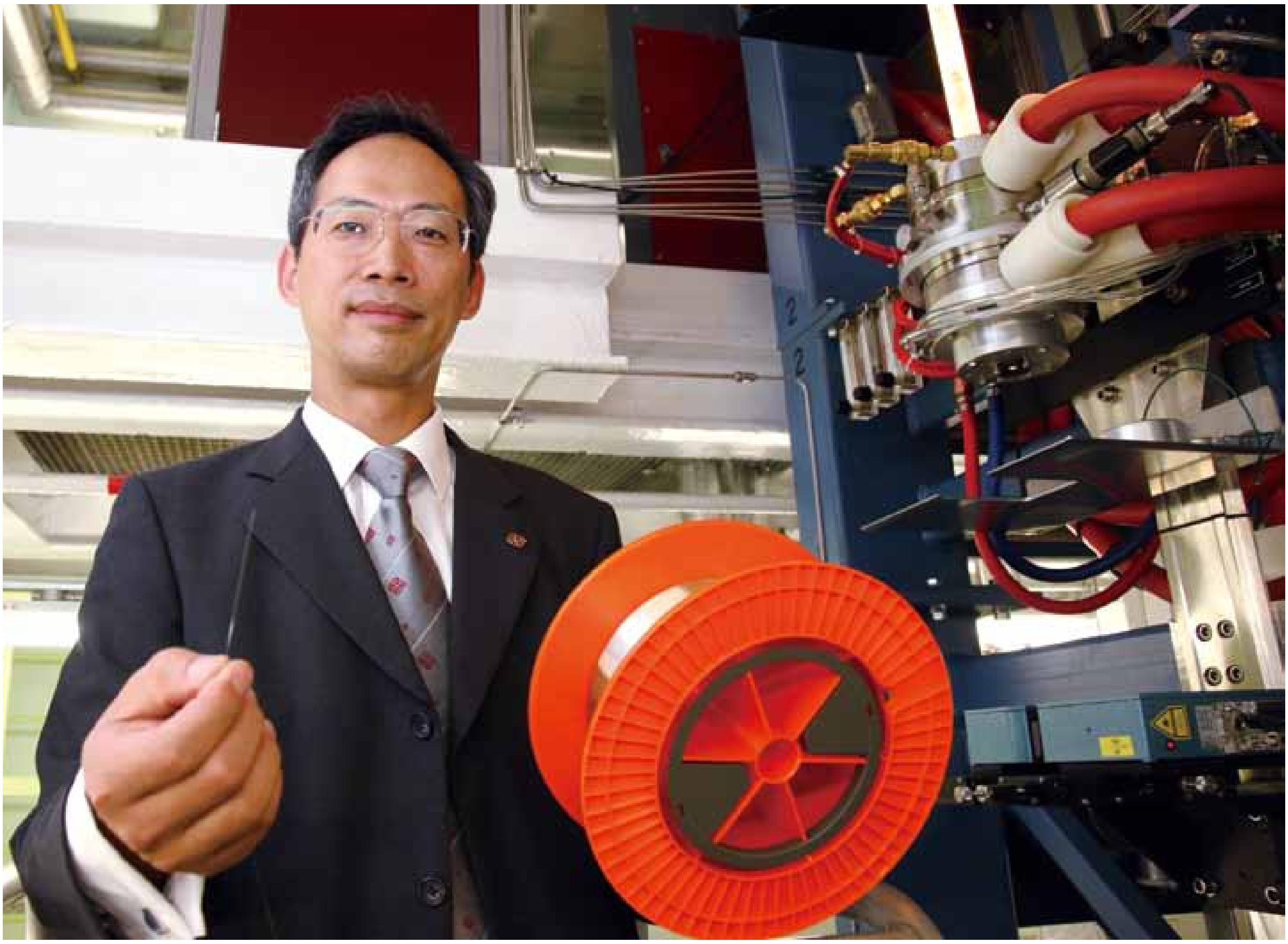
Life Changing Forces: Optical Fibre Technology at PolyU
發展光纖科技　優化人類生活

When the Specialty Optical Fibre Fabrication Laboratory was set up at PolyU's Faculty of Engineering a year ago, expectations were high – with the state-of-the-art equipment, including Hong Kong's first specialty fibre drawing tower costing over US$2 million, an army of experienced and talented experts, and 17 years' wealth of research experience in optical fibre technology. There is little doubt that the University should further assert its role as the regional hub of optical fibre technology with its developments in the newest type of optical fibres, the micro-structured fibres.

