



# STATE KEY LABORATORY OF ADVANCED DISPLAYS AND OPTOELECTRONICS TECHNOLOGIES



# WELCOME

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## ABOUT US

The State Key Laboratory was opened in 2013 upon the approval by Ministry of Science and Technology (MOST) of the Central Government. It was initially operated by the collaboration between the Hong Kong University of Science and Technology and Sun Yat-Sen University.

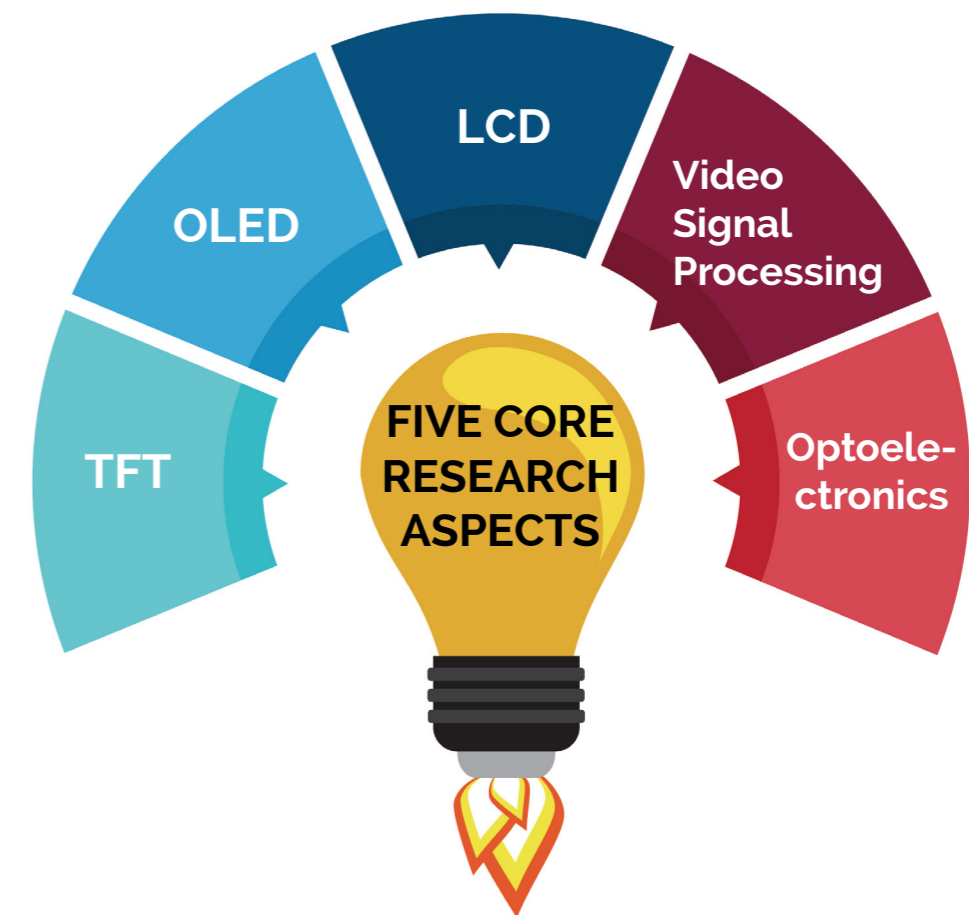
In September 2018, Partner SKL was renamed into State Key Laboratory (SKL), following the agreement by MOST and the Innovation & Technology Bureau on commencing joint-funded projects. It signifies a more solid support and recognition to the State Key Laboratory of Advanced Displays and Optoelectronics Technologies (SKL of ADT). Prof. H.S. Kwok, Dr William M W Mong Chair Professor of Nanotechnology, and also the Department of Electronic and Computer Engineering, serves as the Director of the laboratory. The research team consists of 23 professors from School of Engineering and School of Science, including Prof. Ching W. Tang, who is internationally known as "Father of OLED". Since the establishment of Centre for Display Research, the laboratory has published over 2000 papers and obtained over 100 US patents and 60 Chinese patents.

## OUR OBJECTIVES

- Become the leading display research center in China
- Collaborate with the display industry and market to develop advanced displays and optoelectronics technologies
- Generate intellectual properties on display and optoelectronics technology
- Create a world-class platform for exchanges between Chinese and foreign researchers on display research

The SKL's research focuses on exploring cutting-edge and highly industrial-applicable display inventions. The SKL explores five core aspects: (1) thin-film transistors (TFTs); (2) organic light-emitting diodes (OLEDs); (3) liquid-crystal displays (LCDs); (4) video information processing and circuit design; and (5) flexible, high-resolution silicon LED and nano-optoelectronic displays.

The SKL places particular emphasis on "green displays" such as active matrix OLED (AMOLED) displays, field sequential color LCDs (FS-LCDs) and bistable LCDs, all of which feature low power consumption. In addition to conducting research, the SKL also offers training and short courses for enterprises in mainland China, as well as organizes seminars and conferences with international research institutes.



