 to 100+ smaller than the relevant wavelengths. Thus, the metamaterial could be thin and small, and still manipulate and attenuate low frequency sound.

Stage Two: Wave Absorption

Gradually, many academics and practitioners in the field started to take notice of these groundbreaking results. More people began to repeat the HKUST findings and consider the possibilities that such outcomes could open up. Some enthusiasts even built mechanical devices and demonstrated them on YouTube. Tellingly, the number of citations for the research team's original *Science* article began to rise, indicating that more researchers were exploring the area.

But Prof Sheng was still not satisfied. He wanted to determine a way to not only reflect sound but also to totally dissipate the energy. With sound absorption and mitigation already a huge market, it would require a material with near total-absorption capabilities to take the findings downstream to commercialization and into general use, a key aim for Prof Sheng.

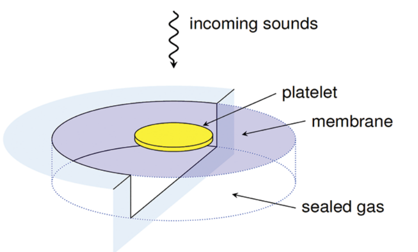
Then in 2013 came a decisive realization: latex membrane + button + sealed chamber with air. In hindsight, this invention was stunningly simple. Yet it was to prove the missing link in the quest for perfect absorption. Significant papers followed in *Nature Materials* (2014) and *Applied Physics Letters* (2015). The first explained how this concept could be utilized to enable complete absorption of acoustic waves, or conversion into other forms of energy, such as an electrical current. The second provided the experimental findings of two sample products, detailing observations of sound absorption up to 99.7% through destructive interference to stop backscattering, using decorated membrane resonators.

HKUST developed a thin, lightweight membrane-type acoustic metamaterial. The flimsy membrane, decorated by a button and backed by a shallow cell, could absorb more than 99% of low frequency sound.

Industrial Application

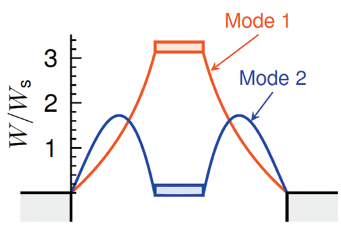
Approaches by industry as to potential applications have also taken off. One major company, for example, is interested in investigating whether the efficiency of turbines, currently limited by noise emission, could be boosted through using the acoustic metamaterial discovery to reduce such noise. Even a 1% increase in efficiency of turbines could translate into billions of dollars in fuel savings over the years. Meanwhile, a start-up company in Hong Kong Science Park, is seeking to mass produce sound absorbing panels based on the patented technology.

As we now herald the prospect of a much more peaceful existence in the future, Prof Sheng and his researchers are heading back to those original acoustic metamaterial models to see if they can be applied in a totally different context. Their next goal is nothing short of earth shattering: to explore the possibility of whether acoustic metamaterials can be used to attenuate seismic waves.



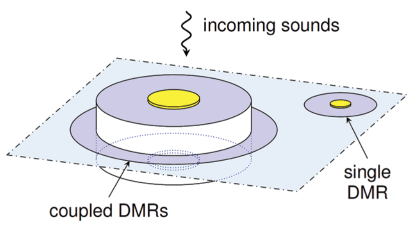
Schematic illustration for a unit of the metasurface. By sealing a layer of gas in a shallow cell with a decorated membrane resonator, this composite structure converts the originally reflective solid surface to be totally absorbing at designed frequencies.

Nature Materials 13, 873–878 (2014)



Cross-sectional illustration of the two lowest frequency resonance modes excited by the incident wave. Here W is the normal displacement of the membrane, normalized to the incident sound wave amplitude W_S. The flat rectangle at the center indicates the platelet that decorates the membrane.

Nature Materials 13, 873–878 (2014)



A flat-panel composite absorber with two decorated membrane resonators (DMRs). By combining a coupled DMRs placed in close vicinity to a single DMR, a panel can totally absorb sound, independent of the incident direction.

Applied Physics Letters 107, 104104 (2015)

Boundless Vision

The HKUST Jockey Club Institute for Advanced Study (IAS) gathers great global minds to wrestle with frontier research challenges in a range of fields, serving as an international knowledge hub for Asia and drawing top researchers to HKUST.

IAS was established in 2006 in a pioneering move for Hong Kong and the region. Prof Stephen Hawking gave the inaugural lecture. The Institute, now housed in a dedicated building in an appropriately lofty spot on the HKUST campus, has gone on to become an active and productive center for intellectual problem solving and interaction between brilliant minds from around the world. It has championed collaborative research and advanced fundamental and applied knowledge, especially in areas of relevance to regional development.

Leading academics have been appointed to the Institute: economist and Nobel Laureate Prof Sir Christopher Pissarides and astrophysicist and Nobel Laureate Prof George Smoot are both IAS Helmut & Anna Pao Sohmen Professor-at Large; chemistry, physics and organic electronics pioneer Prof Ching W Tang, the first Chinese Wolf Prize Laureate in Chemistry, is IAS Bank of East Asia Professor; and eminent mathematician Prof Gunther Uhlmann is IAS Si Yuan Professor. Prof Tang and Prof Uhlmann also serve as Chair Professors in their respective fields at HKUST.

Each year, IAS Visiting Professors and Visiting Fellows – most are members of national academies or of equivalent stature – are invited to HKUST. Prominent scholars from leading universities are engaged as IAS Senior Fellows and IAS Fellows to foster research synergy with such visitors and IAS professors. Rising stars from various disciplines also work closely with IAS as Junior Fellows and Postdoctoral Fellows.

As one of IAS's long-term partners, Gordon Research Conference meetings in different subject areas are regularly hosted, often with HKUST faculty acting as chair.

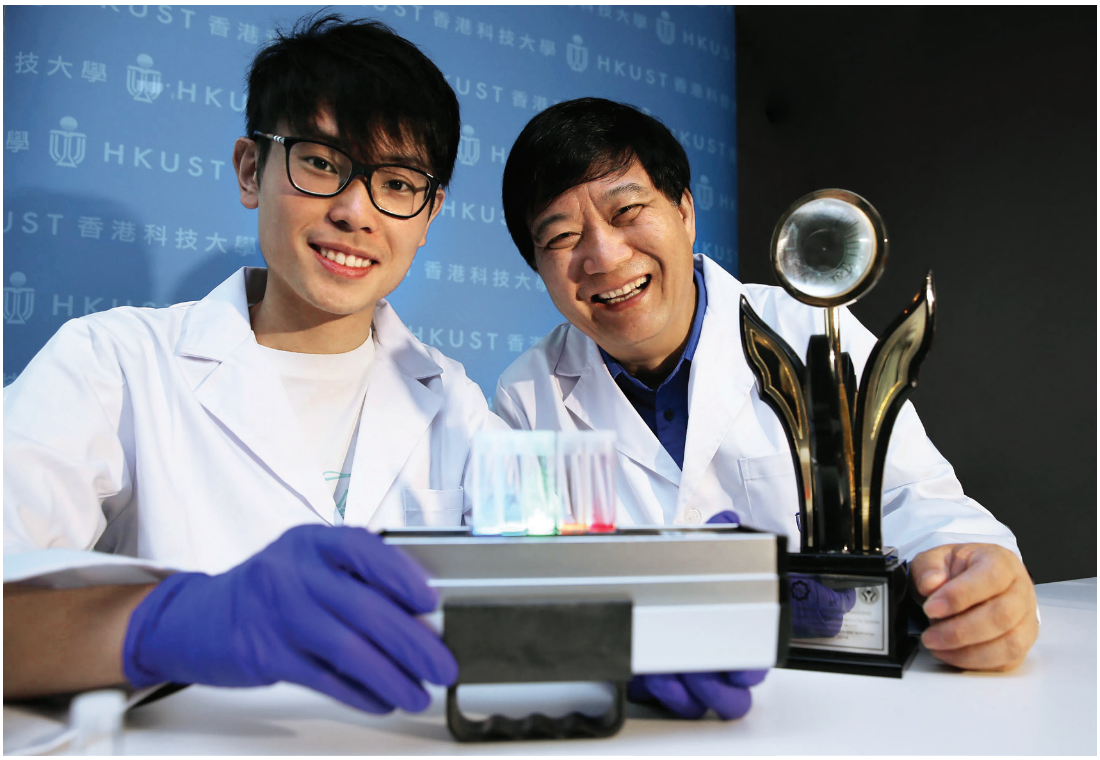
Topical research programs range from neural engineering and materials science to creative Chinese writing, assisting in the formation of research clusters and spurring fresh directions. Distinguished lectures and joint school lectures widen the Institute's reach. In addition, public programs and lectures by IAS professors draw the community's attention to the latest academic perspectives and developments.

The success of IAS has helped raise Hong Kong's overall profile as a meeting point for intellectual discussion and as a vibrant location to incubate global breakthroughs and thought leaders. "At IAS, we seek to ignite local, regional and global brain power to traverse the challenges of today," said cosmologist Prof Henry Tye, IAS Director. "In doing so, we have created a highly significant collective resource to help transform the future."

HKUST Jockey Club Institute for Adavnced Study

GLOWING SUCCESS

Chemists at HKUST are leading a revolution in luminescence



Prof Ben Zhong Tang (right) received the Khwarizmi International Award (Second Class) from the Iranian Organization for Science and Technology in 2014 for his research into AIE-gens.

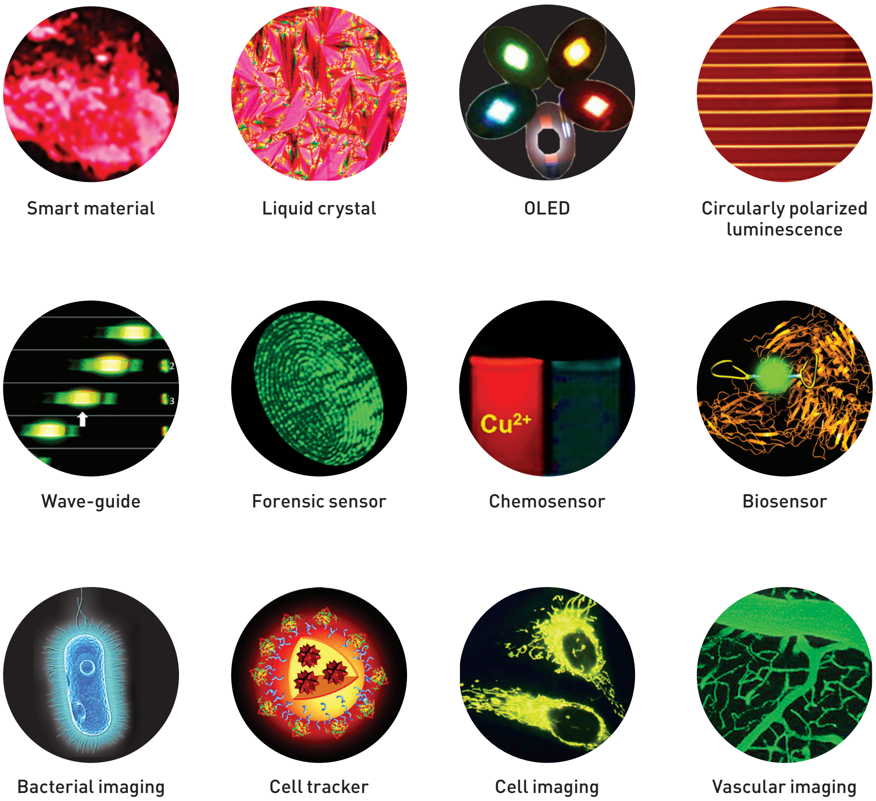
Novel light-emitting molecules created through the curiosity-inspired research of Prof Ben Zhong Tang could bring quantum improvements in key technologies we rely on today, ranging from biomedicine and healthcare to opto-electronics. Prof Tang, Chair Professor of Chemistry and Biomedical Engineering, is the father of "aggregation-induced emission" (AIE). Prof Tang and his team have already discovered hundreds of AIE materials, including one used for tracking cancer cells inside the human body, another for more effective visualization of fingerprints, yet another for assaying bacterial activities.

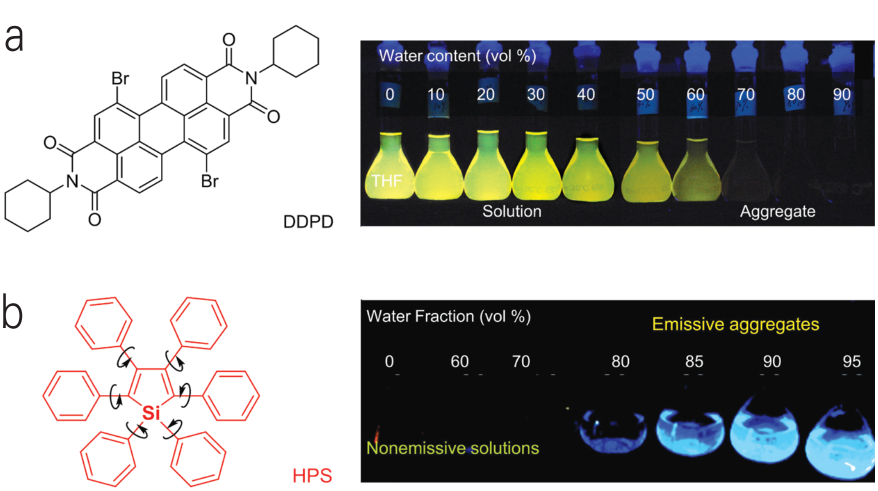
Prof Tang's endeavors, spurred by an experimental anomaly observed in 2001, led to the identification of molecules that emit light when crowded together, a concept Prof Tang named AIE. Driven by the spirit of enquiry to explore further, Prof Tang went on to research AIE phenomena, processes, theories and applications. He has gained national and international recognition for his discoveries.

In December 2015, HKUST gained approval from the Ministry of Science and Technology to establish the Hong Kong Branch of Chinese National Engineering Research Center (CNERC) for Tissue Restoration and Reconstruction. The Center

> "We have been working on AIE-gens for a decade and a half but there is much more still to uncover. Seeing research that started with the simple question 'why?' develop into a global field of discovery is tremendously exciting. A whole new world is opening up"
>
> **PROF BEN ZHONG TANG**
> Stephen K.C. Cheong Professor of Science, Academician, Chinese Academy of Sciences

Potential Applications of AIE Materials





Traditional light-emitting materials often emit weak or no light in concentrated solutions or in a solid state. This is known as "aggregation-caused quenching" (ACQ) (Figure a).

In 2001, Prof Tang and his team discovered abnormal emission behavior in some molecules, where aggregation played a constructive instead of a destructive role. A series of silole derivatives while non-emissive in dilute solutions were found to be highly luminescent when aggregated or cast into solid films (Figure b).

Since light emission is induced by aggregate formation, the process was named "aggregation-induced emission" (AIE), which is the exact opposite of ACQ.

in Hong Kong will be headed by Prof Tang and will concentrate on new luminescent materials and their hi-tech applications in biomedical sensors and chemical probes. Such work could benefit numerous fields, including detection, imaging, quarantine, inspection, diagnosis, environmental protection and homeland security. The Center will also encourage academic, research and development, and industry collaboration.

Earlier, in 2012, the Ministry of Science and Technology of China incorporated AIE into its National Basic Research Program – also known as the 973 Program – and awarded Prof Tang a RMB30 million (US$4.6 million) grant for further development of AIE. In addition, Prof Tang and his AIE research have been the subject of high-profile overseas media reports, including a recent feature in *The New York Times*, an interview by CNBC and a news feature article in *Nature*.

Previously, aggregation was seen as detrimental to light emission because most light-emitting molecules dimmed in their solid form/condensed state, a phenomenon known as "aggregation-caused quenching" (ACQ).

Through experiments, Prof Tang's team discovered that the intriguing mechanism behind the AIE phenomenon lies in the shape of the molecule. Most light-emitting molecules are flat and stack together when crowded, which extinguishes their luminescence. In contrast, AIE-gens are often propeller shaped, so they lock together when crowded and are forced to release their energy as photons.

"This was conceptually new," Prof Tang explained. "Once you have a new concept, you can build a platform for future development." Scientists across the world responded. Numerous papers have been published independently or in partnership with the HKUST chemists and, in 2013, AIE was among the top 100 research topics, according to Thomson Reuters.

"The promise of AIE materials is extensive. They can help improve our practical capabilities in many different fields. These benefits for society are what make such research so worthwhile to pursue," Prof Tang said.

NEXT-GENERATION

TRAILBLAZERS

The leading-edge studies of a trio of young HKUST scientists have been recognized with highly competitive Croucher Innovation Awards from Hong Kong's prestigious independent private funding body

Quantum Stars

The significance of research into quantum materials and information science by two early career HKUST physicists has been moved ahead by funding awards from the Croucher Foundation, a long time champion of research excellence in natural sciences, technology and medicine in Hong Kong.

Prof Gyu Boong Jo, Department of Physics, received a HK$5 million Croucher Innovation Award 2016 for use over five years for his outstanding achievements in the quest to realize synthetic quantum systems using ultracold atoms. Physics colleague Prof Kam Tuen Law received the same award in 2015 for his studies on exotic states of condensed matter, which could have important applications for the quantum computers of the future, among other uses.

The Croucher Foundation, set up in 1979, established the Innovation Awards in 2012 to identify and support a small number of exceptionally talented "rising stars" in science, working at an internationally competitive level.