香港理工大學工程學院一年前成立「特種光纖研究實驗室」時，大家都對它有很高的期望，該實驗室設有最頂尖的儀器，包括全香港首部、價值高達二百多萬美元的特種光纖拉絲機；還有經驗豐富的專家團隊，以及理大累積了十七年研究光纖技術的經驗。理大將透過發展最新的微結構光纖科技，進一步確立其區域光纖科技樞紐的角色。

微結構光纖與今天被廣泛使用的傳統光纖可謂大相逕庭。傳統光纖是外加保護層的實心玻璃纖維，而理大則利用先進技術，製造纖維內可擁有多條空心氣管的「微結構光纖」，透過不同大小及不同排列形式的空心



In Prof. Alex Wai's hand is the newest type of optical fibres, micro-structured fibres, pulled by the specialty fibre drawing tower.
衛炳江教授手上拿著由特種光纖拉絲機拉出最新型的「微結構光纖」。

Micro-structured fibres are a far-cry from the conventional optical fibers which are commonly used today. Where the conventional optical fibers featured solid cores and claddings, the technology and skills available at PolyU enables the University to create micro-structured fibres that contains air holes running the length of the fibre – novel arrangement of the air holes in the core and cladding affects the fibre's properties in guiding light such as dispersion, nonlinearity, and absorption, thus implying different performances in processing optical signal, or transmitting high speed data and light energy for different purposes.

"We see a wide range of possibilities in applying the technology of optical fibre are being opened up," said Prof. Alex Wai, Dean of Faculty of Engineering and Chair Professor of Optical Communications, who had been researching in the field for nearly 30 years. He noted that in a few years' time, the laboratory should come up with yet another revolutionary change in optical communication by creating powerful optical fibres that are perhaps 10 times more efficient in transmitting information than now.

"Optical fibre technology has primarily been concerned with optical communications technology, as put forward by Prof. Charles Kao in the late 60s. Since then, the mode of modern communication has never been the same

Prof. Wai (right) explaining the difference between micro-structured fibres and conventional optical fibres. On the left is Prof. Lu Chao.
衛教授（右）解釋微結構光纖及傳統光纖的分別。旁邊的是呂超教授。

氣管，提升光纖在光折射、非 性及吸收方面的性能，應用在傳送影像、資料及光能的不同技術中。

「光纖科技衍生了種種的可能性。」理大工程學院院長兼光通訊學講座教授衛炳江教授說。衛教授在光纖研究的範疇有近三十年的經驗，他預期在未來數年內，「特種光纖研究實驗室」將開發可能較現時傳訊速度快十倍或以上的新一代光纖，這將會是光通訊範疇的革命性發展。

「光纖科技的研究起初主要和光通訊有關，即高錕教授於六十年代所提出的學說。從那時起，現代通訊的模式再也不一樣。現時，光纖科技正在不斷演變，並擴展至其他領域的應用層面，例如：傳感系統、生命科學、測量及結構工程等，而『特種光纖研究實驗室』將在研發嶄新的光纖科技應用上起領導作用。」

理大以結合學術研究及工商業的實際應用而見稱，一直積極參與本地及地區性的工商業發展項目。

例如在光通訊方面，理大電子及資訊工程學系呂超教授的團隊正與在生產通訊設備全球領先、並擁有如英國電訊公司等著名客戶的華為技術有限公司合作，開發新一代高容量光通訊網絡，其用作實驗的網絡已經能夠傳輸每秒一千億位至超過一千五百公里的距離。光纖在傳訊網絡上是極有效的媒介，因為相比起電線，它不易受衰減情況而影響。另外，光纖亦較少受到訊號干擾，因為它不受電力干擾，所以不會接收到其他電線所傳送的環境雜音。