# FACILITIES



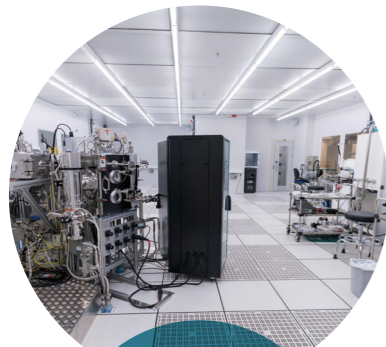
Centre for Display Research

The Centre for Display Research (CDR) at HKUST was established with seed funding from the Hong Kong Government's Trade and Industry Department. CDR provides technical support services for local LCD manufacturers, conducts research in advanced displays that will be of value to the local industry and trains students with hands-on experience in LCD manufacturing for the local industry.

The Nanosystem Fabrication Facility (NFF) of HKUST is the first microfabrication laboratory established at a tertiary institution in Hong Kong. The mission of the NFF is to provide facilities for the faculty and students of the HKUST to conduct teaching and research, particularly in new discrete semiconductor devices, novel microsensors and microactuators, advanced nanoelectronics process technology and application-specific integrated circuits (ASIC).



Nanosystem Fabrication Facility



Organic Electronics Laboratory

The Organic Electronics Laboratory (OEL) has a floor space of 1,030 square meters and resides in Cheng Yu Tung Building. Built in 2016, OEL is led by Prof. Ching W. Tang, Chair Professor in the Department of Electronic and Computer Engineering and currently the Director of SKL. Advanced equipment for OLED research and development has been deployed in OEL to expand the research capability of the SKL. Last year, a cluster tool was installed as a key instrument for OLED degradation study and deposition process development. It comprises a central transfer chamber for substrate delivery and five detachable process chambers for device fabrication. OEL provides a platform for researchers to conduct fundamental research on OLED materials and devices and to develop new technologies for advanced OLED displays.



## MAJOR EVENTS & MILESTONES

# International Conferences & Seminars

SKL has organised a total of eleven joint seminars with Department of ECE and SID HK Chapter from 2018 until now. Apart from organizing seminars, the research team also actively participates in international conferences around the world.

## SID Display Week 2018

May 20-25, 2018 | Los Angeles



The team led by Prof. Kwok and Prof. Srivastava won the "Best Prototype in Innovation Zone" award from The Society for Information Display with their new display technology. (See more on p.16)

## Shun Hing/Panasonic Expo-The Future of Living

Nov 7-10, 2018

Hong Kong Convention and Exhibition Centre



SKL was invited to showcase the University's scientific research projects and achievements.

## Postgraduate Workshop on Display Research (PGWS) & 2nd Advances in Display Workshop

Dec 3-4, 2018 | HKUST and HK Science Park



Professors and students from seven participating universities gathered at HKUST. Four speakers were also invited at the Advances in Display Workshop held in Science Park the next day.

## The 25th International Display Workshop (IDW'18)

Dec 12-14, 2018 | Nagoya, Japan



Dr. Fion Yeung at her oral presentation and Prof. Srivastava at his invited talk.

## 2019 International Conference on Display Technology (ICDT)

Mar 26-29, 2019 | Kunshan, Suzhou, China



With China becoming the new driving engine for global display industry, SID has set up operations entity in China and organized the ICDT. 2019 marks the third year of this conference.

## SID Display Week 2019

May 12-17, 2019 | San Jose



Prof. Kwok was awarded the prestigious Jan Rajchman Prize at the SID. The award was presented during the Society for Information Display (SID) Award Banquet on May 13, 2019. (See more on p.18)

## Visitors for academic exchange

As one of the significant laboratories at the University, SKL receives various group of visitors and delegation every year. The lab visits provide a more in-depth understanding about the school's research excellence and also to explore possible collaboration opportunities.



Mr. Huang Wei, Vice Minister of the Ministry of Science and Technology



Mr. Huang Liuquan, Deputy Director of HK and Macao Affairs of The State Council



Mr. Somkid Jatusripitak, Thai Deputy Prime Minister of Economy



Standing Committee of Beijing Municipal Committee of CPC



Young entrepreneurs and students from SUN Start-UP Network of Germany



Japan Science and Technology Agency (JST)



Beijing Municipal Party Committee Organization Department



Sun Hung Kai Properties (Left) and Mr. Xie Ming, Deputy Director of Nansha FTZ and his delegation (Right)



Delegation from Dongguan Science and Technology Bureau (Left) and the Photonics Industry & Technology Development Association of Taiwan (Right)