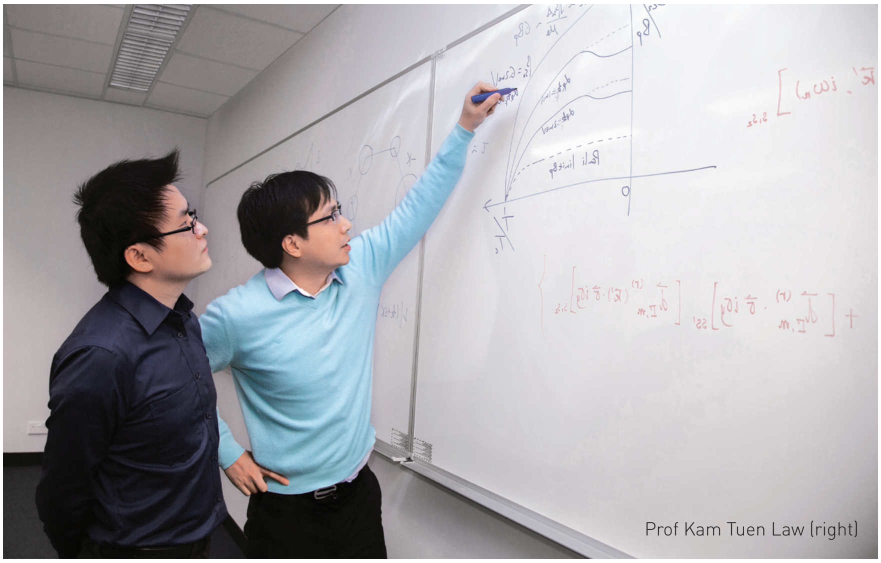
Prof Jo and his team have been focusing on using a dilute gas of ultracold atoms, managing to control atoms at around 100 billionth of 1 Kelvin above absolute zero through techniques adopted from atomic molecular optical (AMO) physics.

He has discovered an unconventional quantum state with minimal loss of coherence within ultracold atoms. In addition, he has created an artificial Kagome crystalline structure – a traditional Japanese woven bamboo pattern – for ultracold atoms with the hope of realizing a new phase of matter.

Prof Jo joined HKUST in 2013, following a postdoctoral fellowship at the University of California, Berkeley, after obtaining his PhD degree at the Massachusetts Institute of Technology (MIT). His findings have already inspired researchers around the world to focus on this quantum effect, which may be applied to create better inertial sensors, gyroscopes, and gravimeters, as well as applications in next-generation information storage and processing systems using ultracold atoms.

Prof Law is a condensed matter theorist, studying the electronic properties of solid-state materials. His research focuses

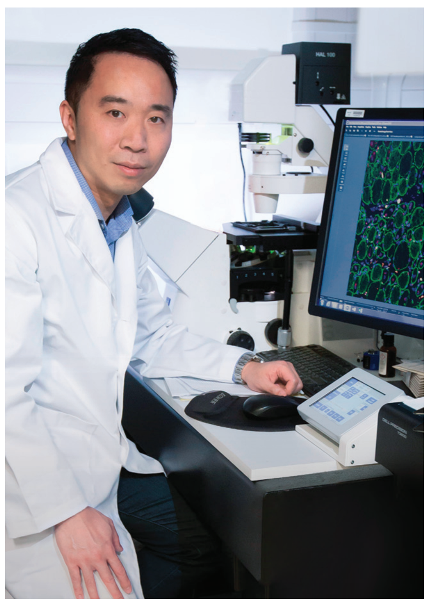
> "We seek to understand better the many-body system in condensed matter to help discover new materials or systems"
>
> **PROF GYU BOONG JO**
> Assistant Professor of Physics



Prof Kam Tuen Law (right)

> The award provides funding to form an internationally competitive research group in Hong Kong. Top researchers can also be brought in to share their insights and new discoveries

PROF KAM TUEN LAW
Assistant Professor of Physics



> We try to understand how stem cells are poised for action during tissue regeneration, and why this is impaired during aging

PROF TOM CHEUNG
Assistant Professor of Life Science

on topological phases, such as fractional quantum Hall states and topological superconductors that host an exotic type of particle called non-Abelian anyons. Such non-Abelian particles can form quantum bits in which quantum information can be encoded and manipulated. The understanding of topological phases could be important for building quantum computers.

He is also interested in novel superconductors. Recently, Prof Law and his experimental collaborators in the Netherlands and the US discovered a new type of superconductor called "Ising superconductor". These superconductors are extremely robust against the detrimental effects of magnetic fields and also have potential applications for realizing topological superconductors and spintronics.

Prof Law obtained his BSc degree at HKUST in 2003. After obtaining his PhD degree at Brown University, he became the first joint postdoctoral fellow of the HKUST Jockey Club Institute for Advanced Study and MIT in 2008. He was a Croucher Postdoctoral Fellow at MIT from 2009-11.

Muscling in on Aging

Prof Tom Cheung is among the leading young scientists contributing to global efforts to reduce the challenges of aging for the individual and society, as acknowledged by his Croucher Innovation Award in 2015. The HK$5 million funding is being used to support his team's research into muscle stem cells and how functional decline could be ameliorated as people grow older.

Stem cells have a unique ability to repair tissues. Thorough understanding of how stem cells work could open new ways to future medical intervention, particularly in the area of regenerative medicine.

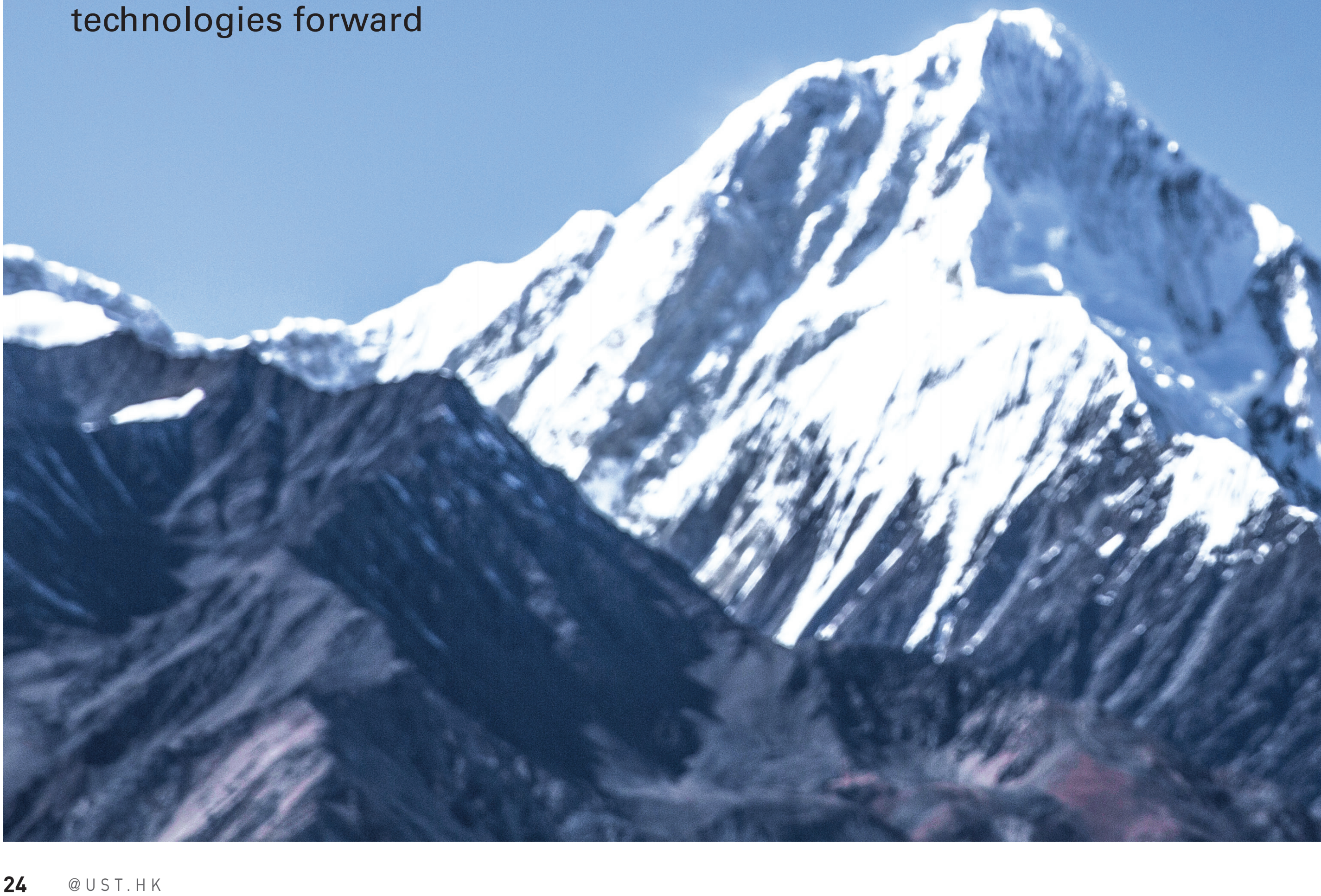
Prof Cheung's lab is seeking to gain a better understanding of why tissue regeneration is impaired during aging. Surprisingly, stem cell number remains relatively constant during aging. However, its potency gradually declines, resulting in an impairment of tissue regeneration. Recently, the researchers' results suggest that genes are silenced epigenetically during the aging process. Prof Cheung's team is trying to devise an approach for the rejuvenation of stem cells in old tissues.

The results could lead to new regenerative medicine approaches for age-related diseases such as sarcopenia, an age-related muscle disease that is involved in the degenerative loss of skeletal muscle mass and strength.

"Increased lifespan in developed countries creates a number of issues with regard to healthcare and social assistance provided to elderly people," said Prof Cheung, who joined HKUST in 2013 from Stanford University School of Medicine. "We need to better understand the process of biological aging to improve health and longevity. This would then help to reduce social and economic needs as the population ages."

FLYING HIGH

The consumer drone market has taken off, with HKUST researchers helping to lift it skyward and now propelling fresh technologies forward



When the early prototypes of a flying robot were built at HKUST just 10 years ago by then Electronic and Computer Engineering MPhil student Frank Wang, with the help of his supervisor Prof Zexiang Li, peers and colleagues described the creations as "toys".

Yet in 2009, their unmanned miniature helicopter successfully made the world's first autonomous flights to survey Mount Everest, helping to contribute to the commercialization of a disruptive technology that has since opened the way for an amazing range of innovative civilian applications in fields as diverse as aerial photography, search and rescue, and even, potentially, book deliveries. Uses should continue to expand with the latest advances in such technology, led by researchers at HKUST.

Key Breakthrough

The quadrotor drones that Frank, Prof Li, and their team built – less than one meter in diameter, sophisticated and easy to operate – brought together important progress in motion control, communication and navigation technologies. In doing so, they fast-forwarded a global consumer and business sector expected to grow to US$4-5.6 billion by 2020, according to market estimates.* The drone industry is now dominated by DJI, the company that Frank launched in 2006, with the help of Prof Li.

The key technological breakthrough was achieved when Frank's research at HKUST employed control technologies for low-altitude flying. This built on the motion control applications that HKUST faculty members had been developing for machine tools in the manufacturing industry. However, the motion control requirements of an unmanned aerial vehicle (UAV) – as drones or flying robots are also called – are much more challenging because of unpredictable conditions in the three-dimensional environment of the air. This is where Frank, and the faculty members who supported him, exerted their expertise.

The flight controller they developed provided stability for the flying robot, operating in real time and fast enough to handle the dynamics of the platform. Hover accuracy, and agility to rapidly change orientation or altitude without becoming unstable, and robustness in strong wind conditions allowed the UAV to support further applications beyond Frank's original joy of flying model

** PR Newswire, MarketsandMarkets*

"The drones that we usually speak about these days are essentially a flying platform that can fly at low altitude and low speed, with very sophisticated functions. With that platform you can do a lot of things, seen by the many uses that are rapidly emerging"

PROF MICHAEL WANG

Professor of Mechanical and Aerospace Engineering, Electronic and Computer Engineering, Director, HKUST Robotics Institute

Leading the Way

HKUST researchers are making landmark advances in unmanned aerial vehicle technology

2006

MPhil student Frank Wang and the team developed HKUST's first autonomous flying robot.

2009

Prof Zexiang Li and his research team's unmanned drone made the world's first high-altitude autonomous flight at Mount Everest.

2010

Postgraduate students, Frank Wang and Jianyu Song, flew their unmanned autonomous helicopter across the Yarlung Zangbo Grand Canyon, Tibet, the world's deepest canyon.

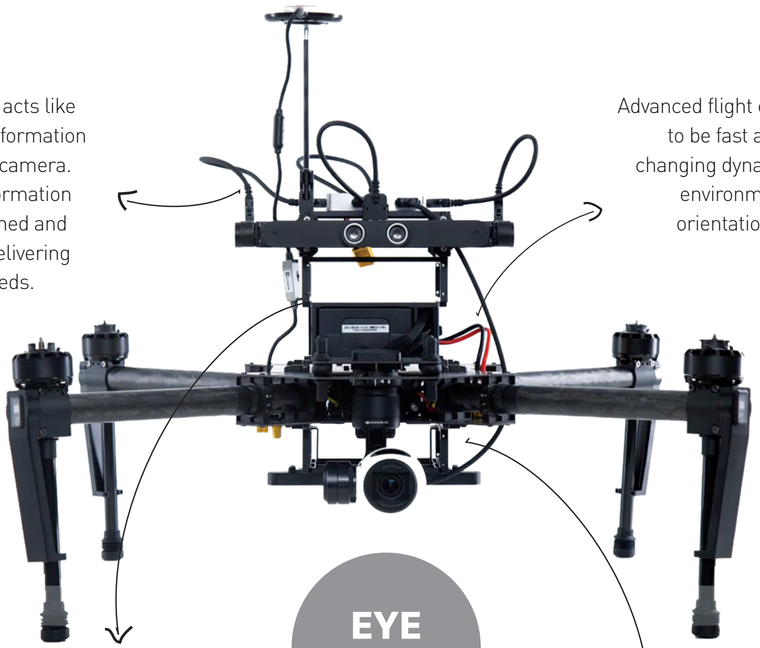
Going **Solo**

Eye

On-board computer vision system acts like the eye of the drone, processing information at 50Hz – faster than a cell phone camera. Through visual-inertial fusion, information from the drone's camera is combined and processed by an inertial sensor, delivering increased accuracy at greater speeds.

Flight controller

Advanced flight control enables the flying robot to be fast and agile, and to respond to the changing dynamics of the three-dimensional environment of the air, rapidly changing orientation or altitude without becoming unstable.



Brain

Advanced HKUST motion planning algorithms, including autonomous navigation, state estimation and perception technologies, increase the sensitivity of the flying robot and its ability to respond to its environment within 20 milliseconds of real time. This means the flying robot can independently plan its flight path.

EYE IN THE SKY

Gimbal camera stabilizing device

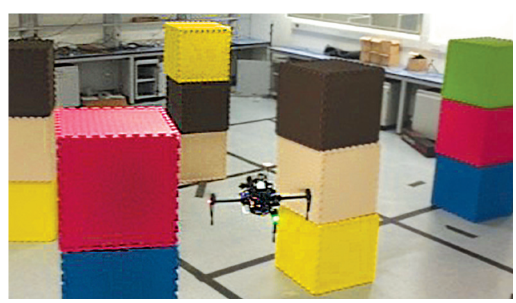
This device, coupled with communication technology, has enabled aerial photography and high-definition video to be shot and streamed from 200 meters in the air to a tablet computer in an office or at home.

2011

Frank Wang, Prof Zexiang Li and their team built a quadrotor drone, less than one meter in diameter, carrying a camera to capture stills and motion, with GPS navigation and communication data links.

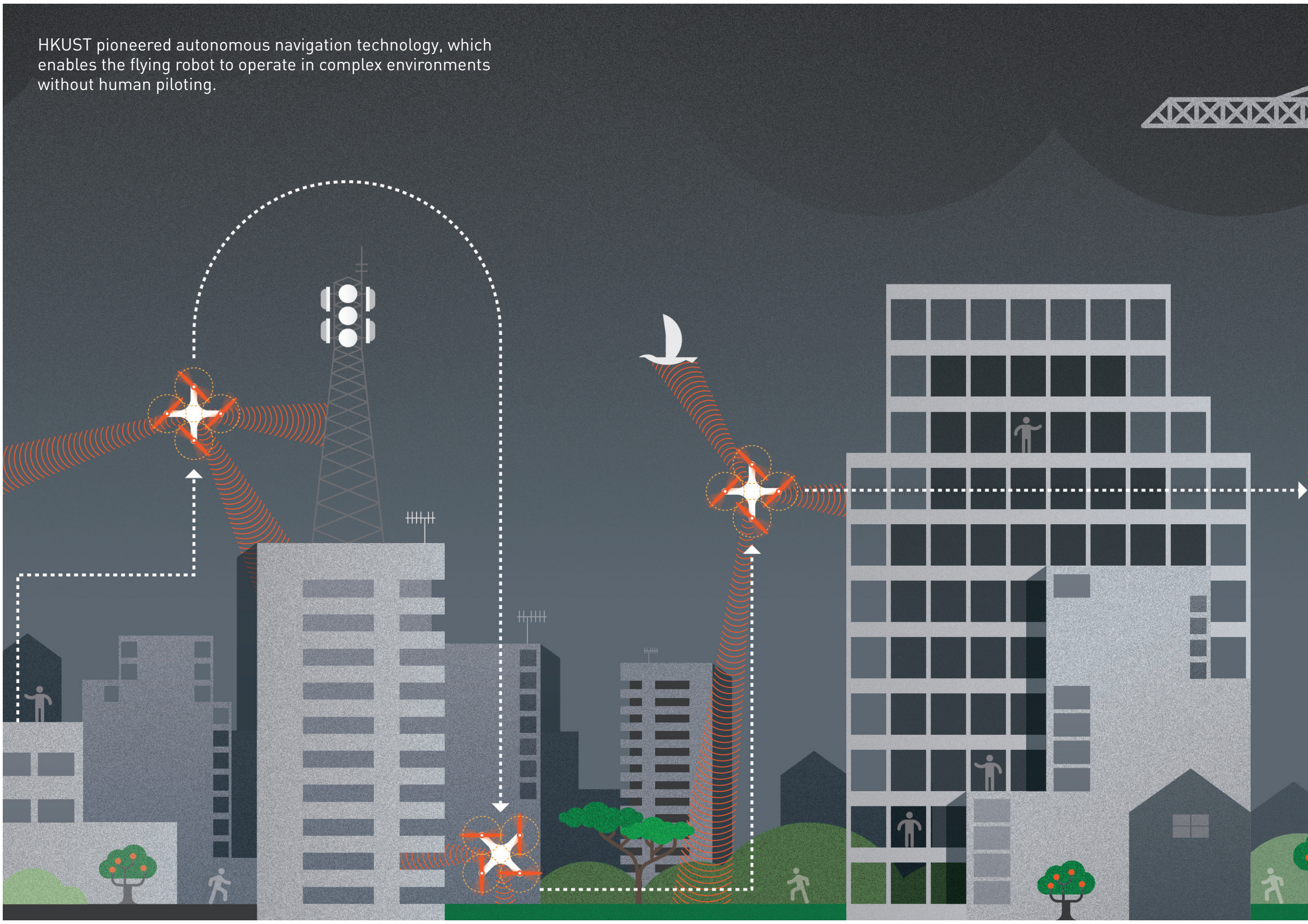
2014

HKUST PhD student Guyue Zhou developed a flying robot prototype with vision navigation, giving rise to the UAV Guidance System.