呂教授表示：「中國的光通訊科技發展在國際上已經獲得學術界及工商界的關注。」

光纖傳感系統

光纖科技的另一範疇在於傳感系統上的應用。光纖本身的特質適應性強，因而可在不同的環境下用作傳感媒介。光纖會因應環境的轉變而調節其傳送的激光，因此可用來感應拉力、壓力、移動、溫度、以及其他不同的力。此外，由於光纖是由玻璃或塑膠而製成的，所以並不導電，因而不受電波干擾，故此成為在佈滿高電壓或易燃氣體的環境下最理想的傳感媒介。

理大研發的光纖傳感系統現已用作監測前九廣鐵路公司的車廂情況及路軌的使用狀況。這個由電機工程學系譚華耀教授及何兆鎏教授研發的系統，現已安裝於東鐵和西鐵沿線，稍後還會安裝於機場快線和輕鐵沿線。

其實，理大與前九廣鐵路公司於二零零四年已合作成立「智能鐵路研究實驗室」，利用創新光纖傳感技術，改善鐵路營運及進一步提升安全程度。

again – and now, optical technology is morphing and spreading over into other territories in its applications, like sensing systems, life science, surveying and structural engineering. And the laboratory of PolyU is going to spearhead the research in these new, innovative uses."

Well-known for its remarkable abilities in bridging academic researches with practical uses in the industrial and business community, PolyU has already been engaged in industrial and corporate projects on local and regional levels.

In the area of optical communication, for example, Prof. Lu Chao of Department of Electronic and Information Engineering and his colleagues are going hand in hand with Huawei Technologies, a world-leading communication equipment company which features an illustrious clientele including the British Telecom (BT) in the UK, in developing the next generation of high capacity optical communication networks. Up till now, the experimental network is already capable of transmitting 100 gigabits of data per second to a distance of more than 1,500 km. Optical fibres are more effective medium for telecommunication and networking as they are much less susceptible to attenuation compared to electrical cables. It also suffers less signal interference as it is immune to electrical interference, and is therefore not picking up any other environmental noise from other cables.

"Optical communication technology of China has already gained both academic and commercial interest in the international community," Prof. Lu said.

Optical Fibre in Sensing Systems

Another thread of optical technology is its potential in sensor systems. Due to its versatile nature, optical fibres are applicable to a wide range of set-ups as the medium of sensing system. Optical fibres can be used as sensors to measure strain, pressure, movement, temperature and other forces through the modulation of light in reaction to the environment. Other benefits of optical fibres, made of glass or plastic, are their immunity to electrical interference, and the fact that they do not conduct electricity. These make them the ideal medium for sensing in high-voltage set-ups, or environments where explosive gases are present.

Fiber optic sensor system developed by Prof. Tam Hwa-yaw (left) and Prof. Ho Siu-lau.
譚華耀教授(左)及何兆鎏教授共同研發光纖傳感系統

The fiber optic sensor system developed by PolyU is already at use in monitoring the train conditions and track activities of the then KCRC. A brain child of Prof. Tam Hwa-yaw and Prof. Ho Siu-lau of the Department of Electrical Engineering, the system is already installed along the East Rail and West Rail lines, whilst similar systems are soon to be installed in the Airport Express and Light Rail lines.

「傳感系統的研究是一個很廣闊的領域。」衛教授說。「例如光纖傳感系統較以往的電纜傳感系統優勝得多，因為它不會受電波干擾而產生訊號故障。光纖傳感系統亦可以更有效地監察路軌的使用狀況，因它可以偵察及記錄路軌出現的損　、變化和受壓的情況，有助鑑定及找出潛在的路軌問題。」

「光纖傳感系統亦可以用來量度多種不同的參數。我們正研究利用這技術量度氣體的可行性，將來亦可能用作監測發電廠的安全。

The then KCRC has jointly set up a Smart Railway Research Labortary with PolyU in 2004 to enhace the operation and safety of railways, particulary through the innovative use of fiber optic sensor technologies.