Mr. Wang Zhigang, Minister of the Ministry of Science and Technology



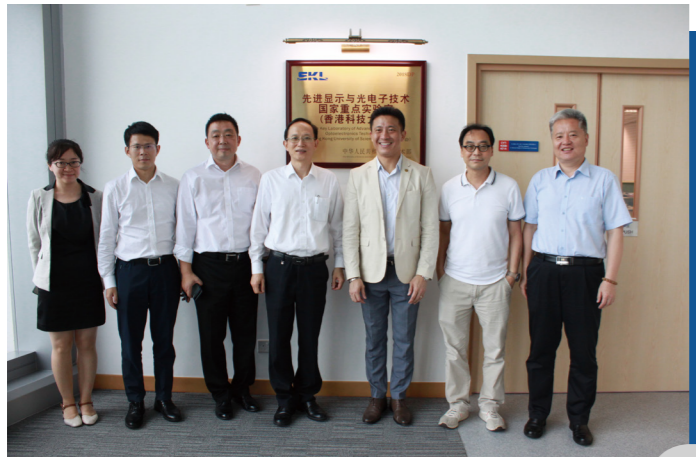
Department of Educational, Scientific and Technological Affairs, LOCPG

KONKA Group Co. Ltd (Left) and K. Wah Group Co. Ltd (Right)



Belarusian State University of Informatics and Radioelectronics (Left) and Shenzhen Development and Reform Commission (Right)





Delegation from Shenzhen Longhua District



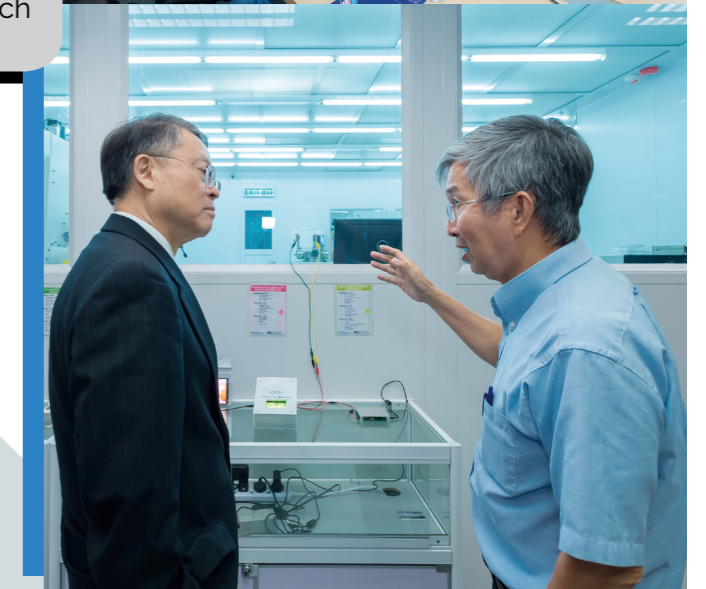
Riizhao government officials (top) and senior government officials of the Plan of Greater Bay Area (bottom)



Qianhai Inno-Tech Investment (top) and Consul General of Singapore, Ms FOO Teow Lee (bottom)



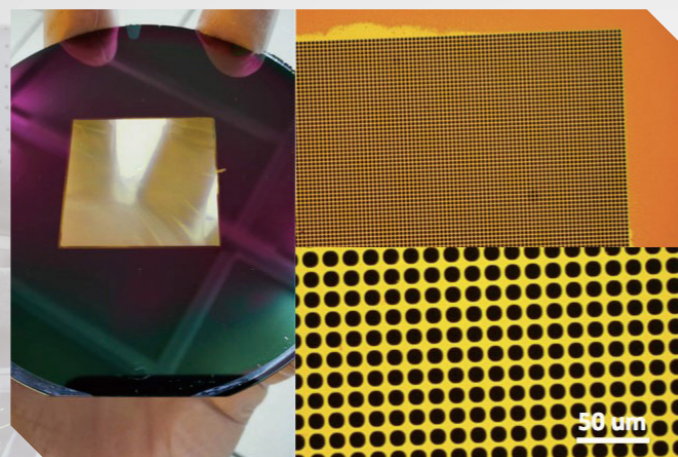
President Mianheng Jiang of ShanghaiTech University



# Achievements

## OLED

To realize ultrahigh resolution OLED displays for VR/AR applications, we have successfully developed silicon nitride (SiNx) based shadow masks for OLED pixel patterning. We have achieved 2000 PPI resolution in these shadow masks with diagonals up to 3 inches. These SiNx shadow masks can be mass-produced by standard micro-fabrication processes.



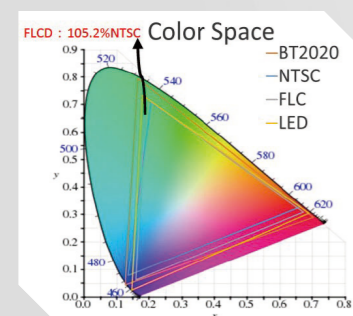
## μLED display system

Our team has developed a smart μLED display system employing VLC as the near-field communication (NFC) technology for portable devices equipped with μLED displays. In the transmitter, a VLC modulator is integrated into a 400×240 gallium nitride (GaN) μLED display with a pixel size of 30×30 μm<sup>2</sup> to enable simultaneous display and VLC functions.