2015

Prof Shaojie Shen developed technology to free UAVs from GPS control, equipping the flying robot with its own intelligence to navigate more autonomously and respond more independently to real-time conditions.



HKUST pioneered autonomous navigation technology, which enables the flying robot to operate in complex environments without human piloting.

aircraft. The first was to carry cameras for aerial photography and movie making. GPS navigation, their gimbal camera stabilizing device, and communication data links enabled high-definition video to be shot and streamed from the robot flying 200 meters in the air to a tablet computer.

Far-reaching Autonomous Systems

HKUST is now a global leader in UAV technology. Building on this success, Autonomous Systems and Robotics is among the University's five strategic areas for development. Prof Michael Wang, Director of the new HKUST Robotics Institute, explained that the field involves many aspects of technologies from different disciplines. The Institute seeks to facilitate University-wide activity embracing electronic, mechanical, aerospace engineering, computer science, business and education. For UAVs, the Institute's focus will be further enhancement of the technologies involved to extend business and civil uses.

Prof Shaojie Shen, Department of Electronic and Computer Engineering, is among those leading such advances. He returned to his alma mater in 2014 after completing doctoral studies at the University of Pennsylvania because of HKUST's strong connections with industry, including DJI, Texas Instruments and cell phone chip company QUALCOM, among others. The particular challenge that Prof Shen is interested in is how to free UAVs from GPS control, so they can sense and evaluate the environment, and respond intelligently to situations they find while on their flight missions. Drones currently on the market still depend on people to ensure their safety in the air.

Indoor Flights

The solutions now being tested, for which patent applications are already filed, will give UAVs the sensitivity to fly indoors in

“

In two to three years, the flying robot will have the mobility to dive into forests and send medicines to people. This is not science fiction. It will happen

”

PROF SHAOJIE SHEN

Assistant Professor of Electronic and Computer Engineering

cluttered spaces, and even fly through a skyscraper window. They will also be equipped with perception capabilities, utilizing algorithms to know what they need to do next – fundamental technology that will underpin future drone applications in complex environment, such as post-disaster recovery and close-range inspection of infrastructure.

The autonomous navigation technology is already enabling the vehicle to avoid most obstacles in the laboratory setting at HKUST. Testing is now underway to ensure its full reliability for commercial use, in which it will need to sense and avoid anything from a mountain to an electric wire. The applications for this new level of mobility and control are almost limitless.

Working with Industry

In addition, a number of companies that have their origins in robotics and autonomous system breakthroughs achieved by

"Our top priority should be what kind of skills we want to equip our students with so they become a major force in advancing technology, industry and the economy – not just to set up their own companies but to change the world"

PROF ZEXIANG LI

Professor of Electronic and Computer Engineering, and Director, HKUST Automation Technology Center

Soaring **Together**

HKUST students have explored the potential of drone technology in recent international competitions.

In November 2015, a team of research students led by Prof Shaojie Shen won first prize in the International Aerial Robotics Competition, Asia/Pacific. The team used the latest autonomous navigation technology to enable the flying robot to move a number of ground robots out of the contest field.

Meanwhile, a HKUST-led team of Hong Kong undergraduates demonstrated an innovative application for drones at the 2015 Global Grand Challenges Summit, organized by the Chinese Academy of Engineering (CAE), US National Academy of Engineering and UK Royal Academy of Engineering. 15 elite teams, rigorously selected from China, the US and the UK, competed to create novel solutions. The competition was hosted by CAE in Beijing in September 2015.

The cross-disciplinary group of undergraduates presented innovative ideas and a business plan to develop drones to inspect high-rise buildings and civic structures. The entry involved a unique integrated system that could autonomously survey a building or structure using advanced simultaneous localization and mapping technologies. Thermal imaging and sensor fusion technology would enable it to recognize surface cracks and abnormality for disaster prevention and mitigation. The team was awarded third place, sharing this prize with MIT, for their impressive ideas.

Frank Wang (left) with his mentor Prof Zexiang Li.

HKUST students and their academic mentors are both benefiting from and supporting future innovation in a university-industry model, facilitated by leading international practices in intellectual property and technology transfer.

DJI is the best-known example and model for others, with an on-going relationship with HKUST. Today, DJI has grown to employ more than 5,000 people in different locations around the world. It now funds several scholarships for HKUST graduate students to pursue robotics research and several graduates have gone on to take up leading positions with the Shenzhen-based company.

Other companies co-founded by faculty and students in the area of automation include Googol Technology Limited, now a leading motion control company in China, and QKM Technology, which is pioneering the use of robotics for the assembly of smartphones and other small precision electronic products. The Zhuhai Yunzhou Intelligence Technology Limited is another successful company established by HKUST students. It develops unmanned surface vessel used for environmental protection, hydro-geological mapping and cleaning maintenance.

“

HKUST was fundamental to DJI's development. During my studies, I was encouraged by my professors to pursue my lifelong passion for flying devices. Little did I envision then that my fantasy could realize the commercialization of a disruptive technology

”

FRANK WANG

HKUST BEng 2006, MPhil 2011, Founder and CEO, DJI

HKUST Robotics Institute **into the Intelligent Machine Age**

Robotics has the potential to be as transformative for manufacturing and society as the internet has been on our daily life and work. Robots can empower people in their daily lives, across work, leisure and domestic needs.

Economies around the world are pinning their hopes that robots will play a key role in the next generation of manufacturing, to increase efficiency, address labor shortages, and free people from work that is dull, dangerous, or dirty.

However, manufacturers face many obstacles. In the "3C" industries of computing, communications, and consumer electronics, for example, robots need to manipulate tiny parts in confined spaces with far greater precision than in well-established uses in the automobile industry. And as with unmanned aerial vehicles, there is a demand for them to be ever more intelligent in the industry and societal tasks they take on.

"To address these challenges, a totally new and innovative approach is needed to design robots," said Prof Michael Wang, Director, HKUST Robotics Institute.

The interdisciplinary Institute builds on 25 years of cutting-edge engineering research at the University. Scientists across engineering departments will bring together leading research in areas ranging from manufacturing system design and statistical process control to advanced visual and audio interfaces and networked sensing, estimation and control.

The Institute also provides broad education in the science and technologies of robotics, and incubates innovative start-ups with the potential to propel the knowledge economy of the region to new heights.

THE BIG PICTURE

The vast oceans of digital information now being created could reshape our lives, with the **HKUST Big Data Institute** already fathoming this brave new world

The "Big Data" age is well and truly upon us. Huge sets of information are being accumulated through sensor networks, scientific measurements, financial transactions, medical images, web interactions, and social media, among others. Indeed, 2016 is the year in which global internet traffic is expected to surpass one zettabyte – the equivalent of a trillion gigabytes – and keep on rising.* We now need to know how to mine and analyze what all this information can tell us about the world. It is a development being boldly embraced by the HKUST Big Data Institute.

With data science a targeted area of research excellence at the University, the recently established Institute is set to leverage the leading reputation of HKUST academics to forge an interdisciplinary platform that serves as a springboard for new fields of enquiry and technologies in computer science and beyond. Indeed, the opportunities that big data offers in addressing major global challenges and advancing discipline-specific understanding are huge. The financial world, city living, and e-commerce are just some of the many sectors that stand to benefit.

HKUST faculty's expertise covers core techniques and technologies to extract, integrate, manage, analyze, visualize, and discover knowledge from large and heterogeneous data sets. Research initiatives range from the use of "deep learning" (building and training neural networks) and "transfer learning" (ability to recognize and apply knowledge learned in previous tasks to novel tasks) to produce biological and health knowledge to the development of algorithms for computer vision applications.

External research partnerships include an agreement with China's largest integrated IT service provider Digital China Holdings Ltd to explore smart city service provision and the application of big data information technologies. The WeChat-HKUST Joint Lab on Artificial Intelligence Technology also provides HKUST researchers access to data generated by 650 million active users for studying artificial intelligence – in particular in areas of natural language processing including speech recognition.

"The big data world is swimming in information. However, such data will remain just data without ways to extract, integrate, store, compact, retrieve, analyze, and predict from it"

PROF QIANG YANG

New Bright Professor of Engineering, Head, Department of Computer Science and Engineering, and Director, HKUST Big Data Institute, Inaugural Editor-in-Chief of IEEE Transactions on Big Data

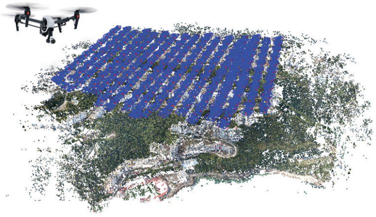
Big data has tremendous potential to open up studies and applications that would otherwise not be possible. Supported by internationally renowned research teams across the Schools of Science, Engineering, Business and Humanities and Social Science, and east-west vision and networks, the HKUST Big Data Institute is well positioned to lead and contribute to this exciting development, both to academia and society. Finding out how the future will be reshaped by those zettabytes of data begins here…

** Cisco® Visual Networking Index (VNI), The Zettabyte Era: Trends and Analysis*

Top left: Prof Qiang Yang discussing with his research students.

Top right: HKUST signed a Framework Agreement with Digital China to build Smart City Research Institute, September 2015.

Bottom: Plaque unveiling ceremony for the WeChat-HKUST Joint Laboratory on Artificial Intelligence Technology, November 2015.



Left: A drone autonomously captures images of the HKUST campus.

Below: 3D mapping technology is used to reproduce images of HKUST campus from different angles.

> 3D reconstruction from photographs is not the end. It is the beginning!

PROF LONG QUAN

Professor of Computer Science and Engineering, and Director, HKUST Center for Visual Computing and Image Science

RECONSTRUCTING THE **WORLD IN 3D**

Through research into computer vision, the huge amounts of visual data now available are being usefully mined and set to work. This is being achieved through the development of algorithms and technologies for applications such as 3D mapping. With such guidance, we would locate destinations not by today's 2D charts filled with geographical symbols but by our mobile phones equipped with GPS and its visual sensor, the phone camera. Terrain could be known beforehand, assisting rescue missions and expeditions. Urban locations would be revealed as they actually appear, making getting lost in a strange place a thing of the past.

Computer vision expert Prof Long Quan has spent the past two decades driving forward the fundamentals of 3D reconstruction. He was involved in theoretical developments in the 1990s, contributing to many fundamental 3D vision algorithms, including the minimum six-point algorithm from three views and projective reconstruction from multiple views. He also participated in the practical side of 3D modeling by integrating computer graphics algorithms. Since joining HKUST in 2001, he and his team have made exciting advances that include a fully automatic 3D reconstruction methodology from very large numbers of images, and recent algorithms and systems to address the "missing detail" challenge of current technology.

In this latest move forward, 3D details at ground level that could not be captured before using street-view camera cars, such as side views of buildings, are now made possible by unmanned aerial vehicles (UAVs) and can be merged with low-flying aerial views by fully automated methodologies. The enhanced accuracy this development has provided has created interest among global peers and major companies, including Google, Airbus and Mainland China businesses, Prof Quan said.

Given his focus on visual 3D reconstruction of landscapes, and visual data analysis, Prof Quan is also involved in helping machines understand and recognize what they are seeing. This could be buildings or trees, or whether an object is man-made or vegetation. Such research is intrinsically linked to UAV technology, part of the University's targeted research excellence area of autonomous systems and robotics (see "Flying High" P24). The UAVs and their cameras allow the capture of a large amount of unoccluded visual data for recognition and monitoring as well as 3D reconstruction. HKUST computer vision researchers are seeking to provide autonomous system researchers with better tools to analyze what they are capturing.

In addition, given the capability of 3D measuring, the work heralds a likely revolution in photogrammetry, the science of making measurements by using photographs, often aerial ones, to survey and map terrain. In line with this, the HKUST start-up launched by Prof Quan's group has recently enabled the online cloud platform, altizure.com, through which the ambitious objective of mapping the world using drone photographs may be realized.

CLEANING UP

What's the alternative to our unsustainable, polluting, energy-guzzling way of life? HKUST researchers across different fields are coming up with answers

The Paris global climate talks in December 2015. The Beijing smog that caused the city's first red pollution alert warning in the same month. The two events in their very different ways bring home the urgency as well as the enormity of the task facing us all in moving forward to a sustainable way of life.

Researchers at HKUST, combining novel interdisciplinary insights, unique east-west positioning and understanding, and strong links with industry and governmental organizations, are hard at work in this race against time. In 2014-15, 69 environment-related research projects were carried out across the University, supported by HK$50 million in funding.

Here, the spotlight (naturally, LED) falls on significant HKUST advances in energy-saving technologies and renewables, displays, and air quality monitoring. Other cutting-edge green team contributions will be featured in future issues.

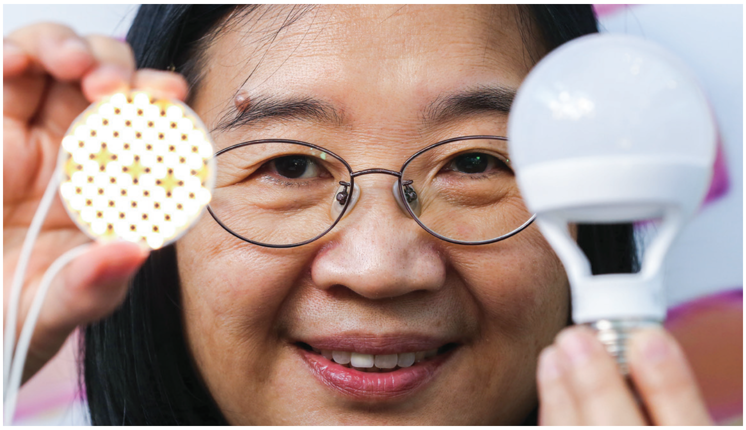
A BRIGHTER FUTURE

Lighting takes up to 15% of the total power consumption globally, according to the enlighten initiative.* Demand for lighting will only increase in future years.

Light-emitting diodes, or LEDs, offer an energy-efficient solution to lighting. Compared to the legacy incandescent and fluorescent lights, LEDs consume significantly less power and also enjoy a much longer lifetime, upward of 50,000 hours. Unlike fluorescent lights, they are non-hazardous as they do not use mercury. Given all these benefits, LEDs are increasingly being used in general indoor and outdoor lighting, following successful applications such as backlighting LCD televisions, headlights for automobiles, and large-area billboards.

Today, global LED adoption in general lighting is still relatively small mainly because LED lights are expensive in terms of the initial cost compared to incandescent and fluorescent lights. Up to now that cost factor appears to have played a more significant role in decision-making than benefits to the environment, said Prof Kei May Lau, Chair Professor of Electronic and Computer Engineering. Reliability issues of products on the market made by manufacturers cutting corners for lower cost at the expense of good design are another factor.

An expert in semiconductor materials and devices, Prof Lau set up the University's Photonics Technology Center in 2001 to advance LED research. She also coined the term "ecotronics" to describe the economically affordable and environmentally friendly electronic technologies, such as LEDs, that she and her colleagues have been developing. Her work is based around compound semiconductors (GaN, GaAs, InP) and optimization of optoelectronic technologies to assist the development of GaN-based LEDs at the early stage, improving the efficiency, stability, as well as packaging designs, benefitting LED performance and consumer perceptions on the capabilities of LEDs as a lighting source.