"Sensor system is a big area to explore," Prof. Wai said. "For example, optic fibre sensor systems are far better than the previous cable sensor systems because they are not susceptible to signaling problems caused by electrical interference. Optical fibre sensor systems also better monitor track activities because they can detect and record the strains, movements and pressure of track activities, and hence help identify and locate potential track problems."

"Optical fibre sensor system is capable of measuring a wide range of things - for example, we are now working on the possibility of applying the technology on gas measuring, which may be applicable in monitoring the safety of power plants. On the other hand, our laboratory is also studying the different combinations of optical fibre materials in order to further open up the range of their applications – plastic optical fibre, for example, could have applications in life science including invasive surgery navigation."

Health-check for Mega-Structures

To fully exploit the technology, researchers from different departments of the University have been converging their efforts in discovering innovative uses of fibre optics, one of which extends into the field of construction and architecture. The Mega-Structure Diagnostic and Prognostic System, developed by a team led by Ir Prof. Ko Jan-ming, Vice President (Special Duties) and Chair Professor of Structural Engineering, and Dr Ni Yi-qing, Associate Professor of PolyU Department of Civil and Structural Engineering, is a marriage between optical fibre technology and technologies from different disciplines, such as sensing, communication, information technology, signal processing, data management, system identification, etc. The system provides structural monitoring, control, maintenance and management for mega-structures and performs complete health monitoring throughout its life-cycle. It facilitates prevention of structural failure as it allows early identification of structural deterioration and damage, as well as post-disaster structural safety assessment.

The system is especially valuable in mega-structure projects. The 610-meter Guangzhou New TV Tower, touted as the highest TV tower in the world, is now using the system for structural safety assessment. The monitoring system of the Tower is equipped with over 700 sensors in 16 different kinds for continuous measurement of structural responses and applied loadings. Data will then be transmitted to the Data Processing and Control System for processing and analysis on a real-time basis.

At the 37th International Exhibition of Inventions, New Techniques and Products held in Geneva earlier this year, the system won the Special Prize and a Gold Medal for its application in the Tower. Recently, the system has also been awarded the Gold Prize of the 2009 China International Industry Fair held in Shanghai.

另一方面，理大的實驗室正研究不同的光纖物料組合，以擴展其應用範疇，舉例而言，塑膠光纖便有可能應用於生命科學上，包括在侵入性手術中作導航之用。」

大型結構的健康監測系統

理大不同學系一直聯手發掘光纖的創新用途，以期可將光纖科技發揚光大，其中包括在建築範疇上的應用。由理大副校長 (專責事務) 兼結構工程講座教授高贊明教授、工程師，以及土木及結構工程學系副教授倪一清博士帶領的團隊所研發的「大型結構診斷與預測系統」，便是將光纖技術結合其他科技，包括傳感、通訊、信號處理、資料管理、系統識別及結構分析等領域的技術，為大型結構提供了一套包括結構施工監控、健康監測、以及保養和管理的全面服務，而有關服務是可應用於大型結構的整個壽命期內。這系統可以提早發現隨時間累積的結構退化和損傷，從而防止結構破壞的出現，更可以在災難發生後用來評估結構的安全程度。

Prof. Ko Jan-ming introduces the Mega-Structure Diagnostic and Prognostic System installed in the Guangzhou New TV Tower.
高贊明教授介紹應用於廣州新電視塔的「大型結構診斷與預測系統」。

Guangzhou New TV Tower
廣州新電視塔

Hong Kong as an Innovation & Technology Hub

The multi-disciplinary, application-oriented approach to the development of optical fibre technology sheds light on the road ahead for scientific research and economic development of Hong Kong, noted Prof. Wai, who regarded science and technology not only as an acadmic discipline but also as a vehicle for change in the society. Scientific research and innovations, he said, are both valuable to the well-being of our society, but the realization of their value is highly dependent on the structural set-up of the economy.

"The award of Nobel Prize in Physics to Prof. Charles Kao has proved that Hong Kong is not lacking in high-calibre scientific experts," Prof. Wai said. "The question to whether Hong Kong can become a hub of innovations and scientific research, and the very reason why this question is now in the mind of Hong Kong people, reflect that the Hong Kong society is now calling for a change in mentality – from an otherwise opportunistic mindset to one that cares about the true driving force of growth for our society. With the global financial melt-down, the time that calls for a structural change of Hong Kong, and the Chinese mainland, into a knowledge-based society finally comes."