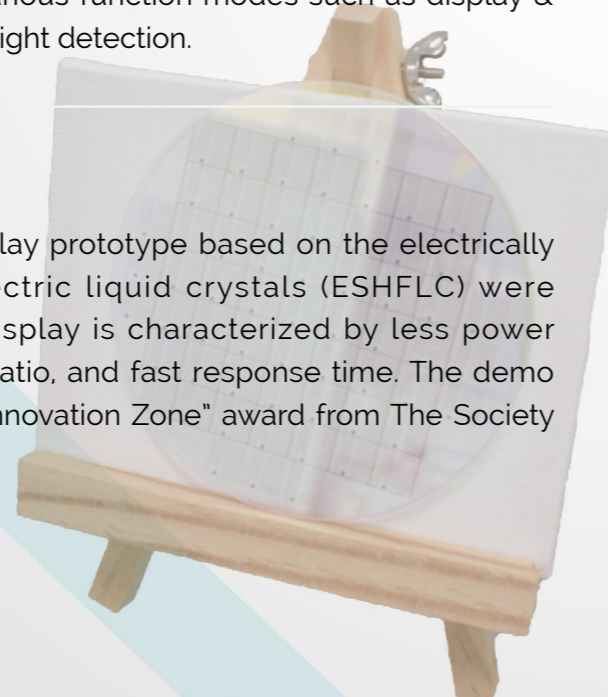
## Micro-LED

We proposed a fully functional time-division multiplexing GaN-based Micro-LED devices. With appropriate bias conditions, the devices worked under various function modes such as display & lighting, temperature sensing, light energy harvesting, and light detection.

## ESHFLC



A field sequential color display prototype based on the electrically suppressed helix ferroelectric liquid crystals (ESHFLC) were developed. The ESHFLC display is characterized by less power consumption, high contrast ratio, and fast response time. The demo won the "Best Prototype in Innovation Zone" award from The Society for Information Display".

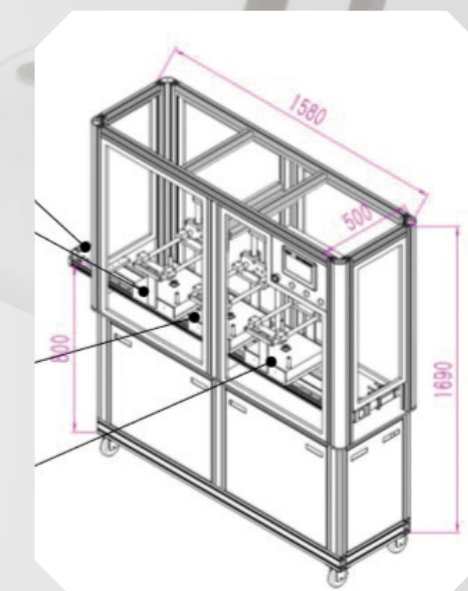


## Novel Metal Oxide Thin-Film Transistors

MO-based circuits were developed by monolithically integrating enhancement-mode and depletion-mode MO TFTs, showing high performance with easy integration process. High flexibility is pursued by not only the display but also the internet of things (IoT). MO-based flexible circuits were successfully developed in 2018 and are under the process of commercialization

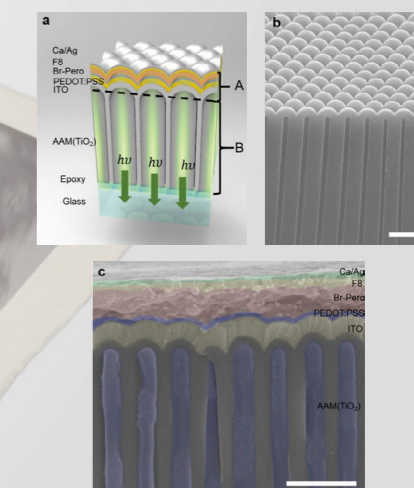
## Photoalignment technology commercialization

A lot of research works on photoalignment technology application areas, namely IPS TFT LCD and VA passive LCD, have been done. We found that the alignment effect on the CF plate is not as good as in the Array plate. For the VA passive LCD application, we have got a higher viscosity mixture and there is no CF plate. We can apply a conventional APR printing method. To facilitate our photoalignment technology application, we have also designed a new light exposure system. Patent is filed for this 45° uniform LED light emission head.



## Perovskite LEDs

With a systematic optical study, we found that the light extraction enhancement arises from a two-step light management process, namely light coupling from nanodomains and optical antennas effect from photonic crystals. Our efforts on the nanophotonic PeLEDs help researchers to further improve the device performance from the nanophotonic engineering perspective.