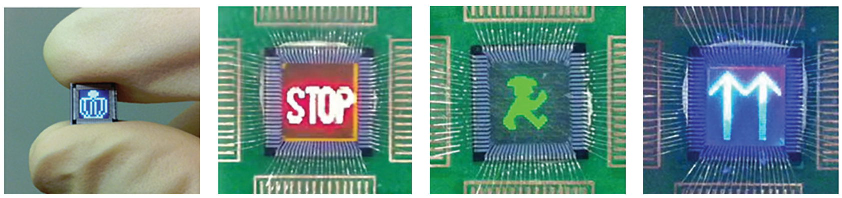


> One watt saved is more than one watt created
>
> **PROF KEI MAY LAU**
> Fang Professor of Engineering

The HKUST research team is one of the leading groups worldwide in its focus on integrating ICs and LEDs. Using silicon integrated circuit technologies in conjunction with LED lighting, Prof Lau and her research team developed innovative device design to make the actual LED system more user-friendly. This involved "a delicate balance of optical science, materials science, thermal science and electronics," explained Prof Lau, who was recently awarded a large-scale Theme-based Research Scheme project, supported by Hong Kong Research Grants Council, to further advance LED-based lighting technologies.

The licensed technologies developed by Prof Lau's team will likely open up new applications, improve reliability and lower manufacturing costs through integration of LEDs on silicon wafers. Among novel applications, the first LEDoS (GaN-LED on silicon) active micro-displays were successfully demonstrated in 2013, namely a 0.19 inch, 1,700 pixel per inch passive matrix LEDoS micro-display and a high resolution 400 x 240 active-matrix micro-display. Applications include projectors and head-up displays, which allow users to read data without moving their head as required in vehicles today. Advantages include visibility under bright daylight, power efficiency, thermal stability, longer lifespan and robustness under harsh conditions.

** United Nations Environment Programme (UNEP)-Global Environment Facility (GEF), www.enlighten-initiative.org*



Light emitting diode on silicon (LEDoS) micro-displays

IEEE/OSA Journal of Display Technology, Vol.9, Issue 8, 2013

WATCH OUT!

Flexible displays that can be rolled up. Healthcare electronic wearables. 3D optically rewritable e-paper available for re-use thousands of times. The next generation of screens is about to catch your eye in numerous innovative ways.

Over the past 20 years HKUST research in optoelectronic displays has already brought many advances that have made an impact on the development of consumer electronics, ranging from computer monitors to watch dials and television screens, making a difference to what we see and how well we see it.

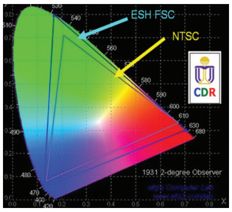
The Center for Display Research was founded in 1995, undertaking both basic research advances on liquid crystal displays (LCDs) and applied work that was later transferred to industry. It was a time when only a handful of universities around the world had ventured into the display area due to its multidisciplinary nature and the need for teamwork, said Prof Hoi-Sing Kwok, Chair Professor of Electronic and Computer Engineering. "If people work on their own, they can only tackle small problems," Prof Kwok noted. "In our entire-system approach, several faculty members truly work together, each regarded as important."

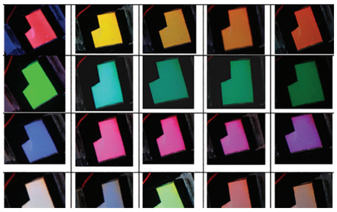
Inventions include liquid crystal on silicon (LCOS) micro-displays, integrating LCDs with silicon-wafer integrated circuits that can be used in high-definition televisions, among other applications; a fundamental new LCD alignment method using light, called photo-alignment, offering top optical quality and good contrast; and a revolutionary thin-film transistor technology that combines the integrated circuit into the glass display panel, offering slimness, cheaper and better performance, as well as a sharper image. Solutions to specific practical problems have encompassed a multicolor LCD without color filter, later licensed to industry, and reflective displays without a rear polarizer made in collaboration with a watch company.

"Displays are everywhere. Even small improvements can have large societal and economic impact"

PROF HOI-SING KWOK

Dr William MW Mong Professor of Nanotechnology, Director, Partner State Key Laboratory on Advanced Displays and Optoelectronics



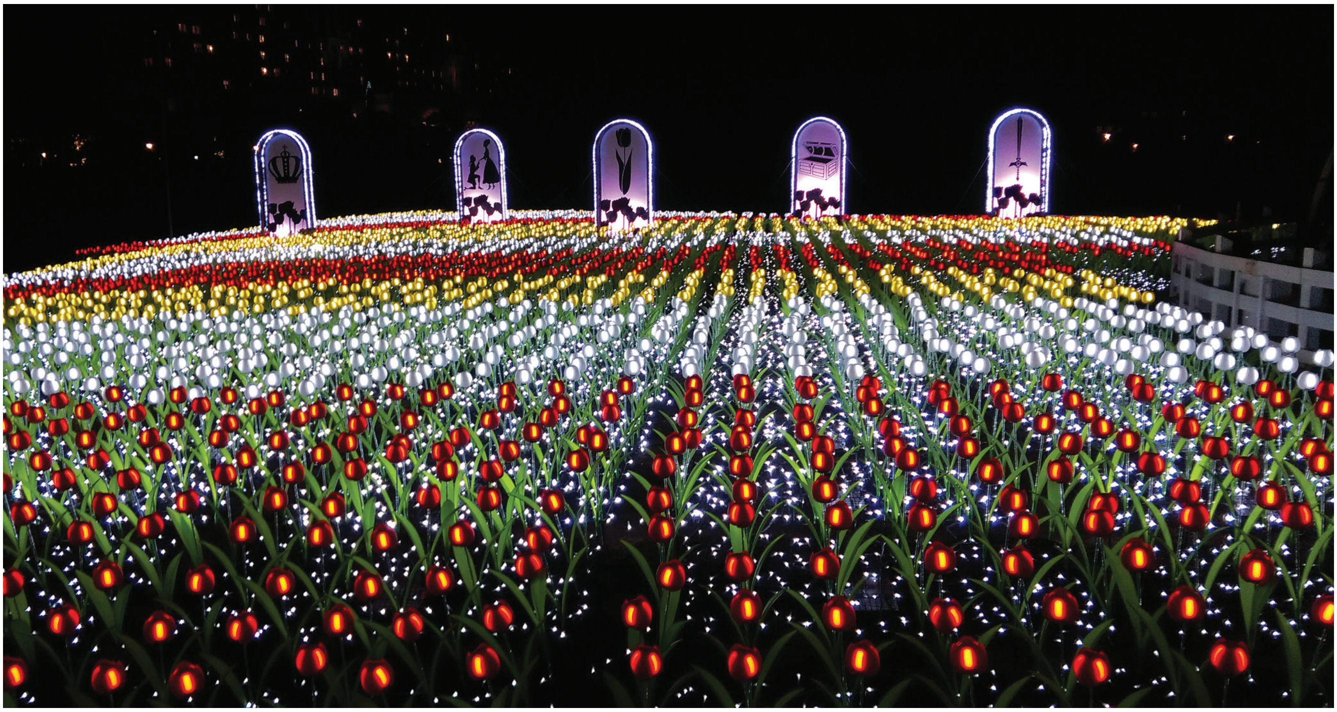


Ferroelectric liquid crystal-based field sequential color display using photo-alignment technology. Applications include micro-display and mobile display, with the advantages of power saving, high contrast ratio, good shock stability, extremely fast switching time (~10μs), wide view angle and large color gamut.

Partrner State Key Laboratory: **Focus on Display Excellence**

In 2013, the Center for Display Research was awarded the prestigious recognition of Partner State Key Laboratory (PSKL) on Advanced Displays and Optoelectronics Technologies by the Ministry of Science and Technology of China. The laboratory was established in partnership with Sun Yat-sen University in Guangdong, focusing on core research areas in LCD devices, third-generation organic LED (OLED) devices, video signal processing and integrated circuit design, thin-film transistor array technology and frontier technologies including green displays. Prof Hoi-Sing Kwok is the Founding Director.

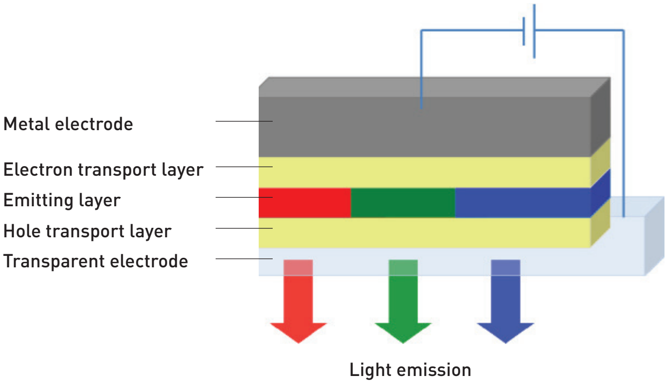
Opening ceremony for Partner State Key Laboratory on Advanced Displays and Optoelectronics.



Organic LED (OLED) is another important display research area at HKUST – led by IAS Bank of East Asia Professor Ching W Tang, the first Chinese Wolf Prize Laureate in Chemistry, regarded internationally as the founding father of OLEDs. The OLED revolution sparked by Prof Tang's discovery of the organic hetero-junction in the early 1980s led to a new display technology and a rapidly growing industry. OLED displays are more energy-efficient, thinner and lighter than conventional liquid-crystal displays (LCD). Because of these superior features, OLED displays are being used in today's smartphones, tablets, watches, laptops, and large-screen TVs. The next-generation televisions based on OLED will not only have superior picture quality but can be made flexible and so thin that they can be literally stuck to the wall.

Prof Tang is now embarking on the OLED's "blue" problem – the instability of blue OLED emitters – and to further improve the lifespan of blue emitters through new material designs and fine-tuning the layer architecture in the device. In addition, Prof Tang's team will also undertake research to come up with unconventional methods for patterning full color high-resolution display panels, with an aim of lowering the manufacturing cost.

With their highly successful and proven multidisciplinary "entire system" approach, HKUST researchers are well-positioned to embrace the future challenges at the frontier of emerging display technologies.



OLED utilizes a stack of thin organic films to transport charges (electrons and holes) and produce light via electron-hole recombination.

> The 'blue' problem is perhaps the last frontier to be tackled in OLED material research; solutions will make quantum jump improvements in performance and cost

PROF CHING W TANG

IAS Bank of East Asia Professor,
Chair Professor of Electronic and Computer Engineering, Chemistry and Physics

RACE FOR RENEWABLES

Pollutant emissions are largely a byproduct of our need for energy generation and transportation, which today are usually powered by fossil fuels, namely oil, coal and gas. One major emission is carbon dioxide, a greenhouse gas that contributes directly to global warming when generated in quantities that outstrip nature's assimilative capacity. Others, such as particulate matter, are toxic to human health. Yet currently, only 2% of energy is derived from "clean air" renewables, such as wind and solar.

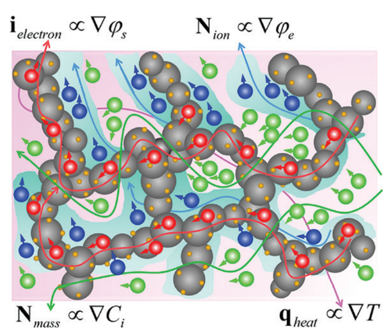
The key challenges for renewables include stability in generation, on-tap availability, cost-efficiency, and high performance. Wind farms require large areas of land and highly efficient solar panels are often expensive to produce. Both face an "intermittent generation" problem and energy storage to cover such gaps remains a huge challenge.

HKUST researchers have set out to address these complex issues that often cut across conventional academic disciplines and boundaries.

"My dream is a net zero energy community, where all energy is self sustainable"

PROF TIANSHOU ZHAO

Chair Professor of Mechanical and Aerospace Engineering, and Director, HKUST Energy Institute



Coupling of heat and mass transfer with electrochemistry.

Fuel Cells

Prof Tianshou Zhao has been advancing the potential for wider use of clean energy for the past 15 years through his groundbreaking work on direct alcohol fuel cells and advanced battery technologies.

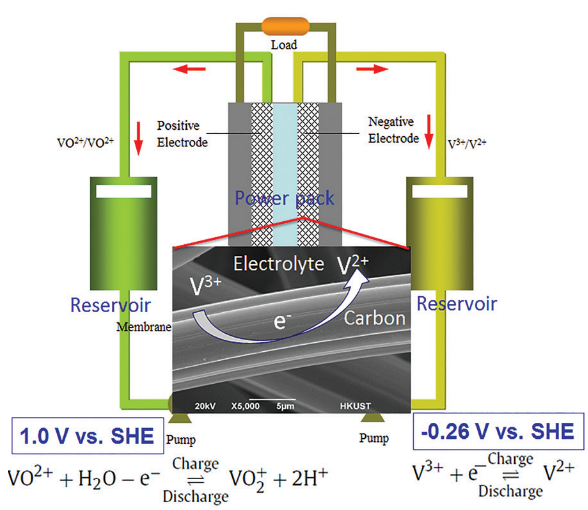
Prof Zhao sees immense potential in fuel cells as an alternative source of energy. Fuel cells generate electricity through converting the chemical energy of a fuel such as hydrogen, ethanol and methanol, all of which can be directly produced from renewable sources. Fuel cells have high efficiency of around 65%, compared with 30%-35% for traditional heat engines. In addition, they are scalable and can be applied to a wide range of modern lifestyle devices and needs, including cars, mobile phones, computers and buildings.

The main problem with alcohol fuel cells has been low power density, the amount of power produced in relation to the volume of the cell. Based on his seminal work on the underlying mechanism of couple heat/mass energy transfer and electrochemical kinetics in fuel cells, Prof Zhao discovered that the issue lay in integrating the understanding of heat and mass transport, and electrochemistry.

With such insight, a new theoretical framework was developed, which led to a dramatic increase in the performance of direct methanol fuel cells by six times and that of direct ethanol fuel cells by four times. Prof Zhao has demonstrated a prototype model car that can run for 10 hours on 5cc of alcohol fuel. And an MP3 player that plays for 20 hours on 2cc of fuel. The researchers have also discovered that hydrogen can evolve spontaneously from a direct methanol fuel cell. This has given rise to a new technique for hydrogen production at room temperature minus the carbon monoxide species common to traditional methanol reformation.

Such theory and discoveries have helped Prof Zhao's research group to tackle further related issues through electrode design improvements for large-scale redox flow battery technologies that can help solve the "intermittent generation" problem for renewables such as solar and wind by raising power density. In contrast to solid state batteries that integrate energy storage and power pack together, a flow battery separates the storage component from the power pack, meaning that power and capacity can be independently sized and making the technology scalable. The battery lifespan is also increased.

Prof Zhao's unusual blend of electrochemistry and thermo-fluid science is indicative of the non-traditional approach encouraged by HKUST. His team comprises expertise ranging from materials and modeling to fluid sciences and electro-chemistry. He also steers the HKUST Energy Institute, launched in 2014 and now serving as the platform for the University's multidisciplinary research into energy generation, storage, efficiency and policy. Over 50 faculty members across different departments and Schools are involved in such endeavors.



How a vanadium redox flow battery works.

Organic Solar Cells

On the solar energy front, the current focus at HKUST is on organic and hybrid organic-inorganic solar cells that could outperform traditional solar cells at a lower cost. Cross-disciplinary research combines novel materials development and nano-scale device engineering to enhance efficiency and durability of the solar cells. To reduce production cost, flexible thin-film organic solar cells are being developed that would take advantage of high-speed manufacturing processes.

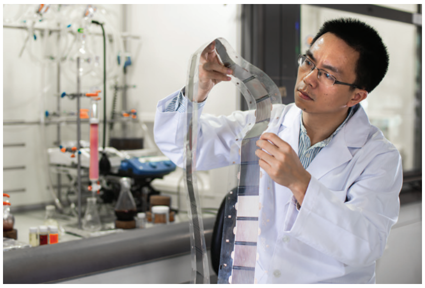
Breakthrough records in the efficiency of organic solar cells have been achieved by Prof Henry Yan and his group in the Department of Chemistry. Organic solar cells offer a flexible alternative to the conventional rigid inorganic solar cells that make up today's solar panels.

The advantages of organic solar cells include faster and cheaper mass production processes due to their flexibility, including roll-to-roll printing similar to newspaper production. These solar cells are also light in weight and environmentally friendly. Such features open up integrated applications for windows, buildings, vehicles, and for charging mobile devices, such as smartphones, among others. Different shapes and colors add to commercialization potential.

The major challenge is to improve performance. While today's inorganic silicon crystalline solar cell has power conversion efficiency of around 20%, most published research results for organic solar cells remain at around 10%, which is still not sufficient for wide-spread commercial applications.

Through observation of a significant material motif that has enabled a novel method of controlling the morphology – the mixing – of materials in the solar cell based on temperature control, Prof Yan has made a major stride in this global race by achieving record-breaking efficiency for single-junction organic solar cells of up to 11.5%. For the first time, Hong Kong research has been featured in the US-based National Renewable Energy Laboratory (NREL) table – an authoritative record of data from around the globe on the best research cell efficiencies. These findings have also appeared in *Nature Communications* (2014) and *Nature Energy* (2016).

Prof Yan and his group have also developed a "family" of polymer and fullerene materials for use in high-efficiency polymer solar cells. In addition, he is working together with Prof Ching W Tang and physics colleagues, including Prof KS Wong and Prof Jiannong Wang, to better understand the properties of the new synthesized materials and improve solar cell performance. Other HKUST researchers are working on harvesting solar energy through chemical means. Prof Zhiyong Fan and his research team focus on engineering nanostructured materials with enhanced light absorbing characteristics, while Prof Shihe Yang and his group have developed methodologies for synthesizing monodispersed nanostructured materials of transition metals with specific properties to be used for solar cells.