"We have the talents and the necessary resources as education has always been one of the top items in government expenditures. What has yet to come into the scene is a vision to be shared amongst government officials, industrialists, business leaders and the wider community

該系統在大型結構項目中發揮極大作用，世界最高(六百一十米)的廣州新電視塔現正利用這套系統來監測其結構安全。這座電視塔採用的診斷與預測系統有多達十六種超過七百個先進的感測器，可以即時連續測量電視塔每時每刻的變形和受力，並把資料即時連續地傳送到系統的「大腦」進行綜合分析處理。

今年，「大型結構診斷與預測系統」在日內瓦舉行的第三十七屆國際發明及創新技術與產品展覽中榮獲金獎及大會特別獎；最近更於上海舉行的中國國際工業博覽會中奪得金獎。

香港成為創新及科技樞紐的願景

衛教授表示，光纖科技日益走向跨界別及應用為本的發展趨勢，正好為香港未來科研及經濟發展路向提供指引。他認為科學及科技

that knowledge is the true foundation for sustainable growth of a society in every one of its facets."

Knowledge, technology and economy are inter-related, explained Prof. Wai, and the financial tsunami has caused global spending power to dip, hampering economic activities in wholesale, retails, exports and trade. As people are shaken out of their complacence, the crisis they are confronted with forces them to think of ways of increasing their competence. On the other hand, the fact that profit-margin of the manufacturing sector in Hong Kong and the Chinese mainland has been thinning out as a result of rising labour costs and increased global competition, seems to be favourable for the development of value-added industry, which warrants for innovations in technology and science.

"It maybe a good thing that the pace of economic development and trade activities are slowing down in Hong Kong," Prof. Wai said. "When there are fewer shortcuts to generate wealth, people slow down and develop something of long-term significance. And time is a crucial factor in the fermentation and accumulation of knowledge. Without time, real knowledge cannot be manufactured.

"Investment on science and technology development is a long-term business. Look at the success of Silicon Valley. Look at the development in the Cambridge area in Boston of the U.S. They did not start out as a short-term development that guaranteed fast commercial returns. It's about taking the time to study and develop something which you truly believe will benefit the human society. This spirit of pursuing knowledge for the benefit of mankind should be the fundamental driving force behind every research into science and technology."