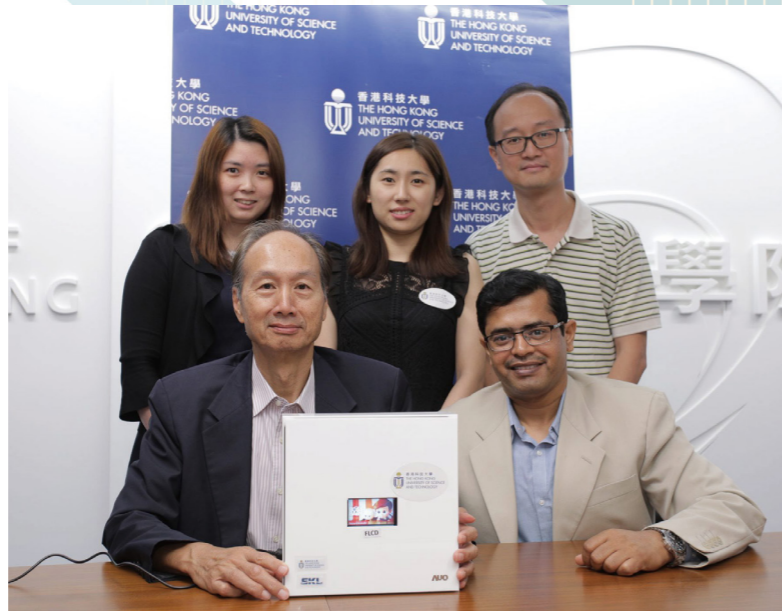
# HKUST Develops a New Generation of LCD with Higher Efficiency, Resolution and Color Performance

2018-07-03

Known as Active Matrix Ferroelectric Liquid Crystal Display (FLCD) - this latest technology developed by a research team led by Chair Professor from the Department of Electronic and Computer Engineering Prof Kwok Hoi-Sing, will see energy efficiency jumped by 3-5 times, and image resolution enhanced by three times – at a lowered cost.

Conventional displays have limited energy efficiency, as color filters block and consume 70% of the backlight and energy. To replace color filters, the team developed a field sequential color technology – enabled by fast ferroelectric liquid crystal, which allows display of color images sequentially in time. This technology relies on human vision to fuse these fast-switching images into a full-color picture, so color filters are no longer necessary. The overall result was a cheaper yet higher-quality display.

Color saturation of the new display is also boosted as the team adopted RGB LED for the backlight instead of the commonly used LED. RGB LED's narrow spectrum contributes to wider color gamut (ranges of color), allowing FLCD to outperform any



Front row: Research team leaders Prof. Kwok (left) and Prof. Srivastva.

display alternatives available today. Its image resolution also increased by three times as the sub-pixels for different colors are removed.

"The FLCD requires relatively low power consumption, so it is highly suitable for portable electronic devices such as smartphones, tablets and laptops, which batteries can live longer than they do now. The new display could also be applied in high-end displays such as virtual reality headsets and head-mounted displays with its higher resolution and color performance," Prof Kwok said.

Developed in collaboration with AU Optronics (AUO) from Taiwan, Prof Kwok's team has recently won the "Best Prototype in Innovation Zone" award with this new technology from The Society for Information Display.



News coverage of the award-winning technology known as FLCD.

# HK, Mainland sign I&T pact

2018-09-20

Joined by Minister of Science & Technology Zhigang Wang, Chief Executive Carrie Lam today witnessed the signing of the Arrangement on Enhancing Innovation & Technology Co-operation between the Mainland and Hong Kong. The Chief Executive met Mr Wang before the signing and plaque presentation and hosted a lunch for the ceremony's guests afterwards at Government House.

The agreement was signed by Secretary for Innovation & Technology Nicholas Yang and Vice Minister of Science & Technology Zhang Jianguo.

The Ministry of Science & Technology (MOST) and the Innovation & Technology Bureau also signed an agreement on commencing jointly funded projects.

A plaque presentation ceremony by Mr Wang followed to mark the renaming of the 16 Partner State Key Laboratories in Hong Kong into State Key Laboratories from today, giving them more flexibility to collaborate with different research and development institutions.



President of HKUST Prof. Wei Shyy and Director of SKL, Prof. Kwok received the new laboratory plaque from Minister of MOST Zhigang Wang.

The arrangement and the agreement signed mark a new page of scientific and technological collaboration between the Mainland and Hong Kong. The presentation of plaques to State Key Laboratories is also of great significance, as this would provide more flexibility for the collaboration between the State Key Laboratories of Hong Kong and the research institutes in the Mainland. It also means solid support and recognition to the State Key Laboratory of Advanced Displays and Optoelectronics Technologies (SKL of ADT).