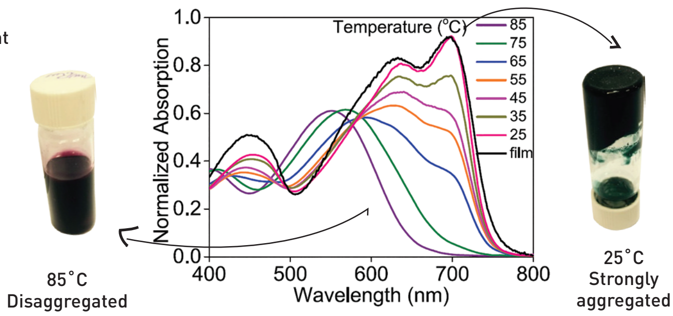


> "This is a really exciting scientific development. Our new organic solar cells have the potential to reach conventional inorganic performance levels"

PROF HENRY YAN
Assistant Professor of Chemistry

Temperature-dependent aggregation enables ideal morphology

The polymer solution is not aggregated at high temperatures, but strongly aggregated at room temperature. This unique property allowed HKUST researchers to achieve multiple cases of record efficiency organic solar cells.



HKUST Energy Institute: **Powering Forward**

The HKUST Energy Institute is a leading international center for energy research and education, with a reputation for excellence across a broad range of fields, which includes sustainable energy generation, storage, distribution and utilization. It is a multidisciplinary platform for integrating, facilitating and enabling University-wide programs in energy-related research, development and education.

Building on HKUST's existing research strengths, the Institute strives to provide a strong and visible leadership role in energy research in Hong Kong, as well as to engage in emerging energy research that will have a long-term, transformative effect on Hong Kong and the nation's energy future. The Institute also promotes knowledge transfer in collaboration with local and international partners and establishes a channel of communication between the University and the public through outreach activities.

AIR POLLUTION: IMPACT ON HEALTH

HKUST Air Quality Collaboration Research Projects – Monitoring sites in Guangdong and Hong Kong

PM2.5 Air Monitoring Station at HKUST Fok Ying Tung Research Institute, in Nansha

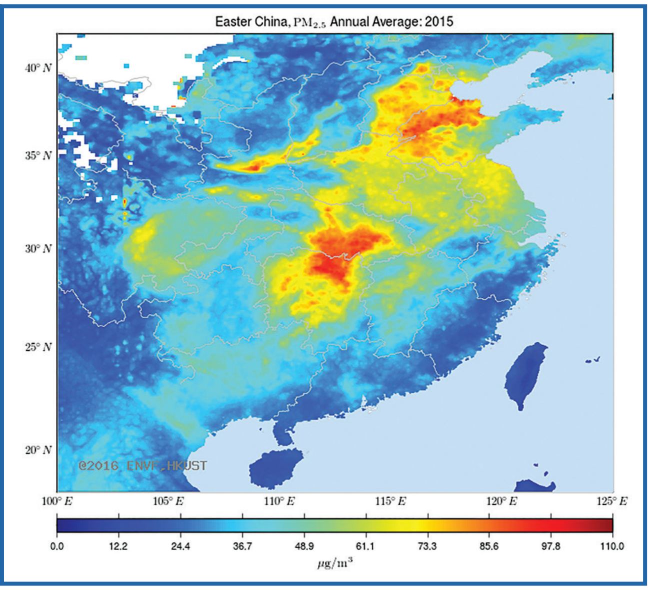
Installation of samplers in Nansha

Worldwide, fine particulate matter (PM2.5) is the most significant atmospheric pollutant. However, PM2.5 measurements are very limited, especially in developing countries such as China where air pollution is particularly serious. In the past decade, HKUST air quality researchers have developed satellite remote-sensing techniques to derive surface PM2.5 concentration, with spatial resolution down to one kilometer, providing a way of looking at air pollution as it affects a city, even in the absence of ground level measurements.

The study of air pollution is a complex subject requiring a multidisciplinary approach. Over the past two decades, HKUST air quality researchers have developed internationally recognized expertise in a range of areas: including atmospheric meteorology and air quality modeling (Prof Jimmy Fung); remote sensing and data analysis (Prof Alexis Lau); chemical and bio-aerosols (Prof Arthur PS Lau); and analytical methods for analysis of field samples (Prof Jianzhen Yu). The research group also collaborates closely with the US Environmental Protection Agency (USEPA) and the World Health Organization (WHO).

HKUST findings have helped Hong Kong government's policy formulation and decision-making. Examples include:

- Early recognition of the significant impact of sulphur dioxide emissions from shipping in Hong Kong, which eventually led to legislation on fuel control for local and ocean-going vessels in 2014 and 2015 respectively.
- Analyses highlighting the significance of road transport – in particular diesel particulate matter – in driving up cancer-causing pollutant risks, paving the way for the US$1.4 billion diesel commercial vehicle replacement scheme in 2014.
- Development of an Air Quality Health Index in collaboration with the Chinese University of Hong Kong in 2014.
- Leading a landmark Pearl River Delta Regional Air Quality Improvement Project to understand and address the regional PM2.5 problem. The 2014 project was the first coordinated research effort conducted jointly by the governments of Hong Kong, Guangdong and Macau to support regional environmental policy and management.



The figure shows the annual mean satellite-retrieved PM2.5 concentrations from HKUST's new aerosol optical depth (AOD)-PM2.5 model, with validations from ground-based air-quality monitoring stations.

> We know how to deal with air pollution and, if we are willing to pay the costs of controlling it, we can improve our air quality. It involves getting information out to people, and making them aware of the effects of air pollution on their health

PROF ALEXIS LAU

Professor of Environment,
Civil and Environmental Engineering,
Director, HKUST Atmospheric Research Center

Prof Alexis Lau (second from left) and Prof Jimmy Fung (second from right)

Supersite Seeks Answers

In a landmark regional move, the University established the first Air Quality Research Supersite on campus in 2011 to investigate the sources and nature of toxic ambient particulate matter (PM) in Hong Kong and the Pearl River Delta. Supported by the Hong Kong University Grants Committee and the Environment and Conservation Fund, the Supersite is equipped with an automatic weather station tower and exclusive real-time instrumentation for physical and chemical characterization of particulates. The data provides a basis for advanced air quality modeling and determining the impact of traffic-related PMs, and how such particles affect visibility over southern China. In parallel, an air quality monitoring station located at the HKUST campus in Nansha, Guangzhou, provides complementary measurements of chemical components of PM2.5 in the Pearl River Delta.

HKUST air quality research supersite

HKUST Sustainability

Eco-friendly **Campus Living**

HKUST is not only setting out to impact others but to live as it proposes we should all endeavor to do. The HKUST 2020 Sustainability Challenge, launched in 2015, provides the University with a clear vision for eco-friendly living by turning the campus into a vibrant showcase for zero-carbon, zero-waste and net-positive environmental impact.

The action plan seeks to create a proactive Sustainability Network, reaching across education, operations, research and the campus population, and serving as a model for sustainable aspirations globally. The dynamic initiative encompasses: development of sustainability curricula; provision for the systematic reduction of waste, energy use and greenhouse gas production in daily operations; applied research that can demonstrate fresh ideas and solutions; and communication and projects to motivate campus community involvement.

Five-year targets are in place for each area. These objectives range from educating graduates that have the ability and commitment to serve as sustainability problem-solvers, locally and globally, to aggressive operational goals to decrease energy and greenhouse gases by 10% and waste by 50%.

BEATING THE BRAIN DRAIN

In the past two decades, HKUST researchers have made many pace-setting contributions to molecular neuroscience, the area of life science focused on understanding the nervous system

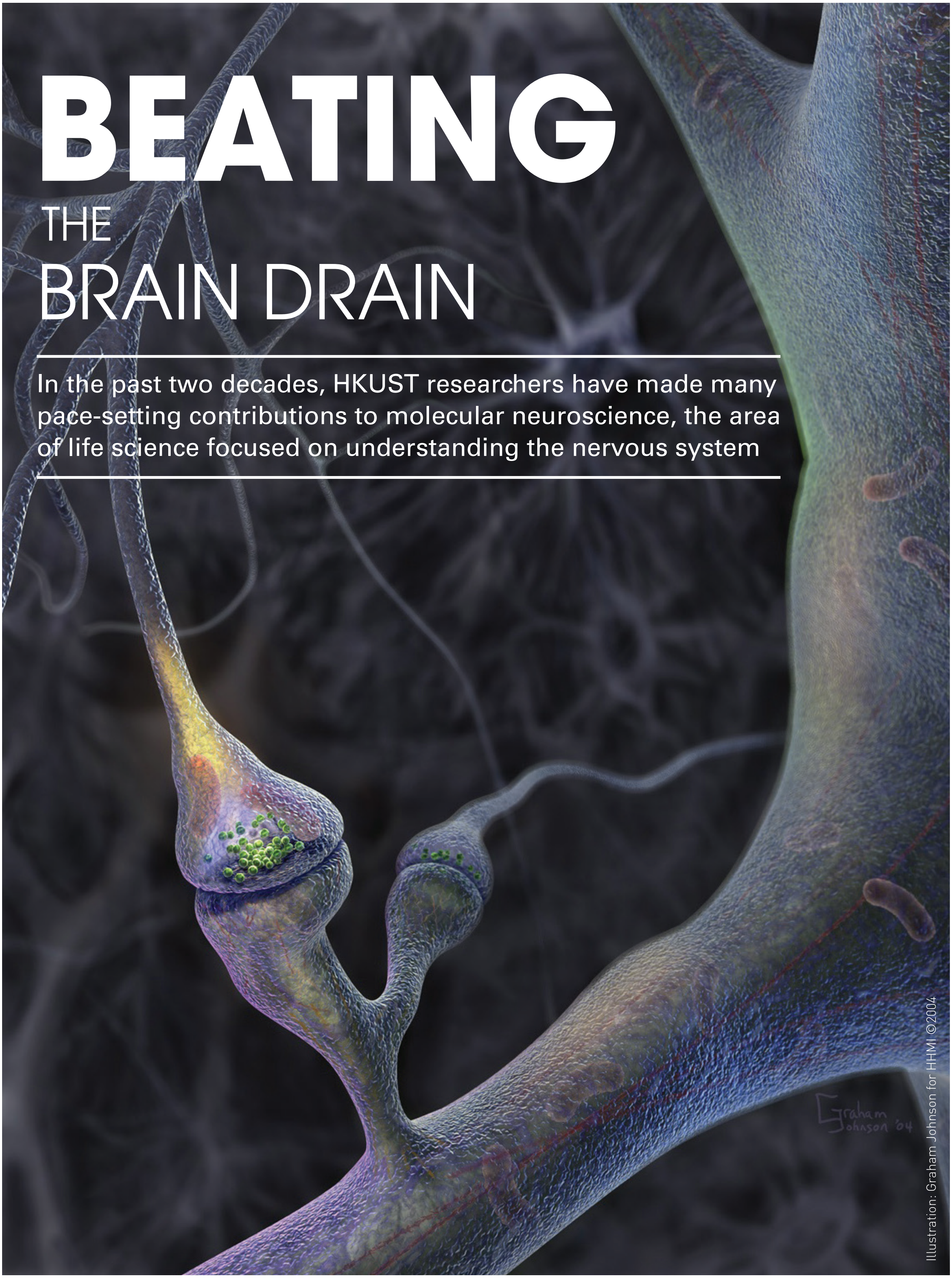


Illustration: Graham Johnson for HHMI ©2004

Neurodegenerative diseases emerge when synapse connections falter and neurons begin to fade at a faster rate than the normal aging process. How and why this happens, and what, if anything, can be done to slow or stop the process or even reverse the devastating effects, is one of the great challenges for life science and medicine.

HKUST scientists have been immersed in clarifying these mysteries over the past 20 years. Leveraging on multidisciplinary expertise, they are working at the cutting-edge of discovery and offer fresh hope that the battle against dementia and other such devastating conditions can be won. Their significant research findings have resulted in a stream of innovative avenues in molecular neuroscience.

World-class Discoveries

Breakthroughs have been derived from undertaking focused research at the molecular level. By unraveling signaling mechanisms underlying normal brain functions, and those that specifically exhibit aberrant behavior in diseased conditions, HKUST scientists are shedding light on the molecular basis of neurodegenerative diseases.

Exciting work is on-going, with teams of HKUST scientists engaged in critical research on:

- Identification and delineation of neuronal signal transduction pathways in synapse development and plasticity, and the regulation of neuronal survival;
- Cellular and molecular mechanisms of synaptic dysfunction, neuronal death, and age-related triggers in Alzheimer's disease;
- Identification of biomarkers for Alzheimer's disease;
- Aberrant proteins and signaling mechanisms in Huntington's and Parkinson's diseases;
- Understanding mechanisms for differentiation and integration of neural stem cells;
- Development of state-of-the-art imaging technology for brain research;
- Developing potential therapeutic approaches to slow the progression of neurodegenerative diseases.

“Research into neurodegenerative diseases is vital because there are no cures and clear understanding is still lacking. People suffering from Alzheimer's and Parkinson's, among others, are rapidly increasing due to aging populations worldwide. This is a challenge we must address”

PROF NANCY IP

The Morningside Professor of Life Science,
Director, State Key Laboratory of Molecular Neuroscience,
Academician, Chinese Academy of Sciences,
Foreign Associate, US National Academy of Sciences

Such research was given added impetus following the establishment of the Molecular Neuroscience Center at HKUST in 1999, which brought together a core team of talented researchers to push exploratory frontiers. This was initiated by Prof Nancy Ip who has been an instrumental figure in achieving the University's research strengths in this area. In 2001, the Center was awarded major support of HK$26.8 million for five years under the Areas of Excellence (AoE) Scheme initiated by the Hong Kong University Grants Committee. This was later extended by HK$27.5 million for another three years.

Potential Drug Leads

HKUST researchers have broken new ground in understanding neurodegenerative diseases. Over the years, a number of proteins (for example, cyclin-dependent kinase 5, α2-chimaerin, EphA4 and PICK1), and their signal transduction pathways have been investigated to reveal the pivotal roles they play in brain functions, such as neuronal survival, differentiation and synaptic plasticity. Most recently, they have identified the protein interleukin (IL)-33 as a potential Alzheimer's treatment. These novel findings have been recognized internationally and published in prestigious academic journals.

The University's scientists have also identified potential therapeutic interventions to slow neurodegeneration. Leveraging their strong expertise in traditional Chinese medicinal herbs, the team has identified small molecules derived from such herbs as potential drug leads. This research has been supported by innovative use of the latest *in vitro* and *in vivo* drug development technologies. The University is also in the process of licensing several patents to biopharmaceutical companies, which will invest in further development of these drug leads into viable treatments.

Prof Nancy Ip reviewing experimental data with her students.

Proper brain functions depend on the intricate interplay of well-coordinated signaling pathways in brain cells that are induced by extracellular stimuli. Cell surface receptors serve as links to transduce signals to the intracellular targets, and dysregulation of these signaling events can result in neurodegenerative diseases. The research undertaken by Prof Ip, is focused on unraveling molecular mechanisms essential for modulation of different brain functions, in particular neuronal communication as well as wiring of neural circuit, both critical for learning and memory. Through research, Prof Ip and her team are opening doors to new understanding of the brain structure and its function to help combat brain diseases and disorders, many of which are currently incurable.

EphA4 Breakthrough

Prof Ip and her team had an exciting breakthrough with their discovery that cell surface receptor protein EphA4 is a key player in Alzheimer's disease pathology. EphA4 regulates the signaling between neurons, and hence brain plasticity that is vital for normal cognitive functions including memory. It dampens neuronal communication through two mechanisms. The first is morphological, in reducing the number of communication points, known as synapses, between brain cells. The second is biochemical, by degrading or reducing the number of neurotransmitter receptors that are responsible for communication between excitatory neurons.

Once these mechanisms were understood, mouse models were used to confirm the link with Alzheimer's disease. The groundbreaking findings were published in 2007 and 2011 in *Nature Neuroscience*, a leading journal in the field.

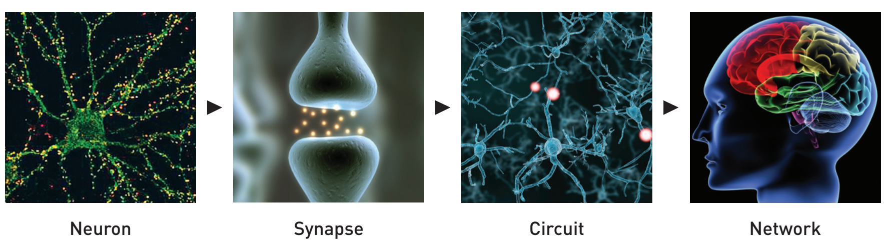
Chinese Medicine 'Blockade'

This discovery, the culmination of more than a decade of research, was closely followed by a second major breakthrough – identification of a small molecule derived from a traditional Chinese medicine herb to block EphA4 activity and rescue neuronal communication impairment observed in Alzheimer's disease. The team explored ways to block the negative EphA4 regulatory pathway, turning to a traditional Chinese medicine library for potential "blockades". This translational stage of the research was funded by the Hong Kong government's Innovation and Technology Commission and the S. H. Ho Foundation. After testing dozens of potential compounds, a hit was identified from the herb *gou teng* (*Uncaria rhynchophylla)* in collaboration with computer scientists.

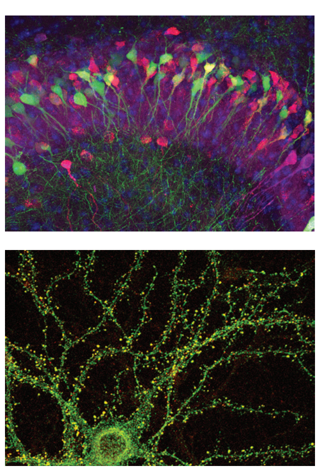
The team prepared the active molecule and orally administered it to transgenic model mice exhibiting Alzheimer's disease-like pathologies (AD model mice). The resulting effect was that neuronal communication was restored to normal and synaptic impairment was rescued. The findings were published in 2014 in *Proceedings of the National Academy of Sciences* (*PNAS*), and received worldwide attention and strong media interest since they represented a potential new strategy for developing treatments for Alzheimer's disease.