不單是一門學科，更是推動社會進步的工具。科研和創新固然是關乎社會的福祉，但能否充份體現它們的價值，則要視乎其所處時代的經濟架構。

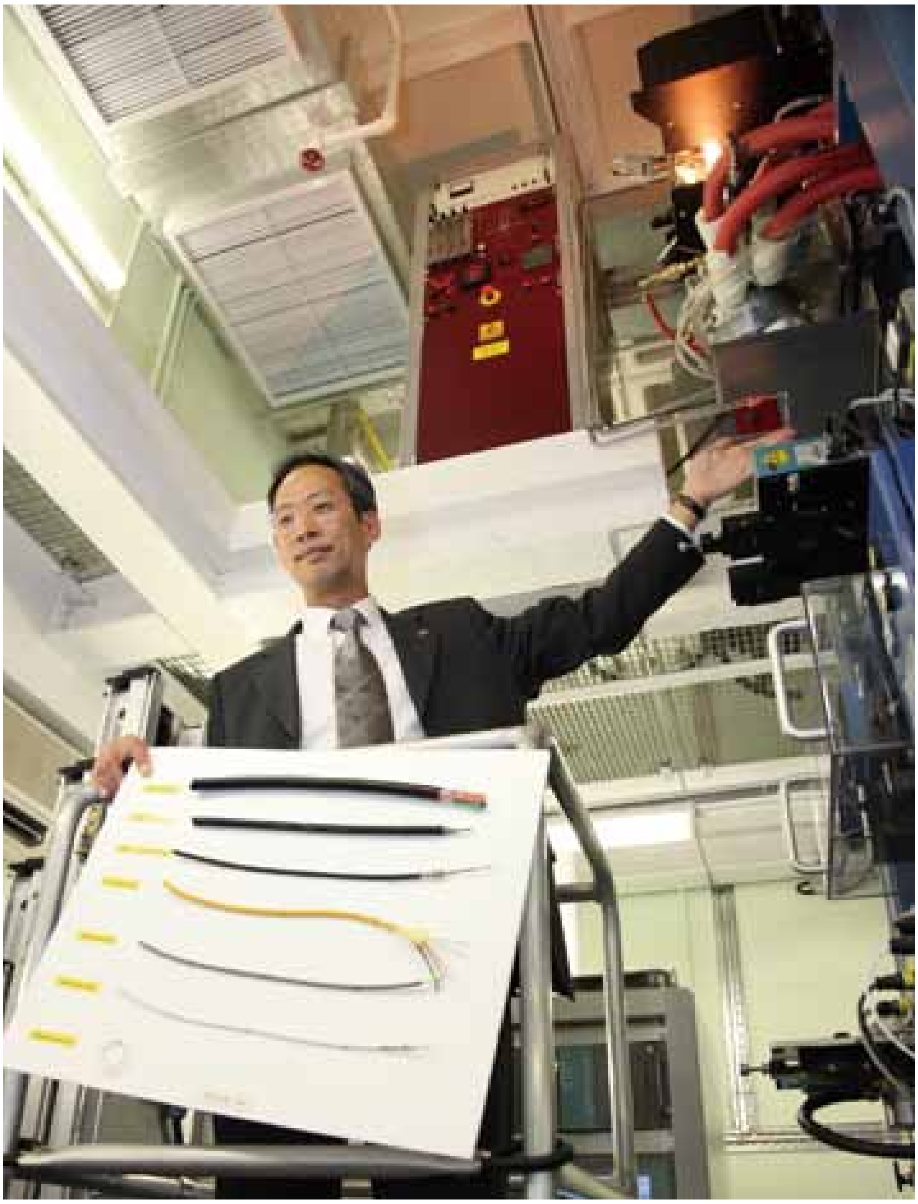
「高錕教授獲頒諾貝爾物理學獎，正好說明了香港並不是沒有科技人才。」衛教授說。「香港能否成為創新和科技樞紐，以及香港人開始關心這課題的原因，反映出香港社會渴求一個思想上的轉變 — 從投機的社會心態深化至尋求社會進步的真正動力。但願全球金融危機能夠促使香港和中國內地的經濟進行結構性的轉變，成功轉型為知識型社會。」

「香港有人才，也有所需的資源，因為教育一直是政府重要支出項目之一。但是政府官員、工商界領袖及公眾必須有同一願景，就是要認同知識是社會進步的真正基石。」

衛教授解釋，知識、科技和經濟是互相關連的，而金融危機令全球的消費力急降，大大削弱了批發、零售、出口及貿易活動。人們終於察覺到不可再安於現狀，這次危機迫使他們思索如何提升自己的競爭力。另一方面，香港和中國內地的製造業因為勞工成本上漲、全球競爭加劇而變得利潤微薄。這一切都似乎利好高增值工業的發展，而高增值工業所需的是科技和科學方面的創新。

「香港的經濟發展及商貿活動都放慢了腳步，這也許不是一件壞事。」衛教授說。「當製造財富的捷徑減少了，人們唯有 眼比較長遠的投資。時間是製造和積累知識的重要因素。沒有時間，就不能發展真正的知識。」

「科學及科技發展是一門長遠的投資。像美國矽谷的成功例子和波士頓劍橋區域的發展，它們的起步點都不是保證有經濟回報的短期投資，而是進行長時間及確信對人類社會有貢獻的研究。追求知識來貢獻人類的精神，應該是科研背後最根本的原動力。」



Prof. Wai showing the specialty fibre drawing tower and different cables and optical fibres used for various purposes.
衛教授介紹特種光纖拉絲機、不同類型的電纜和光纖及它們的用途

Overview of Optical Fibre Development: 1960's to present days
六十年代至今的光纖發展

1960's and 1970's
In 1966, Prof. Charles Kao and George A. Hockham of the British company Standard Telephones and Cables, the pioneers to promote optical fibres for communication, argued that the problem of attenuation of optical fibres was attributed to impurities in the fibres rather than the fundamental physical properties of the fibre. This opened up the possibilities of optical communication, as the idea implied that the attenuation in fibres could be removed by increasing the level of purity of fibres. Efforts in optical communication research from the period of 1966 to 1975 were characterized with the goal of producing fibres of perfect purity.