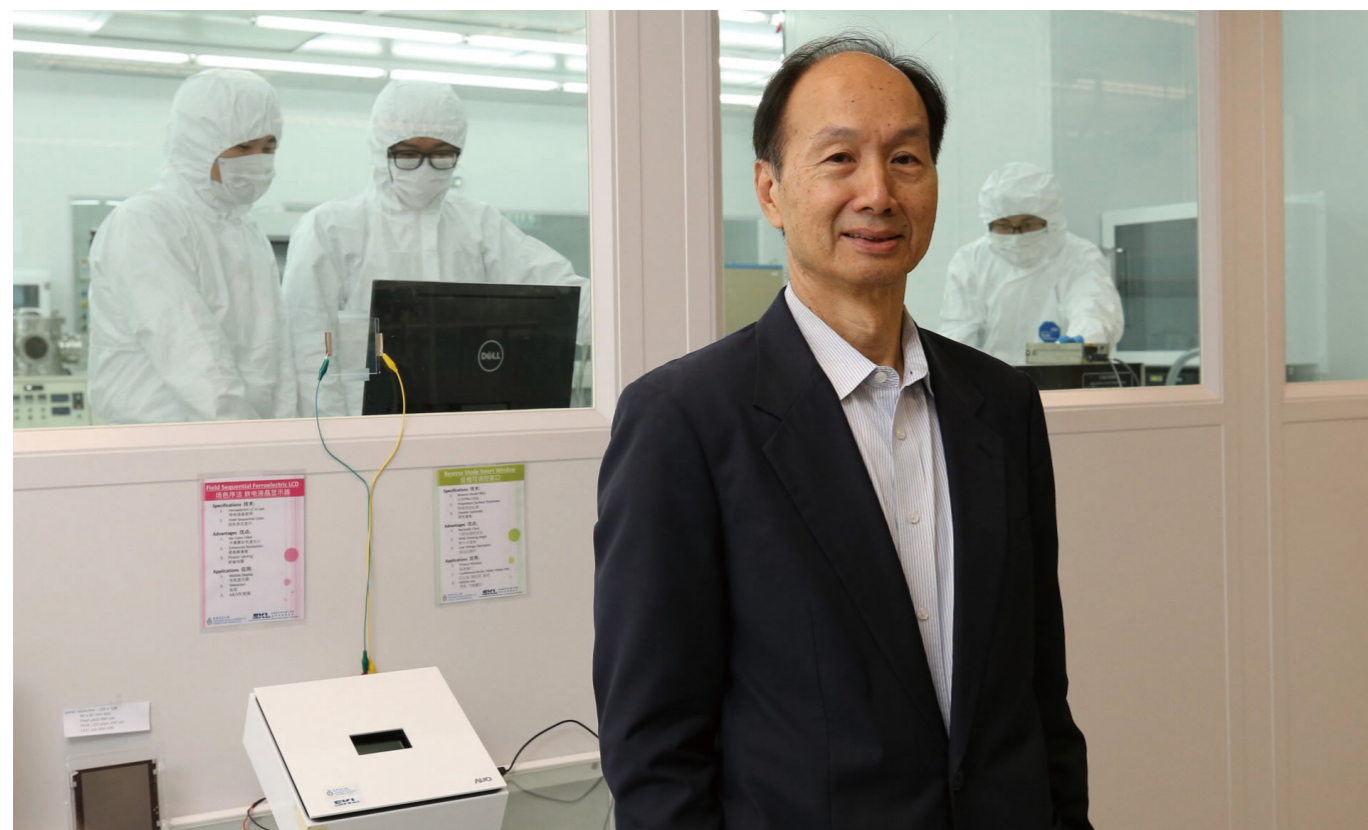


Chief Executive Carrie Lam met with Wang Zhigang at the Government House today with guests who are invited to the ceremony, including the president of local universities and representatives of local R&D institutions.

## Prof. KWOK Hoi-Sing Reaps Prestigious Prize for Contributions to LCD Science and Technology

2019-05-17

Prof. KWOK Hoi-Sing, has been awarded the prestigious 2019 Jan Rajchman Prize by the Society for Information Display (SID). The honor recognizes an outstanding scientific or technical achievement in, or contribution to, research on flat panel displays.



Prof. Kwok Hoi-Sing, who has spent over a quarter of a century researching on display technology, said he felt tremendously honored to receive the prestigious Jan Rajchman Prize.

The award citation says the accolade was presented to Prof. Kwok "for his contributions to liquid-crystal display (LCD) science and technology, and particularly to photoalignment technology and bistable displays".

"I feel tremendously honored to receive this recognition. Indeed this is a high point in my research work on display technology that spanned over one quarter of a century," said Prof. Kwok.

"While we have made incremental improvements to numerous aspects of display technology, what I would label as a 'breakthrough' is in the speed of response in liquid-crystal display. The response

used to be 10 milliseconds. We reduced it 500 times and now the response time can be as short as 100 microseconds. Also, our recent technology on coatable polarizers may revolutionize the way we make flexible and foldable displays," Prof. Kwok said.

The prize was presented during the SID Award Banquet on May 13, 2019 in San Jose, California, US. He is the second recipient of the Jan Rajchman Prize at HKUST since fellow Prof. Ching W. TANG received his award in 2001.

## Prof. Ching W. TANG is awarded the 2019 Kyoto Prize in Advanced Technology

2019-06-14

As the recipient of the 2019 Kyoto Prize in Advanced Technology, Prof. Tang is honored for his pioneering work on organic electronics, including the invention of OLED - Organic Light Emitting Diode. He is a Hong Kong native and the first person of Chinese descent to win the Kyoto Prize since it was established in 1985.

The Kyoto Prize is awarded by the Inamori Foundation annually to individuals who have made global achievements in the categories of Advanced Technology, Basic Sciences, and Arts and Philosophy. Each laureate will receive a diploma, a 20K gold Kyoto Prize medal, and a prize money of 100 million yen.