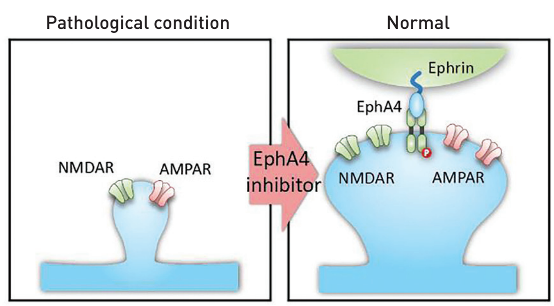
Fresh Light on IL-33

Another recent significant discovery by Prof Ip and her team may be a potential game-changer in the approach to developing therapies for Alzheimer's disease. The team demonstrated the importance of the immune function in the disease



Proper neuronal architecture and communication is integral for normal circuit activity and brain function.





The left two panels illustrate hippocampal neurons and the large number of synapses at one hippocampal neuron. Prof Ip demonstrated that aberrant activity of the cell surface receptor EphA4 at the synapses on the hippocampal neurons results in synaptic dysfunctions in mouse models of Alzheimer's disease (above two panels). Thus, EphA4 inhibitors to block EphA4 activity can be developed as a therapeutic approach for Alzheimer's disease.

pathology and identified the IL-33 protein as a potential treatment for Alzheimer's.

IL-33 is a protein found in a wide variety of cell types in humans, and modulates immune functions. The team discovered that IL-33 function is compromised in individuals with mild cognitive impairment, those who are at high risk of developing Alzheimer's disease. To elucidate its role in disease pathology, the protein was injected into AD model mice, with astonishing results. The mice rapidly recovered their neuronal communication and memory. Additionally, IL-33 injection for only two consecutive days was sufficient to reduce the levels of beta-amyloid (Aβ) protein and, in turn, decrease the deposits of amyloid plaque, a major pathological hallmark of the disease, in the mice brains.

The team further demonstrated that IL-33 mobilized microglia, the immune cells of the brain, to the amyloid plaques to promote the clearance of the Aβ protein. It has been hypothesized that defects in the mechanism underlying Aβ clearance is one of the leading causes of Alzheimer's disease. With additional investigation, IL-33 was found to trigger changes in the microglia, which in turn reduced overall inflammation in the brain. This is a critical finding since inflammation contributes to and drives the pathology of the disease.

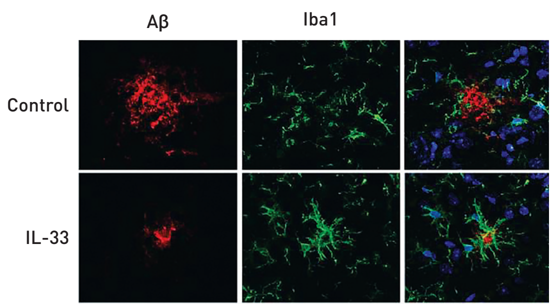
The study was published in *PNAS* in April 2016. The team aims to build upon its findings to further understand the mechanisms underlying Alzheimer's disease as well as evaluate the viability of using IL-33 as a clinical treatment in human. The research has been supported by the Hong Kong Research Grants Council's Collaborative Research Fund.

Search for Early Diagnosis

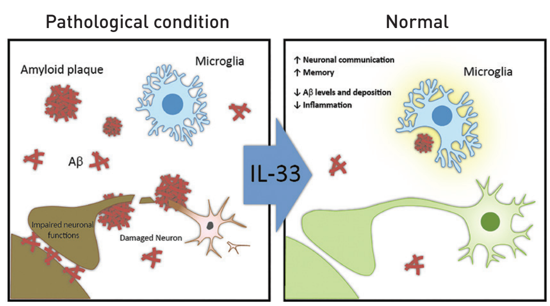
While the interdisciplinary team continues to investigate the complex signaling mechanisms between brain cells and other potential triggers for malfunction, the hunt is now on for biomarkers for early Alzheimer's disease and mild cognitive impairment.

Toward this goal, Prof Ip has initiated a critical project with clinicians in Hong Kong, Mainland China, and globally to identify biomarkers associated with early Alzheimer's and mild cognitive impairment. Success in this area could potentially lead to diagnostic tools and tests that simply and effectively identify individuals with these conditions, prior to manifestation of symptoms.

Furthermore, the question of why some patients with mild cognitive impairment develop Alzheimer's disease, while others do not is also being investigated. The genetic make-up of an individual, combined with inflammatory and environmental factors, are among the potential factors. To unravel these mysteries, Prof Ip is investigating inflammation in the brain to understand the interplay between the immune and nervous systems.



The immune system contributes to the pathogenesis of Alzheimer's disease, but the basis is unclear. Prof Ip demonstrated that injection with IL-33 recruits immune cells to the amyloid plaques, which then triggers amyloid clearance.



Overall, IL-33 restores neuronal communication and memory in the mouse model of Alzheimer's disease and alleviates Alzheimer's disease pathology by reducing inflammation and amyloid toxicity.

Partner State Key Laboratory: **Focus on Molecular Neuroscience Research**

Opening ceremony for Partner State Key Laboratory of Molecular Neuroscience.

The Partner State Key Laboratory (PSKL) of Molecular Neuroscience, established in 2010 by the Ministry of Science and Technology of China, is the first laboratory focused on molecular neuroscience research in Hong Kong. The core focus of the PSKL is to develop frontier research in neuroscience and address fundamental questions related to function of the nervous system and neurological diseases.

The PSKL has forged a long-term partnership with the State Key Laboratory of Neuroscience in Shanghai, and established a research team at the HKUST Shenzhen Research Institute to broaden the platform for innovative basic research as well as drive initiatives in translational research through collaborations with industrial partners.

Aging vs Amyloid

Prof Karl Herrup has championed an alternative hypothesis that emphasizes aging rather than amyloid as the key contributor to the disease. His work focuses on the biology underlying the process of cell death that occurs during the course of Alzheimer's disease, searching for the molecular triggers that start the cell death, and the strategies we can use to try to prevent it.

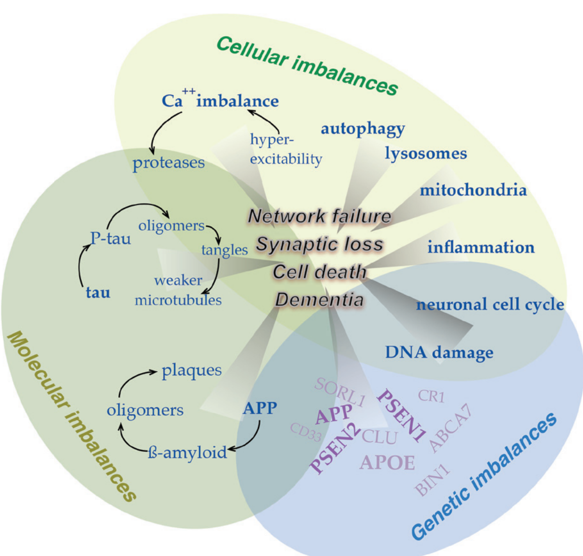
The genesis of human neurons stops almost completely by one year of age; after that, mature adult neurons are incapable of cell division. Yet in the regions of the Alzheimer's disease brain where cell death occurs, Prof Herrup and his team have shown that neurons are trying to do the impossible. They are trying to divide. Prof Herrup has been responsible for identifying the molecular details of why this happens. His search for the signals that fool the cells into making what is essentially a lethal move has led to some remarkable findings. He sees the initiation of cell division as a good, but ultimately fatal instinct. "Neurons sense damage and like skin cells trying to heal a cut, their instinct is to increase their numbers by trying to divide," he said. "But this is not possible in an adult neuron and the instinct goes sour on them. I call it divide and die."

"We can conceive of Alzheimer's disease as aging plus an injury that triggers a decline and a cascade of events. It is not normal aging, but you don't need the amyloid peptide to create it"

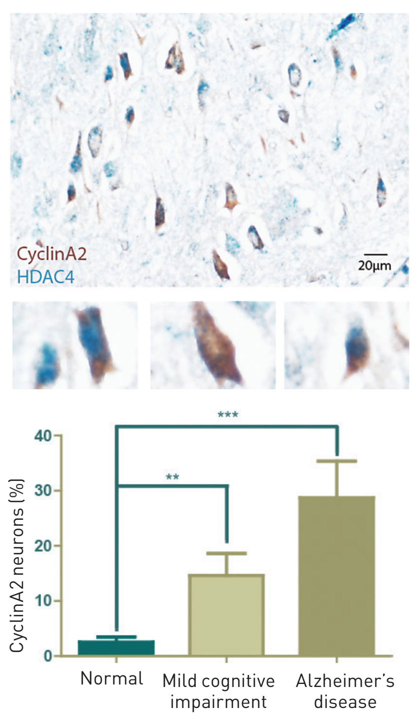
PROF KARL HERRUP
Chair Professor and Head, Division of Life Science,
Co-director, HKUST Super-Resolution Imaging Center

What forces an adult neuron into this situation? Prof Herrup and his team have pioneered work implicating an abnormal immune response. The brain of the person with Alzheimer's has long been recognized as being in a state of chronic inflammation. Both genetic and epidemiological studies point to the importance of this process and the roles that the immune system and neural inflammation can play in modulating neurodegenerative disease.

Over the years, this broad view of the origins of the cells death has led Prof Herrup to raise questions about and ultimately challenge the most prevalent disease model of Alzheimer's – the so-called amyloid cascade hypothesis, which regards the accumulation of beta-amyloid peptides as the root cause of Alzheimer's disease. His views on the topic were recently published in *Nature Neuroscience*. This distinction has important implications for future research – both basic biological science as well as clinical trials.



The causes of Alzheimer's disease can be roughly grouped into three categories (shaded ovals): cellular events (light green), genetic events (blue) and molecular events (dark green), and the various elements interact with each other. Thus, for example, inflammation can enhance the deposition of beta-amyloid peptides, which in turn can influence the deposition of tau and impair synaptic function.



The brown stains show proteins that are normally only found in dividing cells. Their presence in these neurons is a sure sign that something is not right. The blue stain, a separate protein HDAC4, moves to the nucleus when a cell tries to divide. Normal neurons cannot divide, but in Alzheimer's diseased patient the neurons try. This attempt will probably kill them. The histogram shows that as Alzheimer's progresses, the fraction of cells that are trying to divide increases.

PROF KENNY K CHUNG

Associate Professor of Life Science

Comprehending Parkinson's

Parkinson's disease is the second most common neurodegenerative disorder after Alzheimer's disease and the major risk factor for the disease is aging. People with family history of this disease have an increased risk of getting the disorder.

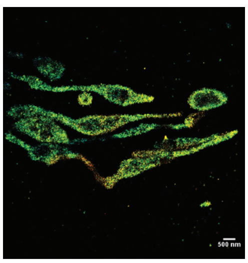
Prof Kenny K Chung has identified important molecular mechanisms of neurodegeneration, focused on familial Parkinson's disease – the form that is caused by genetic mutation(s). He has been working on genes involved in familial cases focusing on the gene known as parkin, its functions in relation to mitochondria, and the neural pathways affected during the disease. Prof Chung and his team have found one of the redox signaling pathways that can affect the function of parkin, and later on other protective genes. This is through nitric oxide, an important signaling molecule in the brain. Once this pathway is understood, one might be able to find ways of pathway modulation for potential therapy for the disease.

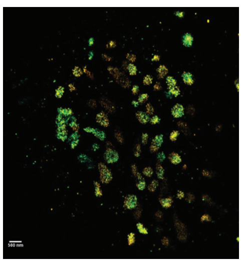
PROF HYOKEUN PARK

Assistant Professor of Life Science

Hunting Huntington's

Prof Hyokeun Park is investigating the roles of brain-derived neurotrophic factor (BDNF). Produced in cell bodies in neurons and transported to synapses, BDNF is important for maintaining synapses in neurons. Research has found that there is a lack of BDNF in the striatum in Huntington's disease patients. Prof Park has observed that there are differences in transport and their release of BDNF-containing vesicles in Huntington's disease mice compared with normal mice. "BDNF is very important for neuron survival. If we can increase the BDNF level in the striatum in Huntington's disease system, it may help slow down the progression of Huntington's disease," he said.





Mitochondrial dysfunction is one of the major contributors to Parkinson's disease.

Left: Dysfunctional mitochondria in a model of Parkinson's disease.

Far left: Healthy mitochondria.

The Power of Proteins

HKUST neuroscientists have made significant advances in understanding synapse and protein trafficking involving kinases C (PICK1), thrombospondin and neuroligin, as well as G-protein-coupled receptors (GPCRs), among others. These are some of the many proteins responsible for changes in neuron communication and information processing that can lead to neurodegeneration.

PICK1 Regulation

Prof Jun Xia, Professor of Life Science, and his team have looked into proteins that are important for synapse formation and function, with advances on thrombospondin and neuroligin published in *Nature Neuroscience*. "Each cell has about 25,000 proteins. Several hundreds are thought to be implicated in neurodegeneration. But we know very little how these proteins act individually or collectively in contributing to neurodegenerative diseases," said Prof Xia.

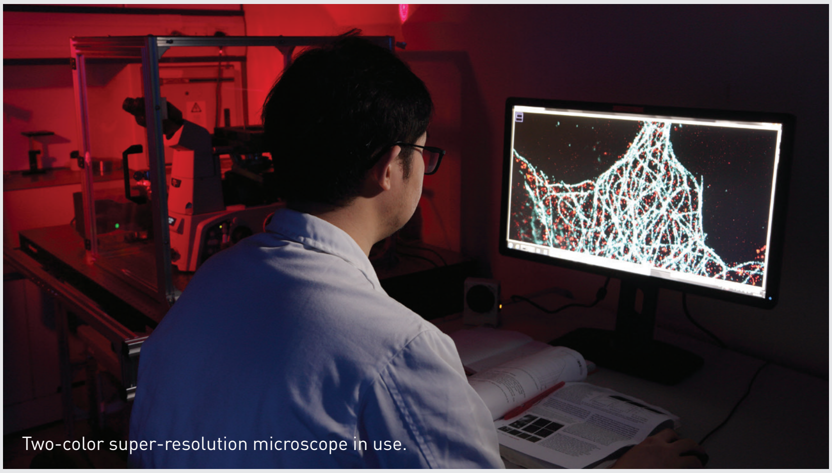
Their studies found that thrombospondin can bind to neuroligin to promote synapse formation. More notably they investigated the regulation of protein trafficking by the PICK1 protein, and how abnormal protein trafficking can contribute to neuron degeneration. Without PICK1 synapse strength cannot be changed, affecting brain plasticity that is vital for normal cognitive functions, including learning and memory.

G-protein

Meanwhile, Prof Yung Hou Wong, Chair Professor of Life Science, and Director of HKUST Biotechnology Research Institute, is studying the molecular mechanisms of how a cell responds to extracellular signals, such as neurotransmitters and hormones. This often involves G-protein-coupled receptors (GPCRs) that use G-proteins to regulate cellular communications in the brain and other organs. They are fundamental to cell communication and malfunctioning of either G-proteins or their receptors may lead to diseases. For example, a defective dopamine receptor system causes Parkinson's disease.

Prof Wong and his team have also screened and identified molecules from traditional Chinese medicinal herbs that work on melatonin receptors, GPCRs that regulate our biological clock. The new drug candidates promise to be more useful than current drugs in treating sleep disorders with fewer side effects, and may also have implications for neurodegenerative diseases, since clinical research shows that patients with these diseases who sleep better have a better prognosis. Melatonin receptors have also been linked with mechanisms that can protect neurons.

Insights into an Infinitesimal World



Two-color super-resolution microscope in use.

Subcellular structures can now be visualized by super-resolution optical microscopes, to the nanometer level.

At HKUST Super-Resolution Imaging Center, physicists Prof Michael Loy and Prof Shengwang Du have taken the lead to work with life scientists, chemists, computer scientists and mathematicians to build state-of-the-art super-resolution localization fluorescence microscopes that are able to resolve tiny structures in cells or tissues that cannot be visualized with traditional optical microscopes. The successful implementation of this technology now underpins the University's strengths in many frontier research areas, including the study of neurodegenerative diseases.

In an on-going study to reveal the molecular organization of subcellular organelles, the central research platform developed focuses on two state-of-the-art microscopes: one stochastic optical reconstruction microscopy (STORM) machine, capable of spatial resolutions of 20 nanometers; and a light sheet microscope with improved sample preservation and fast acquisition times. These advanced tools are helping scientists explore the dynamics of synaptic vesicles in nerve cells and lipid droplets in intestinal cells, and the response of mitochondria to various biological stressors, among others. The project has received almost HK$8 million in funding from Hong Kong Research Grants Council.

The super-resolution microscope allows HKUST neuroscientists to work within a spatial scale previously inconceivable in the probing of the nervous system. The customized microscope is capable of capturing multiple channels at the same time, discerning the relationships between proteins or structures being investigated with high accuracy.