1980's and 1990's
The first generation of optical communication network was created in the 1980's. However, engineers soon encountered the problem of chromatic dispersion with single-mode fibres. The focus of research then shifted to the structures of core and cladding and special optical signal shapes in order to control dispersion and facilitate long-haul high speed optical communication.

Present days
The next generation of high capacity optical communication network is already capable of transmitting more than multi-terabits of data per second to transoceanic distance of more than 10,000 km. The new focus of research and development has now become the exploration of optical technology in other areas of use through the development of micro-structured fibres.

六十及七十年代
一九六六年，光纖通訊研究的先驅高錕教授與英國公司Standard Telephones and Cables的George A. Hockham 提倡以光纖作為通訊媒介，並指出光纖衰減問題的原因是光纖內的雜質，而並非光纖本身的物理特性。這見解意味　只要提高光纖的純淨度，其衰減問題便可解決，更開拓了研究光纖通訊之門。由一九六六至一九七五年，光纖通訊研究都集中於希望製成百分百純淨的光纖。

八十及九十年代
第一代的光纖通訊網絡於八十年代落成。然而，工程師卻要面對單模光纖的色散問題。研究的焦點繼而落在如何改良光纖的結構，以及利用特種光信號形狀，作長途及高速光纖通訊。

目前
新一代的光纖通訊網絡已經能夠於每秒傳輸超過多兆位元至横越海洋一萬公里以外的距離。現時，新的研究及發展焦點是透過利用「微結構光纖」，開拓光纖技術至不同的應用範疇。

Optical Fibre Laboratory Facilities at PolyU
理大有關研究光纖的設施

Specialty Optical Fibre Fabrication Laboratory
Opened in 2008, the Laboratory houses a state-of-the-art fibre drawing tower which is capable of pulling the newest type of optical fibres named micro-structured fibres.

Optical Communications and Networking Research Laboratory
The laboratory is equipped with advanced equipment in optical fiber communications. There are two testbeds: a up to 100 Gb/s dense wavelength division multiplexing direct detection and coherent detection optical fiber transmission testbed and a high speed all-optical packet switching testbed with a total value of over HK$20 million.

Fibre Optic System Laboratory
This laboratory is newly established for research on optical fibre based systems for communication and sensing applications. It has a class 10,000 clean room, test and measurement equipments for optical fibre device and system characterization.

Fibre-optic Research Laboratory
This laboratory is established for research on optical fibre based systems in communication and sensing applications, involving fibre-optic sensors, fibre Bragg gratings, and optical communications. It is equipped with a millimeter resolution optical time domain reflectometer, an optical spectrum analyzer, fibre Bragg grating fabrication facilities, etc.

特種光纖研究實驗室
「特種光纖研究實驗室」於二零零八年設立，擁有最先進的儀器，包括全香港首部特種光纖拉絲機，能夠拉出最新的「微結構光纖」。

光通訊及網絡實驗室
「光通訊及網絡實驗室」備有先進的光纖通訊設備。這總值二千萬港元的設備是由兩個實驗平台組成: 分別是一個高達每秒一千億位元的密集波分複用直接檢測和相干檢測光纖傳輸實驗平台及一個高速全光分組交換實驗平台。

光纖系統實驗室
「光纖系統實驗室」是用作光纖通訊系統及傳感應用系統之研究。實驗室內有一個一萬級的超淨室及光纖器件和系統的測試設備。

光纖研究實驗室
「光纖研究實驗室」的主要研究方向是用作通訊及傳感的光纖系統。這包括光纖傳感器，光纖布拉格光柵和光通訊系統。實驗室的主要設備有毫米精度的光時域反射計、光頻譜儀和光纖布拉格光柵制造系　。