"I am deeply honored by the recognition given to me by the Inamori Foundation," said Prof. Tang, "to a scientist, there is no greater satisfaction than coming up with an invention that leads to practical use by billions of people around the world in every single day. I feel very fortunate that I have contributed to the creation of a new display technology."

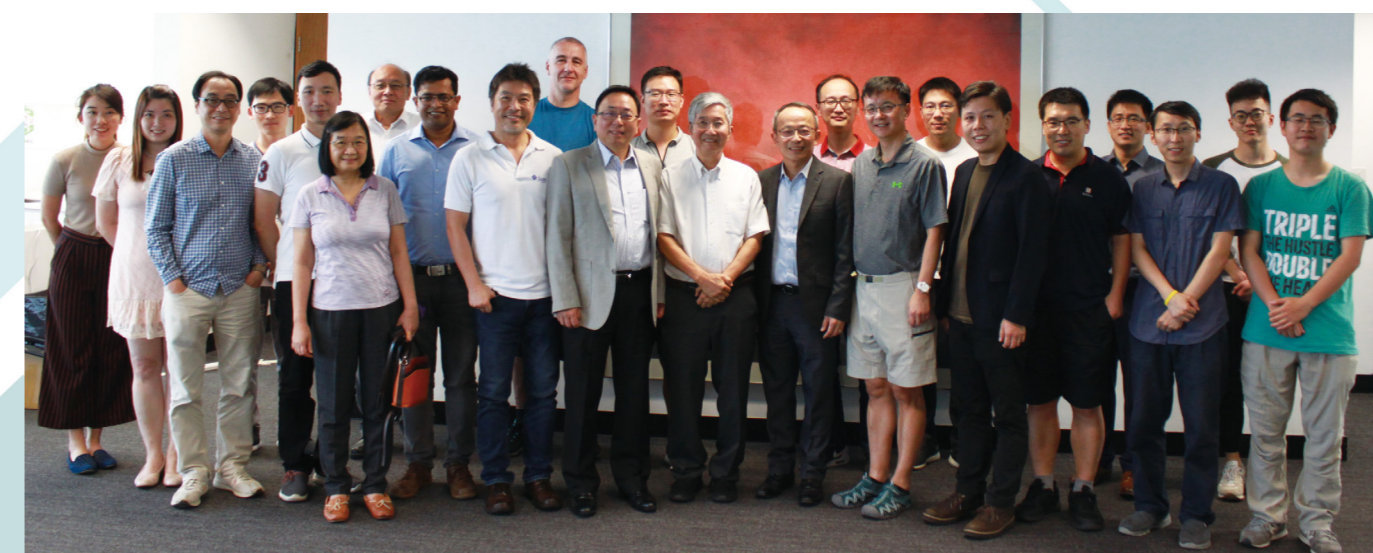
"Ching is a highly talented scientist and engineer and has made fundamental contributions to the development of organic electronics," said Prof. Tim CHENG, Dean of the School of Engineering, "his



Prof. Tim CHENG (left) gave a toast to Prof. Tang for his achievement.

invention of OLED is a synthesis of materials and device research by an individual who has the keen ability to explore new boundaries and seek practical solutions. Who would have believed the most beautiful TVs today are made with molecules stacked in various layers to emit light efficiently? Ching first made it happen, and it seems so obvious after the fact."

The formal award ceremony will be held on Nov 10, 2019 in Kyoto, Japan.



Prof. Tang is joined by various faculty members and the research team at SKL to celebrate this honorable moment.

# International Exchange

## RESEARCH TEAM & COLLABORATIONS

Below: Prof. Kwok (left) and Prof. Tang (right) giving a toast during the transitional dinner as the role of Director is now passed on to Prof. Tang (p. 22).



### International Advisory Committee



The SKL has invited scholars of advanced displays and optoelectronics technologies from around the world to serve on the committee. Committee members participate in regular meetings that aim to review and comment on the SKL's research progress.

### Visiting Scholars



The SKL frequently invites experts on display technology to pay short visits to HKUST. These experts provide professional and effective suggestions for reinforcing our research progress.

#### 2018-2019 Visiting Scholars

Experts	Research Institution
<b>TAIWAN</b>	
Dr. Chun-ta Wang	National Sun Yat Sen University, Kaohsiung, Taiwan
<b>MAINLAND CHINA</b>	
Dr. Jianfeng Zhang	University of Science and Technology, Beijing
Dr. Nannan Lyu	Soochow University, Suzhou
Dr. Dongxiang Luo	Guangdong University of Technology, Guangzhou
<b>OVERSEAS</b>	
Dr. Valerii Vashchenko	State Scientific Institution "Institute for Single Crystals" of National Academy of Sciences of Ukraine
Dr. Olena Vashchenko	State Scientific Institution "Institute for Single Crystals" of National Academy of Sciences of Ukraine
Dr. Vignesh Swaminathan	University of Dublin, Ireland
Dr. Maksym Prodanov	State Scientific Institution "Institute for Single Crystals" of National Academy of Sciences of Ukraine
Dr. Kyselov Oleksiy	Institute of Philosophy of the National Academy of Sciences of Ukraine
Dr. Maksym Diakov	State Scientific Institution "Institute for Single Crystals" of National Academy of Sciences of Ukraine
Dr. Yannick Kervran	University of Rennes, France
Dr. Swadesh Gupta	University of Lucknow, India

# Welcome Aboard



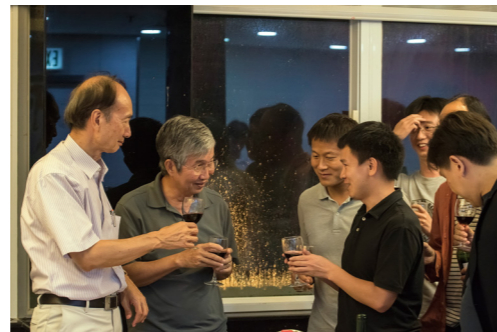
**Prof. Tang takes on the role of Director of SKL starting from 1 July 2019.**

Starting from July 2019, Prof. Ching W. Tang will be the Director of SKL while Prof. Kwok will remain as Visiting Professor and Executive Director of the SKL for the time being.

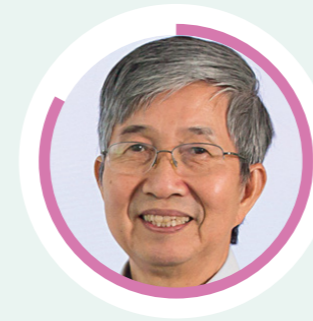
A banquet was held to celebrate this transition between the two professors on 17 June. All the research staff and students of SKL were invited to celebrate Prof. Kwok's outstanding contributions to SKL and also Prof. Tang's new appointment.

"My major goal now is to establish joint laboratory in Shenzhen and also to commercialize our research achievements," said Prof. Kwok, "Prof. Tang has been the advisor from Day 1 when we are writing the proposal for this laboratory seven years ago."

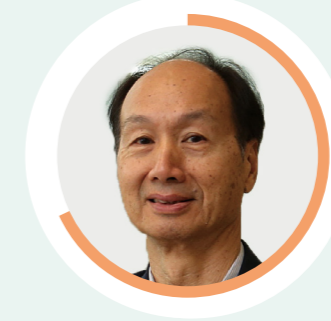
During Prof. Tang's toast, he said, "Prof. Kwok and I will be working more closely together to make the State Key Lab one of the key organization not only in this university, but throughout China and in the world. To achieve that goal, it means that we have to come up with high quality research. We will continue to raise the level of research." The rest of the laboratory members also joined the toast to thank Prof. Kwok for leading the organization.



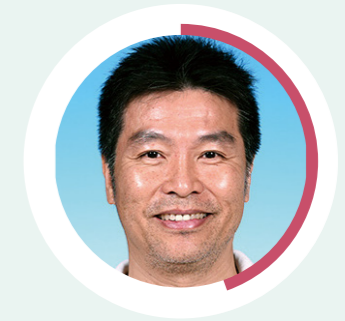
## Research Team



**OLED**  
Prof. Ching W. Tang  
*Director*



**Optoelectronics**  
Prof. Hoi-Sing Kwok  
*Executive Director*



**TFT**  
Prof. Man Wong  
*Associate Director*

### Senior Research Member

Prof. Patrick Yue | Prof. Zhiyong Fan | Prof. Long Quan | Prof. A. K. Srivastava | Prof. Shoucheng Dong

### Research Staff

Mr. K. M. Fung | Mr. Jacob Ho | Dr. Fion Yeung | Dr. Thomas Tang | Dr. Lei Lu | Dr. Vincent Chen | Dr. Guijun Li | Dr. Ken Tseng | Dr. Meng Zhang | Dr. Zhaojun Liu | Dr. Jun Chen | Dr. Zhihe Xia | Dr. Wanlong Zhang | Dr. Yibin Jiang | Dr. Jiapeng Li | Dr. Dongyin Zhou | Mr. Alex Cheung | Mr. Terence Cho | Mr. Addison Cheung | Mr. Howard Chiu | Mr. Joe Chan

### Ph.D Students

Mr. Sunbin Deng | Ms. Cuiling Meng | Ms. Sisi Wang | Mr. Zhibo Sun | Mr. Dunhang Quan | Mr. Sen Xu | Ms. Ke Zhang | Mr. Zhichao Zhou | Mr. Xuchi Liu | Mr. Runxiao Shi | Ms. Zhengnan Yuan | Mr. Yushen Hu | Mr. Xuchi Liu | Mr. Dequan Lin | Mr. Bryan Tam

### M.Phil Students

Mr. Jerry Cheng | Mr. Pengcheng Liu | Mr. Chaudhry Furqan

## Industrial Collaborators

- AU Optronics Corporation (AUO)
- China Star Optoelectronics Technology (CSOT)
- Shenzhen Dalton Electronic Material Co. Ltd (Dalton)
- Truly International Holdings (TRULY)
- DIC Corporation DIC Corporation
- BOE Varitronix (BOE)
- AV Display
- Sun Display
- Infintech



## CONTACT US

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