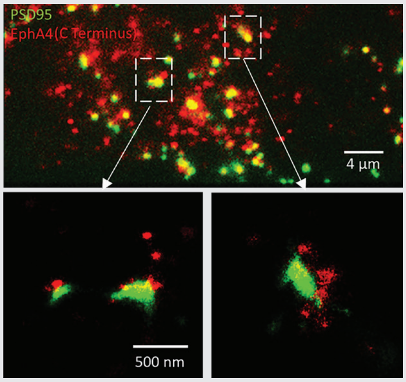
In addition, the team is working on constructing an advanced two-photon light sheet microscope for the observation of living specimens at ultra-high speed, assisted by equipment project funding from the Hong Kong Research Grants Council. Subcellular processes in single cells or embryos can now be recorded in multicolor at speeds of up to 500 frames per second. This provides a new angle to address many biological questions.

PROF MICHAEL LOY

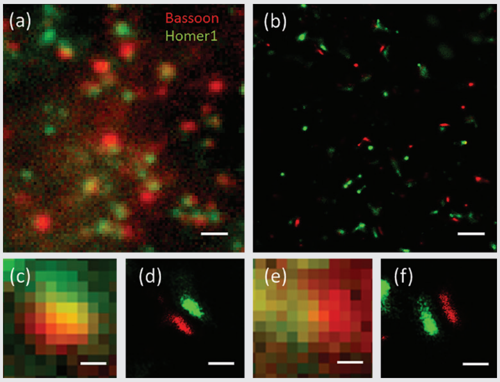
Chair Professor of Physics,
Co-director, HKUST Super-Resolution Imaging Center

“The whole system of super-resolution microscopy is quite complex. If you are a biologist, you might not know what to do with it. If you are a physicist, you might not know what to look at. We recognized this and the two disciplines got together”

Right: Super-resolved structure of the Ephrin receptor (EphA4, red) at peripheral of post synaptic density (PSD95, green) at synaptic region (Prof Nancy Ip Lab).



Far right: Super-resolution microscope can clearly resolve the synaptic structure in mouse brain. (a)(c) and (e) show the EPI-fluorescent image which fails to tell the details of structure. (b) (d) and (f) are super-resolution images acquired by a custom-designed two-color localization microscope. The pre- and post-synaptic structures are clearly resolved. Scale bars: 1μm in (a) and (b); 200nm in (c) and (d).



Given its physical size, population of 1.3 billion, unique history, political and cultural background, and rapid pace of change, China offers challenging terrain for academics to study. Located in the Special Administrative Region of Hong Kong, HKUST economists and social scientists have the academic networks, cultural affiliations as well as global reach to explore the diverse developmental issues facing China. Issues related to aging, corruption, and the labor market are highlighted in this issue

CHINA'S EMERGENCE

AGING **GIANT**

How is the global engine of growth shaping up for a graying but still developing future

China's unparalleled economic rise has lifted 600 million people out of poverty in three decades and turned the country into a key player in the global economy. Now, as the legacy of the one-child policy kicks in, the country's workforce has begun to shrink turning it into a nation that is rapidly aging at the same time as it is developing. Indeed, China has the largest elderly population globally. According to United Nations projections, the current 130 million-plus over the age of 65 are forecast to more than double in the next two decades, reaching one-quarter of China's total population. In 2000, the ratio of the working-age population to the elderly and young population was 12:1. This will drop to around 2:1 by 2050.

The question of how China can meet the challenge of population aging and increasing workforce scarcity is one of the major issues being explored through rigorous data collection and evidence-based analysis by labor economist and China economic development specialist Prof Albert Park. Previously at the University of Oxford, Prof Park joined HKUST in 2011, where he holds a joint appointment as Chair Professor of Social Science and Professor of Economics.

Health and Retirement Insights

HKUST research has been given a tremendous boost by the groundbreaking China Health and Retirement Longitudinal Study (CHARLS), involving Prof Park and academics at Peking University and the University of Southern California. CHARLS builds on the highly influential social science survey model of the Health and Retirement Study pioneered in the US, and is the first effort to extend such state-of-the-art socio-economic data collection to a large developing country. It provides a nationally representative survey following people aged 45 and older over the course of their lives.

The survey program is also distinctive in its aim to continue indefinitely and highly interdisciplinary approach. It contains modules on the family, work and retirement, economic status, health and healthcare utilization, cognition, as well as physical health examinations, including blood samples. Having data from so many different domains enables connections to be drawn that may not be obvious when studying a single discipline, Prof Park said.

The survey polls over 17,500 individuals in more than 10,000 households in 150 counties and districts and 450 villages and urban neighborhoods in 28 of China's 30 provinces (excluding Tibet). Pilot studies began in 2008, with the first CHARLS baseline survey undertaken in 2011. There have been two further waves, with follow-up interviews with individuals in 2013 and 2015.

Showing the evolving nature of the research tools employed, the 2015 survey included an innovative method to measure cognitive function in which respondents are asked to complete different number series in order to measure their fluid intelligence – the capacity to reason and solve logical problems.

Elderly Well-being

In its 2013 baseline report, CHARLS findings drew considerable media attention, revealing that elderly well-being is currently very poor in China. Analysis showed 22.9% of those over 60 – more than 40 million people – lived below the poverty line, and 40% revealed elevated depressive symptoms. Older women were found to be more likely to be in poor physical and mental health than men. Data further showed that only around 47% received financial transfers from non-coresident children and the median transfer amount was modest, indicating that family support for the elderly in China may not be as great a source of assistance as commonly assumed. The overall response rate for the survey was 80%, which is viewed as exceptionally high internationally.

"These people lived through a tumultuous period of history when the country was very, very poor. Even if things subsequently improve a lot, your basic human capital – health, education – are all affected by what you went through when you were young," Prof Park said. "It is a bleak picture today but it will improve for later generations."

In another recent study using CHARLS data ("Age-Expen-

Work Shifts and Labor Costs

Prof Albert Park has been involved in several other data collection projects that provide valuable insights into the Chinese labor market. He played a key role in the China Urban Labor Survey, undertaken with the Chinese Academy of Social Sciences in 2001, 2005 and 2010, with another planned for this year. Each of the earlier surveys investigated the employment situation of over 5,000 urban residents and migrant households in Fuzhou, Shanghai, Shenyang, Wuhan and Xian. The results of research using these data revealed how workers coped with major economic restructuring of state-owned enterprises in the late 1990s as well as the global financial crisis in 2008. Studies also showed how workers' employment conditions have been influenced by the 2008 Labor Contract Law, which significantly improved protection.

In 2015, Prof Park directed a new survey of employers and employees in manufacturing firms in Guangdong, in collaboration with several Chinese institutions, to assess how firms and workers are responding to rapidly rising labor costs. "Chinese firms are now under great competitive pressure and will need to continue to innovate and raise productivity to create high-quality jobs in the next stage of development," he said. "We need to learn more about what factors are influencing this transition."

Thought Leadership on Emerging Markets

The **HKUST Institute for Emerging Market Studies (IEMS)**, directed by Prof Albert Park, was established in 2013, with support from professional services firm Ernst and Young (EY). The Institute's mission is to provide thought leadership on key issues facing businesses and policy-makers in emerging markets. IEMS provides research grants to its 40-plus HKUST Faculty Associates and expands networks with researchers in emerging markets. It also organizes conferences, academic seminars, and business and policy talks to foster discussion and disseminate research findings to a broad audience. The Institute is a member of the World Bank's Network on Jobs and Development initiative, which contributes to the creation of multi-sector, multidisciplinary solutions to the jobs' challenge around the world, based on research and empirical evidence. IEMS is one of four emerging market institutes in different locations supported by EY.

Through the Institute, a series of policy briefs has been regularly published by HKUST faculty, providing research-based policy recommendations on topics including the survival of Hong Kong-owned manufacturing firms in Mainland China, employment gender gap in urban China, internationalization of the renminbi, and minimum wage policies as they affect workers in BRICS (Brazil, Russia, India, China and South Africa).

diture Patterns for Healthcare in China: Are the Rural Elderly Vulnerable", with Qing Xia), Prof Park and his team were the first to document the huge deficit in medical healthcare expenditures of rural elderly as they age.

Policy Relevance and Open Data

From the research findings, several priorities for effectively coping with an aging population have been proposed. These include: increasing benefits of social insurance programs and gradual integration of programs across regions and types; improving quality of preventive healthcare; and raising mandatory retirement ages while designing pension programs that do not detract from work incentives. In addition, the team has undertaken a one-time life history survey of all respondents (results are being analyzed), and is proposing a major study on dementia in China.

Another exciting aspect of CHARLS is that the survey data is publicly available, unlike many China datasets. There are already thousands of registered users, opening the way for developing research excellence around the world in an area of great social need. "CHARLS is well known inside and outside China," said Prof Park. "As more waves of data are collected, it becomes even more useful. It will build on itself. I am very confident that as the project continues this open research tool will become increasingly influential and provide an invaluable data resource to inform policy-making."

"

Following people over time you can get a deeper insight into what determines outcomes as opposed to taking snapshots. You see people before they retire, after they retire, what happens after they get an illness or a spouse passes away. It is much more convincing than comparing groups of people in cross-section

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PROF ALBERT PARK
Chair Professor of Social Science,
Professor of Economics,
Director, HKUST Institute for Emerging Market Studies

Prof Francis Lui took part in the Tsinghua University Forum of China and the World Economy, held in January 2016.

CLEAN SWEEP

The economic consequences of corrupt behavior have been a long-time research focus for Prof Francis Lui

Discussions linking the current anti-corruption crackdown and slowing of the Chinese economy are familiar ground for Prof Francis Ting Ming Lui, who has pioneered research into the economic implications of such behavior since the 1980s. A founding faculty of HKUST's Economics Department Prof Lui is a renowned economist and thought leader in Hong Kong and Mainland China, with frequent contributions in influential news media.

Insufficient Competition

Prof Lui's continuing research into the economics of corruption has shown it to be an imperfect attempt to restore the price mechanism. "An Equilibrium Queuing Model of Bribery", published in the leading *Journal of Political Economy* (1985), and cited over 900 times, was the first to use a highly mathematical model to specify the conditions under which bribery would be a "lubricant" for the economy. He also identified bribery and corruption as a symptom of insufficient market competition rather than a cause. In 1999, "Bureaucratic Corruption and Endogenous Economic Growth" (with co-author I Ehrlich), again published in the *Journal of Political Economy*, combined Prof Lui's past work with new insights following the collapse of the Soviet Union and Eastern European economies, where corruption was discovered to be rampant. In addition, it brought together his work on endogenous growth models, a perspective that views policies, investment capital and a country's internal processes as being the major contributors to economic growth rather than external factors.

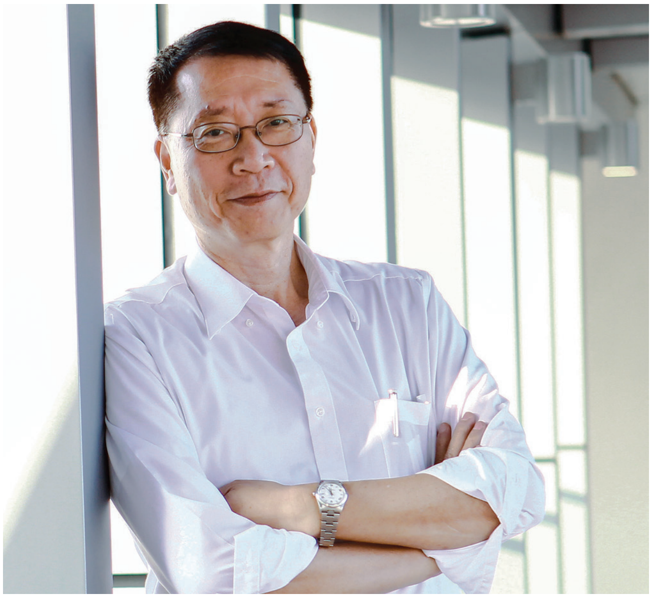
Transferring Research from Campus to Community

An important aspect of HKUST's approach is to bring research findings into arenas beyond the academic community in line with the view that faculty members and researchers have a valuable place in policy and public spheres.

"The impact of academic papers is long term, and its effect on policy-makers may take years to filter down, if at all. To contribute to issues at hand, it is necessary to communicate important ideas accurately in layman's language to popularize the concepts for faster impact," said Prof Francis Lui.

During the Asian financial crisis in the late 1990s, Prof Francis Lui and four other HKUST academics were among a panel of 10 leading economists in Hong Kong invited by the Hong Kong Monetary Authority to give advice. Prof Lui and several economics and finance colleagues also brought their expertise to the public domain through a series of articles in the daily *Hong Kong Economic Journal*, a leading and influential Chinese-language media that covers current economic and financial issues, including state enterprise reform and the role of IT for Hong Kong financial markets.

Prof Lui is frequently quoted in media on China-related economic issues and is also a regular blogger. As an internationally recognized economist, Prof Lui was invited by the Vatican Foundation "Centesimus Annus" to participate in its annual conference in 2013 on "Solidarity and Employment, Is Economic Growth Still Meaningful" and in 2014 on "A Geo-economic View of the World on Growth, Inequalities, and Jobs". He was able to meet the Pope on both occasions.



"Many local government officials do not have the incentive to work as hard or as entrepreneurially as before. This has been seen as one of the reasons for the slowdown in the Chinese economy. There has been a great deal of talk of the lack of lubricant, serving as a support to the theory generated in my original paper."

Long-term Growth

His objective to understand the factors determining China's long-term economic growth – the country's per capita real GDP increase of 21 times since 1978 is unprecedented – and assist policy-making has also led to exploration of demographic transition and incentives to human capital investment conditions.

Prof Lui has looked at the implications of the low fertility rates in Hong Kong and major cities in China ("Demographic Transition, Childless Families and Economic Growth", *The Economic Consequences of Demographic Change in East Asia* [2010]). By 2006, the total fertility rate in Hong Kong was less than one and the proportion of 41- to 44-year-old women with no children was almost 31.8% (39.3% in 2011). Based on data from Mainland China's 2005 one percent population census, he forecast that up to 25% of women in some major Chinese cities, such as Beijing and Shanghai would remain childless by the age of 45.

The canceling of the one-child policy is a good move in his view, though he is less hopeful that the new policy of allowing two children will work. "If you look at the cities in China, many women decide to have zero children. So whether it is a quota of one or two doesn't matter. They would prefer to raise a dog or cat or even a goldfish rather than children."

"There has now been a realization that the current anti-corruption campaign in China has met with difficulties and the economy appears to have stopped working efficiently"

PROF FRANCIS TING MING LUI
Professor of Economics, and Director,
HKUST Center for Economic Development

Prof Lui served as a member of the Population Policy Steering Committee, headed by Ms Carrie Lam, Chief Secretary for Administration of the HKSAR Government.

THE BUSINESS OF *EMOTION*

Marketing research offers tempting insights into consumer decision-making

There is a saying that flattery gets you nowhere. However, HKUST research on the effects of flattery in the retail context proves that in reality it can get you very far. And if we want to deny we are susceptible to a little ego stroking we might heed the words that Shakespeare gave to a conspirator in this observation of the emperor Julius Caesar.

"But when I tell him he hates flatterers,
He says he does, being then most flattered."

Prof Jaideep Sengupta, Chair Professor of Marketing, has long been intrigued by emotions such as flattery, envy, temptation, loneliness and helplessness, and the interface between the psychology they involve and the art and science of marketing.

The theoretical understanding he has brought to how people make decisions because of these emotions has huge implications for both how we understand ourselves and applications in marketing practice. It is no wonder that his research has caught the imagination of fellow academics and the business community the world over.

Prof Sengupta's research falls into two broad areas – consumers' responses to communications from marketers; and their behavior in the retail context: how we make choices.

"At a basic level I try to figure out how and why consumers react to certain bits of marketing information in the way they do. I also like to think by doing that I get a deeper understanding about how we as human beings think and process information," he explained. "What are our hidden motivations? What kinds of unconscious biases do we have? And how and why do we make certain decisions, even outside the consumer realm?"

Flattery Pays

Prof Sengupta's work on flattery, conducted with his PhD student Elaine Chan, has generated new understanding of the role of flattery in inducing purchasing decisions. One study involved analyzing the responses of 55 students who received blatantly flattering messages in a leaflet from a fictional department store. The students' instant (implicit) and more considered (explicit) responses to questions about the store were measured, and three days later they were again asked about their attitudes towards the store and their purchasing intentions.

We would all like to think that flattery – particularly in its most blatant and insincere forms – does not work, as previous research on our rational responses had shown. But the team suspected that there were more complex responses going on and came up with a hypothesis that alongside the explicit or rational negative reaction there would be an implicit positive one, at the gut level beyond our control.

Prof Sengupta and Dr Chan not only found their hypothesis to be correct but also – in an impressive testament to the power of flattery – showed that after three days it was the positive automatic reaction that guided behavior: individuals who had been flattered earlier were more likely to actually purchase from the store.

> Understanding your customer's psychology – and everyone has a customer – is the only way of ensuring that they stay with you
>
> **PROF JAIDEEP SENGUPTA**
> Chinese Estates Professor of Business, Chair Professor of Marketing

The researchers then explored what it takes to resist this type of pressure. What they theorized, and found to be correct, was that if our susceptibility to flattery comes from the need to be self-affirmed, then if we have just done something that makes us feel good we are less likely to succumb to its power. For this study, students were asked to write positive things about themselves before being exposed to the flattery. And as suspected, now that their self-esteem had been raised, even their implicit reaction to the flattery was no longer as positive.

Taking the theme further in a second paper, the researchers looked at what happens if a third person observes another person being flattered. In this case, the student customers were asked to read complimentary comments – this time, genuine-sounding compliments – from a salesperson about another customer before providing their own reactions to that salesperson. Previous research had shown that observers approve of a genuine praise-giver. However, from his knowledge of psychology, Prof Sengupta suspected that human beings are, implicitly, not so altruistic. This is because another motivator – envy – kicks in.

What this research on envy proved was that not only does it trigger the shopper to dislike both the flattered customer and the flatterer, but it motivates them to reduce their envy by buying more expensive products. A similar scenario in real life is in an office context when a boss enthuses over a particular employee's work – in front of other employees. "Conventional wisdom says that one should criticize in private but praise in public. But we suggest that even praising in public can be dangerous because while you might make that person feel good – you are triggering other employees to both dislike you and that person!" said Prof Sengupta.

Such groundbreaking consumer research, which carries both theoretical and practical value, has helped HKUST achieve an enviable standing as one of the leading business schools in Asia, and the world, according to global rankings such as Quacquarelli Symonds (QS) World University Rankings.

Prof Sengupta's research is particularly relevant for marketers in China. "They are fascinated by this work on consumer psychology. They see that the idea of getting inside the consumer's head is vital as they move beyond a simple manufacturing edge to becoming a marketing power and building premium brands."

Temptation and Financial Decisions

Prof Sengupta has found intriguing paradoxes when it comes to how we deal with temptation - research that is relevant to global concerns about obesity. His work provides tips for those looking to resist that delicious piece of dessert – just think of a time when you actually gave in. The psychology at work? Remembering such a time makes you feel that your goal to indulge has been partly satisfied – and that makes you more likely to behave "better" this time around.

In another fascinating study in this area, Prof Sengupta's team has found that just being exposed to a temptation can transform our behavior in a different domain. When an impulsive person was sat in front of a piece of cake, this produced a risk-taking, reward-seeking way of viewing the world. This then translated to financial decisions they were asked to make – such as buying riskier mutual funds over safe bonds. However, if shown a healthy dessert, the safer (and lower-reward!) bonds were more likely to be chosen.

Prof Sengupta's work on envy, jealousy, flattery and temptation – all of which explore the rich psychology of human behavior – is partly inspired by his passion for literature. His parents were both professors of English literature and he grew up steeped in works such as Shakespeare's *Othello* in which jealousy is the downfall of the Moorish king. And what is he doing next? "The emotion of envy is one that I find fascinating – so I'm doing a lot of work on that. I would especially like to study it in the context of social media platforms like Facebook, because Facebook to me is the world's most gigantic envy-inducing platform there is."

Now that is research to look forward to – even though it might tell us a few uncomfortable truths about our psyche.

Good Things Come in Small Packages

Prof Jaideep Sengupta has done extensive research on consumer decision-making in the retail context. One example is the impact of packet size. In an experiment, people were offered orange juice from small and large cartons and asked to rate the taste of the drink. The product from the smaller package was invariably rated as tasting better, even though the contents were identical. The reason? Smaller packages provide less bang for the buck – their price per volume is higher. And consumers therefore think of them as being of higher quality: which then affects how enjoyable they find the drink.

The takeaway for marketers is that if you are targeting the high-end market segment, then smaller packaging is good. The value segment, meanwhile, will appreciate the larger.

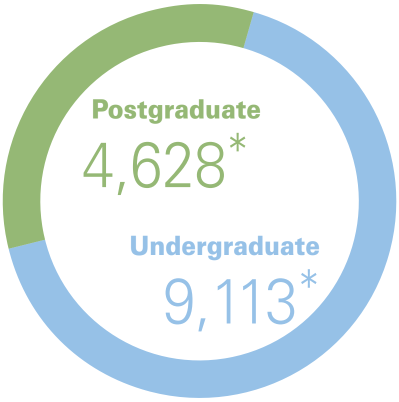
FACTS AT A GLANCE

Established

October 1991

Academic Departments and Divisions

20



Student Enrollment

13,741*

Faculty Members (Regular)

545*^

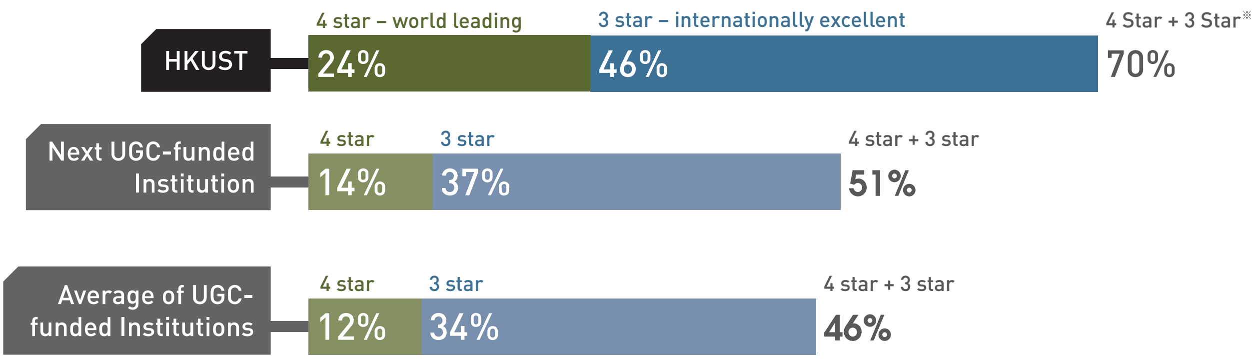
University Rankings*

HKUST		
#2	World's Top 50 Universities Under 50 (two years in a row)	QS Top 50 Under 50 2014-2015
#5	World's Top 300 Asian Universities	QS Asian University Rankings 2015
#7	Asia's Top 100 Universities	Times Higher Education Asia University Rankings 2015
#14	World's Top 150 Universities	Emerging Global Employability University Ranking 2015
#28	World's Top 800 Universities	QS World University Rankings 2015/16
School of Science		
#14	Asia's Top 100 Universities in Natural Sciences	QS Asian University Rankings 2015
#15	Asia's Top 100 Universities in Life Sciences and Medicine	QS Asian University Rankings 2015
#29	World's Top 400 Universities in Natural Sciences	QS World University Rankings 2015
#37	World's Top 100 Universities in Physical Sciences (No. 1 in Hong Kong)	Times Higher Education World University Rankings 2015/16
School of Engineering		
#8	Asia's Top 100 Universities in Engineering and Technology (No. 1 in Hong Kong)	QS Asian University Rankings 2015
#14	World's Top 400 Universities in Engineering and Technology (No. 1 in Hong Kong for six years in a row)	QS World University Rankings 2015
#16	World's Top 100 Universities in Engineering and Technology (No. 1 in Greater China)	Times Higher Education World University Rankings 2015/16
School of Business and Management		
#2	Global EMBA Ranking – for the School's Kellogg-HKUST EMBA Program (two years in a row)	Financial Times EMBA Rankings 2014-2015
#14	Global MBA Ranking – for the School's Full-Time MBA Program	Financial Times MBA Rankings 2015
#10	Asia's Top 100 Universities in Social Sciences and Management	QS Asian University Rankings 2015
#21	Top 100 Business School Research Rankings (No.1 in Asia)	University of Texas at Dallas (UTD) Business School Research Rankings 2015
School of Humanities and Social Science		
#10	Asia's Top 100 Universities in Social Sciences and Management	QS Asian University Rankings 2015
#26	World's Top 400 Universities in Social Sciences and Management	QS World University Rankings 2015
#37	Asia's Top 100 Universities in Arts and Humanities	QS Asian University Rankings 2015

*as at December 2015
^includes teaching-track faculty

Research Assessment Exercise 2014

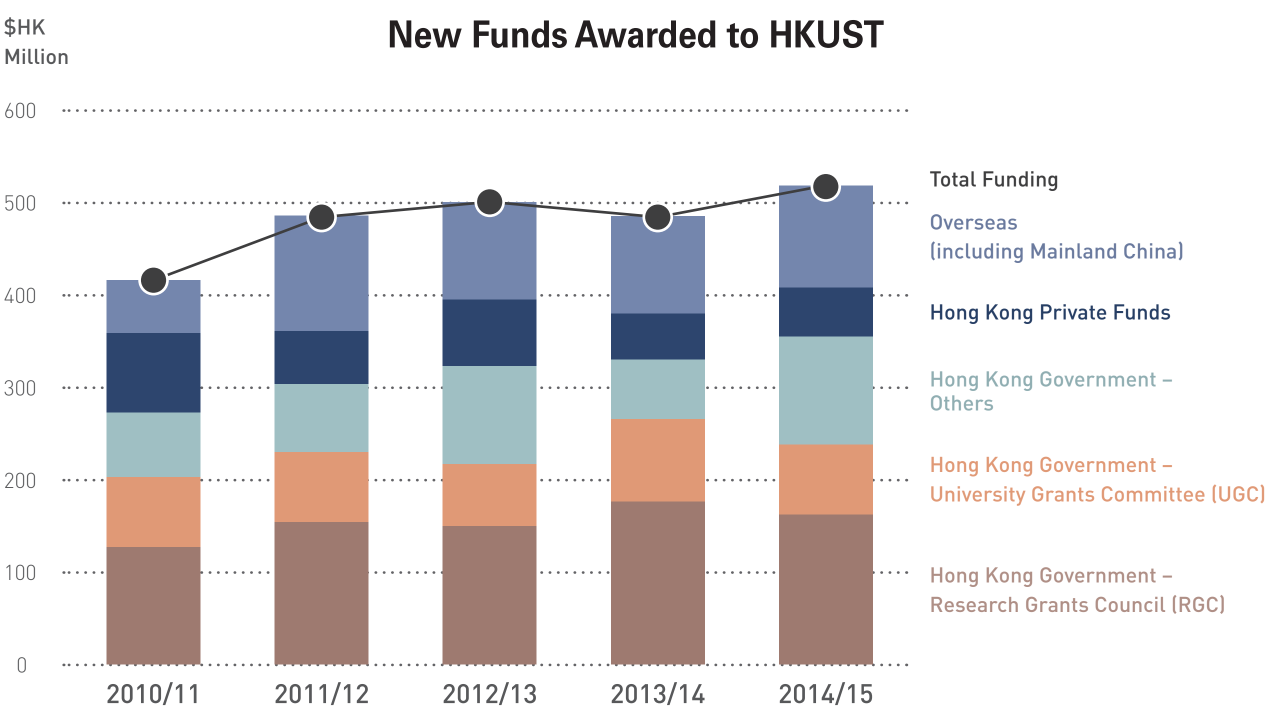
The Research Assessment Exercise (RAE) in 2014 sought to independently assess the research quality of Hong Kong University Grants Committee (UGC)-funded institutions according to rigorous international standards. The research submissions of all Hong Kong academics were assessed by an international panel of 307 distinguished experts. HKUST topped the institutional assessment with a remarkable 70% of its submissions rated either "world leading" (4 star) or "internationally excellent" (3 star), a strong recognition of the research excellence of the University.



※22% of HKUST submissions were rated "international standing" (2 star).
More information on RAE 2014 is available at *http://ugc.edu.hk/eng/ugc/publication/press/2015/pr27012015.htm.*

External Competitive Research Funding

(excluding Government block grants)



Current Major Grants

Areas of Excellence (AoE) Scheme, Theme-based Research Scheme (TBRS) and Collaborative Research Fund (CRF) are large-scale group research grants awarded by Hong Kong Research Grants Council. The grants support internationally recognized research expertise in order to develop areas of excellence that can help maintain and enhance Hong Kong's overall development. They also support research areas of strategic importance for Hong Kong's long-term development, and encourage out-of-the-box cross-disciplinary projects.
Partner State Key Laboratory (PSKL) and Hong Kong Branch of **Chinese National Engineering Research Center (CNERC)** are national research laboratories approved by the Ministry of Science and Technology of China.

Partner State Key Laboratory

Partner State Key Laboratory on Advanced Displays and Optoelectronics Technologies
PROF HOI-SING KWOK

Partner State Key Laboratory of Molecular Neuroscience
PROF NANCY IP

Hong Kong Branch of Chinese National Engineering Research Center

Hong Kong Branch of Chinese National Engineering Research Center for Control and Treatment of Heavy Metal Pollution
PROF GUANGHAO CHEN

Hong Kong Branch of Chinese National Engineering Research Center for Tissue Restoration and Reconstruction
PROF BEN ZHONG TANG

Areas of Excellence Scheme

Mechanistic Basis of Synaptic Development, Signaling and Neuro-disorders
PROF MINGJIE ZHANG

Novel Wave Functional Materials for Manipulating Light and Sound
PROF CHE TING CHAN

Theme-based Research Scheme

Smart Urban Water Supply Systems (Smart UWSS)
PROF MOHAMED S GHIDAOUI

Understanding Debris Flow Mechanisms and Mitigating Risks for a Sustainable Hong Kong
PROF CHARLES WW NG

Stem Cell Strategy for Nervous System Disorders
PROF NANCY IP

Cost-effective and Eco-friendly LED System-on-a-Chip (SoC)
PROF KEI MAY LAU

Transforming Hong Kong's Ocean Container Transport Logistics Network
PROF CHUNG YEE LEE

Collaborative Research Fund

Group Research Projects

Coping with Landslide Risks in Hong Kong under Extreme Storms: Storm Scenarios, Cascading Landslide Hazards and Multi-hazard Risk Assessment
PROF LIMIN ZHANG

Dynamics of Soft Matter at Interfaces: Theory, Simulations and Experiments
PROF PENGER TONG

Total Municipal Organic Waste Management by Integrating Food Waste Disposal and Sewage Treatment (MOW-FAST)
PROF GUANGHAO CHEN

Super-resolution Imaging: Revealing the Molecular Organization of Subcellular Organelles
PROF KARL HERRUP

Research in Fundamental Physics: From the Large Hadron Collider to the Universe
PROF HENRY TYE

Protein Trafficking: Mechanism and Diseases
PROF JUN XIA

From Molecular Dynamics to Systems Biology: A Multi-scale Approach Tightly Integrating Simulation and Experiment to Quantitatively Analyze the Transcription Accuracy of RNA Polymerase II
PROF XUHUI HUANG

Elucidation of the Role of Pax7 in Muscle Stem Cells
PROF ZHENGUO WU

The Role of IL-33 in Synaptic Dysfunctions and Pathogenesis of Alzheimer's Disease
PROF NANCY IP

New Topological States in Cold Atom and Condensed Matter Physics Systems
PROF KAM TUEN LAW

Green Slope Engineering: Bioengineered, Live Cover Systems for Man-made Fill Slopes and Landfill Capillary Barriers in Hong Kong
PROF CHARLES WW NG

Study of Microglia and Acute Myeloid Leukemia in Zebrafish
PROF ZILONG WEN

Equipment Projects

Super-resolution Electron Microscopy Facility for Cross-disciplinary Materials Research
PROF NING WANG

Two-photon Light Sheet Microscope System for Deep and Fast Live Imaging
PROF MICHAEL LOY

A Mask-Making System for Nanoelectronic Device and Circuit Fabrication
PROF MAN SUN CHAN

Research Infrastructure

One of the distinctive features of HKUST's founding vision in 1991 was to encourage interdisciplinary research from the University's earliest days. Recognizing the complexity of a globalized world and the cross-field challenges that issues such as climate change and sustainability presented, the University made key infrastructural provisions to assist top minds in working together to build solutions.

Research Institutes and Centers

A centrally located Academic Building assisted in keeping many faculty members in different fields in close proximity to each other and created the opportunity for natural and frequent interaction. The establishment of research institutes and centers, now numbering 12 and more than 50 respectively, fostered cooperation across traditional boundaries. Key research institutes are:

- HKUST Jockey Club Institute for Advanced Study
- William Mong Institute of Nano Science and Technology
- Institute for the Environment
- Energy Institute
- Robotics Institute
- Big Data Institute
- Institute for Emerging Market Studies
- Institute for Public Policy

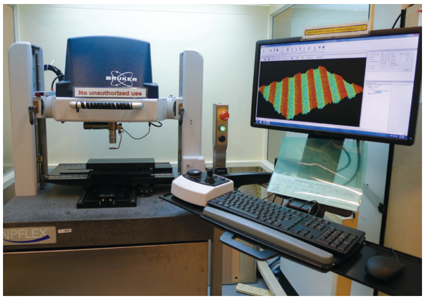
Central Research Facilities

The concept of centralized research facilities provided the University's researchers with opportunities for collaboration and joint research with other institutions and industry. The cutting-edge nature of many of them has also aided HKUST researchers in setting the pace in many fields. They include:

CLP Power Wind/Wave Tunnel Facility: world-class experimental facility to test wind effects on structures and the environment.

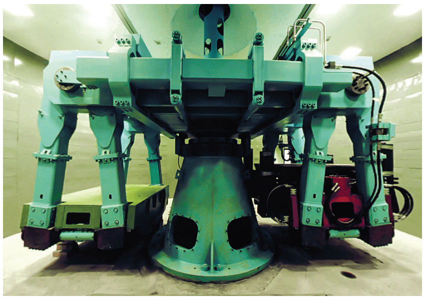
Biosciences Central Research Facility: provides state-of-the-art communal equipment, training, and other activities to aid R&D in all areas of biological sciences.

Nanosystem Fabrication Facility: the first and only complete nanofabrication facility set up in a tertiary institution in Hong Kong.



Design and Manufacturing Services Facility: provides unique service such as design and fabrication of sophisticated mechanical and electronic parts/equipment, nano measurements, computer-aided engineering analysis, 5-axis metrology, and reverse engineering.

Materials Characterization and Preparation Facility: a core facility throughout the University's history. New platforms include the HKUST-Raith Nanotechnology Laboratory, Super-resolution Electron Microscopy Platform, and Center for 1D/2D Quantum Materials.



Geotechnical Centrifuge Facility: physical modeling of engineering problems using the world first in-flight 2D shaking table and the state-of-the-art 4-axis robotic manipulator.

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THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY