

# The Potential of Optical Fiber-Based Technologies



Perry Shum

President Elect, IEEE Photonics Society  
Chair Professor, SUSTech











**Disrupted Disruptors  
Expect the Unexpected**



# 19<sup>th</sup> Century technical predictions

12



**Fig. 17.2** A French prediction for the year 2000.

*Le photo-téléphone*

# History of Fibre Optics

Kao & Hockam, who were working at Standard Telephone Ltd in Harlow, UK, published a research paper that proposed and heralded the advent of the optical communications.

Charles Kuen Kao, whose theoretical analysis, experiments, and advocacy launched fiber-optic communications, first at Standard Telecommunication Labs and later worldwide. (Courtesy Nortel)



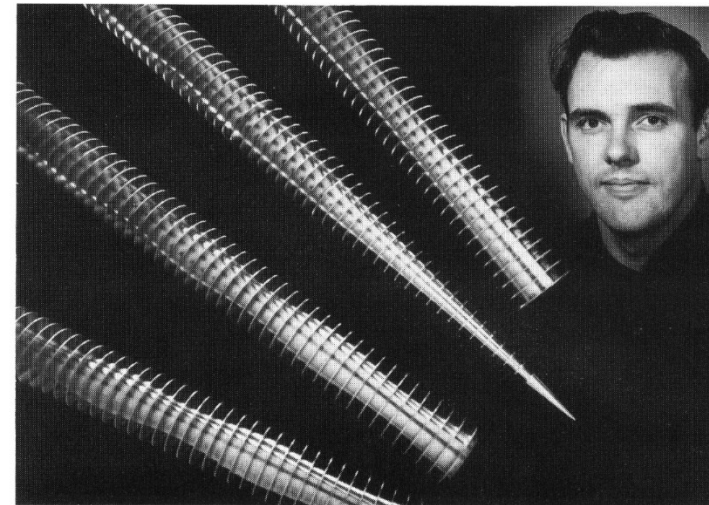
## Dielectric-fibre surface waveguides for optical frequencies

K.C. Kao and G.A. Hockham

*Indexing terms:* Optical fibres, Waveguides

**Abstract:** A dielectric fibre with a refractive index higher than its surrounding region is a form of dielectric waveguide which represents a possible medium for the guided transmission of energy at optical frequencies. The particular type of dielectric-fibre waveguide discussed is one with a circular cross-section. The choice of the mode of propagation for a fibre waveguide used for communication purposes is governed by consideration of loss characteristics and information capacity. Dielectric loss, bending loss and radiation loss are discussed, and mode stability, dispersion and power handling are examined with respect to information capacity. Physical-realisation aspects are also discussed. Experimental investigations at both optical and microwave wavelengths are included.

K.C.Kao and G.A.Hockham, "Dielectric-Fibre Surface Waveguides for Optical Frequencies," *Proc.IEE*, V.133, pp.1151-1158, July 1966.



George Hockham, with the metal waveguides he studied to understand how small internal variations might cause losses in optical fibers. (Courtesy Nortel)

# Frontiers of Photonics Research, 2004



# Landing sites of submarine cable in Singapore

Tuas Landing Site

Changi North Landing Site

Tanah Merah Landing Site



Singapore is connected to 15 active submarine cable systems in 3 designated landing sites



# Optical Spectrum

|                                      |                                      |
|--------------------------------------|--------------------------------------|
| Ultraviolet                          | 200 nm to 400 nm                     |
| Visible spectrum                     | 400 nm (violet/blue) to 700 nm (red) |
| Infrared                             | 700 nm (red) to 2000 nm              |
| Optical fibre communications windows | 850 nm, 1300 nm, 1550 nm             |

• **1280 nm (235 THz) to 1650 nm (182 THz)**

⇓ **53 THz**

**> 12 billion telephone channels ( Kb/s per channel)**

#### World Population

1970 3.9billions,

Now <https://www.worldometers.info/world-population/>

- **Today, 400 Gb/s system is commercially available (you are receiving 12000 Encyclopedia volumes per sec)**



# Current World Population

# 8,040,088,972

[view all people on 1 page >](#)

## TODAY

Births today

**149,538**

Deaths today

**74,882**

Population Growth today

**74,656**

## THIS YEAR

Births this year

**63,290,105**

Deaths this year

**31,692,720**

Population Growth this year

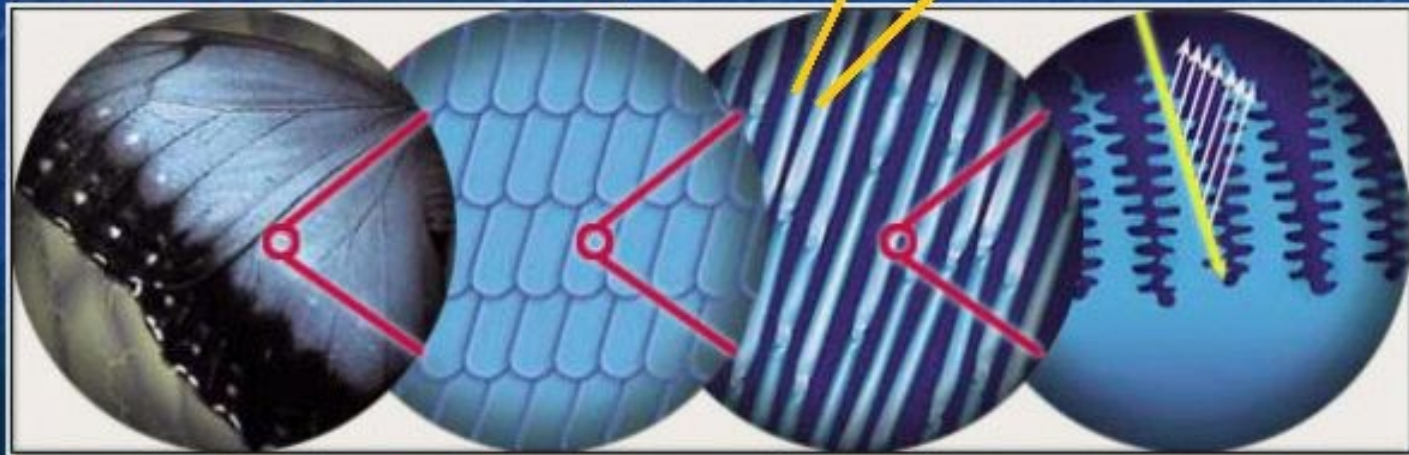
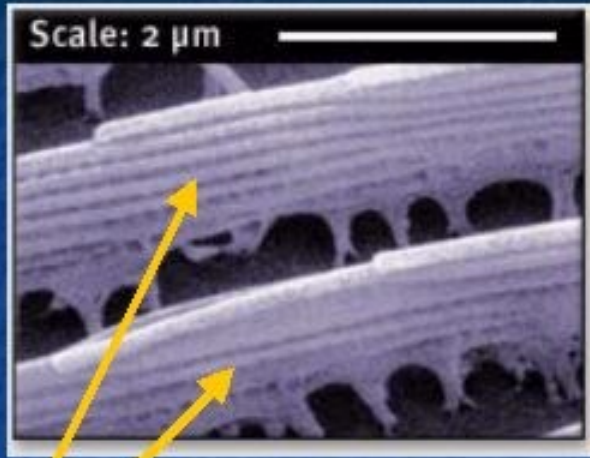
**31,597,385**

# Have you heard of Photonic Crystal Fibre or Holey Fibre ?



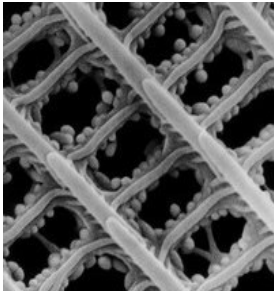
[Harvard Video](#)



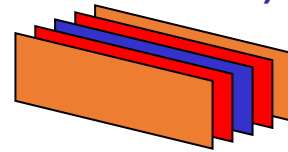
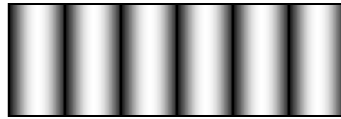


# Photonic Band-gap Structures

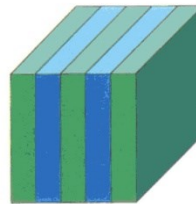
NATURAL



1D Photonic Crystal  
(Bragg grating and thin film stack)

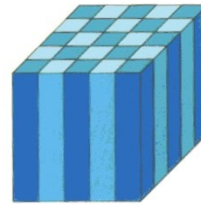


1-D



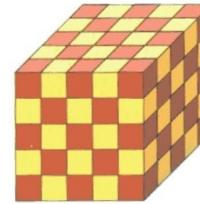
periodic in  
one direction

2-D



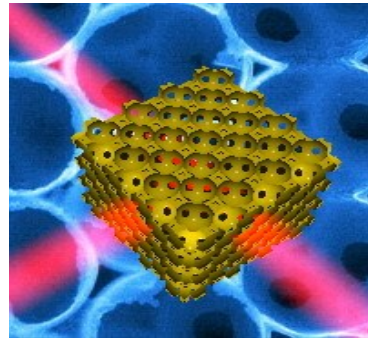
periodic in  
two directions

3-D

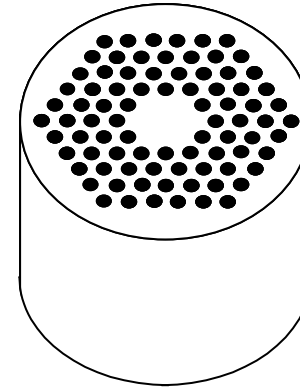


periodic in  
three directions

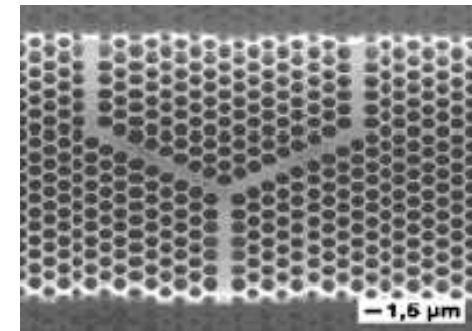
3D  
PHOTONIC  
CRYSTAL



2D Photonic Crystal  
MICROSTRUCTURED  
OPTICAL fibre

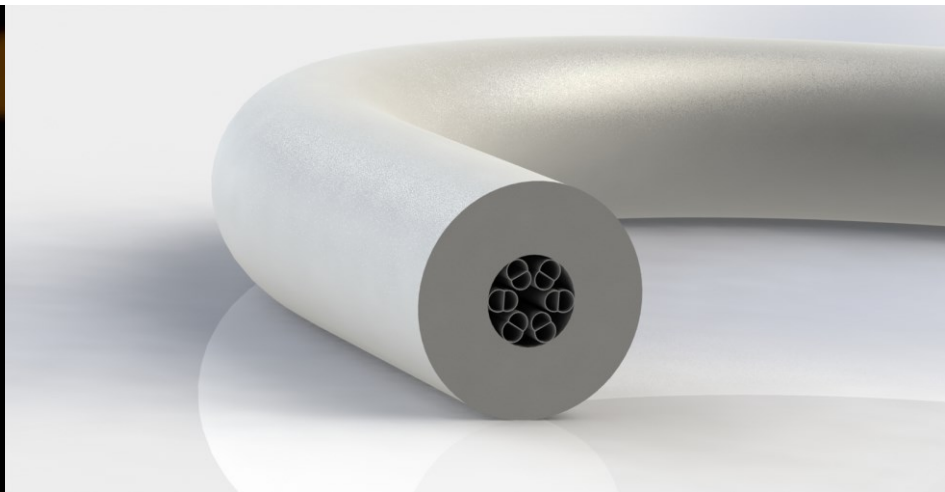
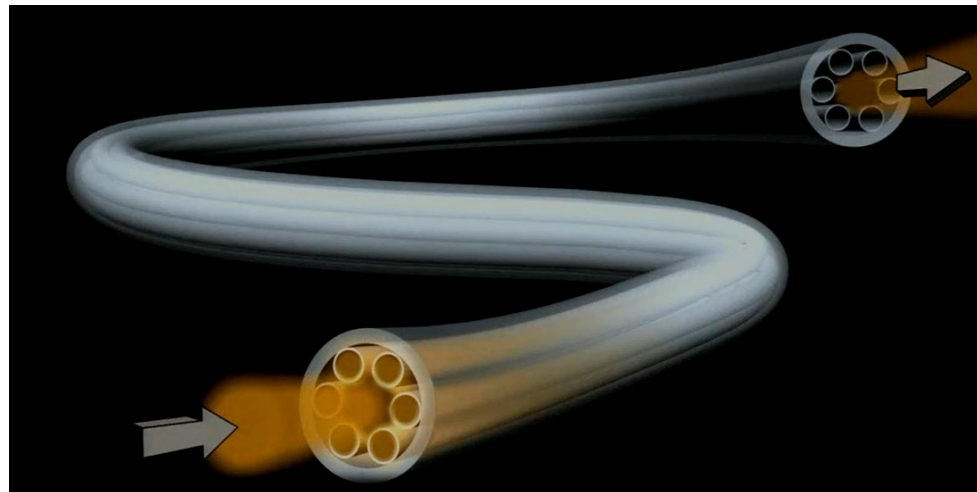
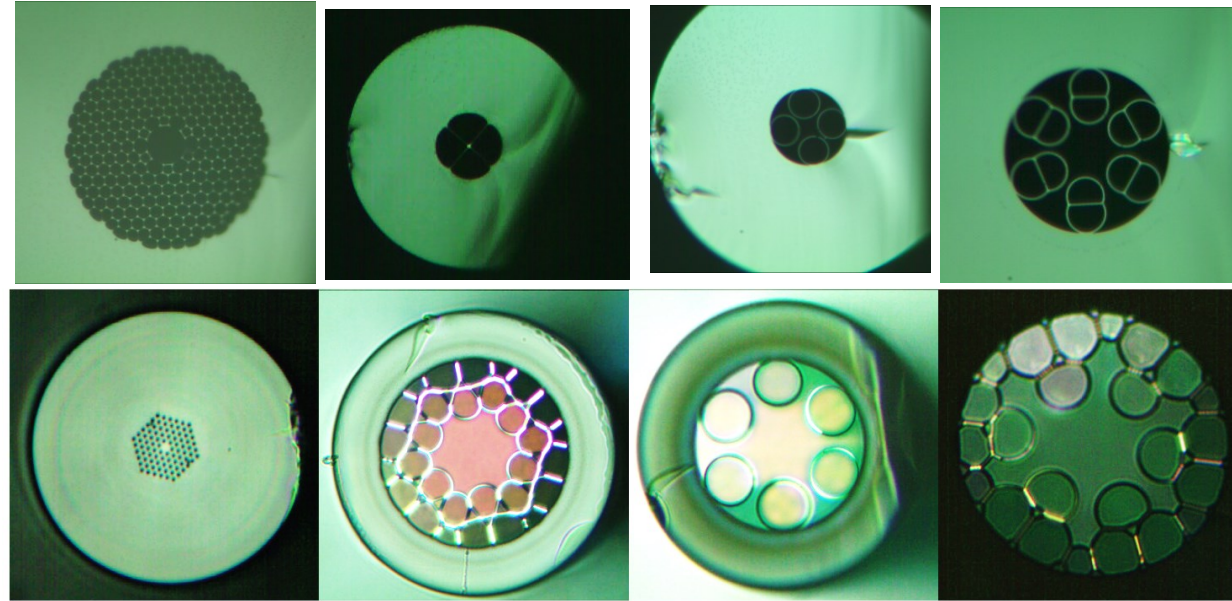


2D Photonic Crystal  
PLANAR WAVEGUIDE

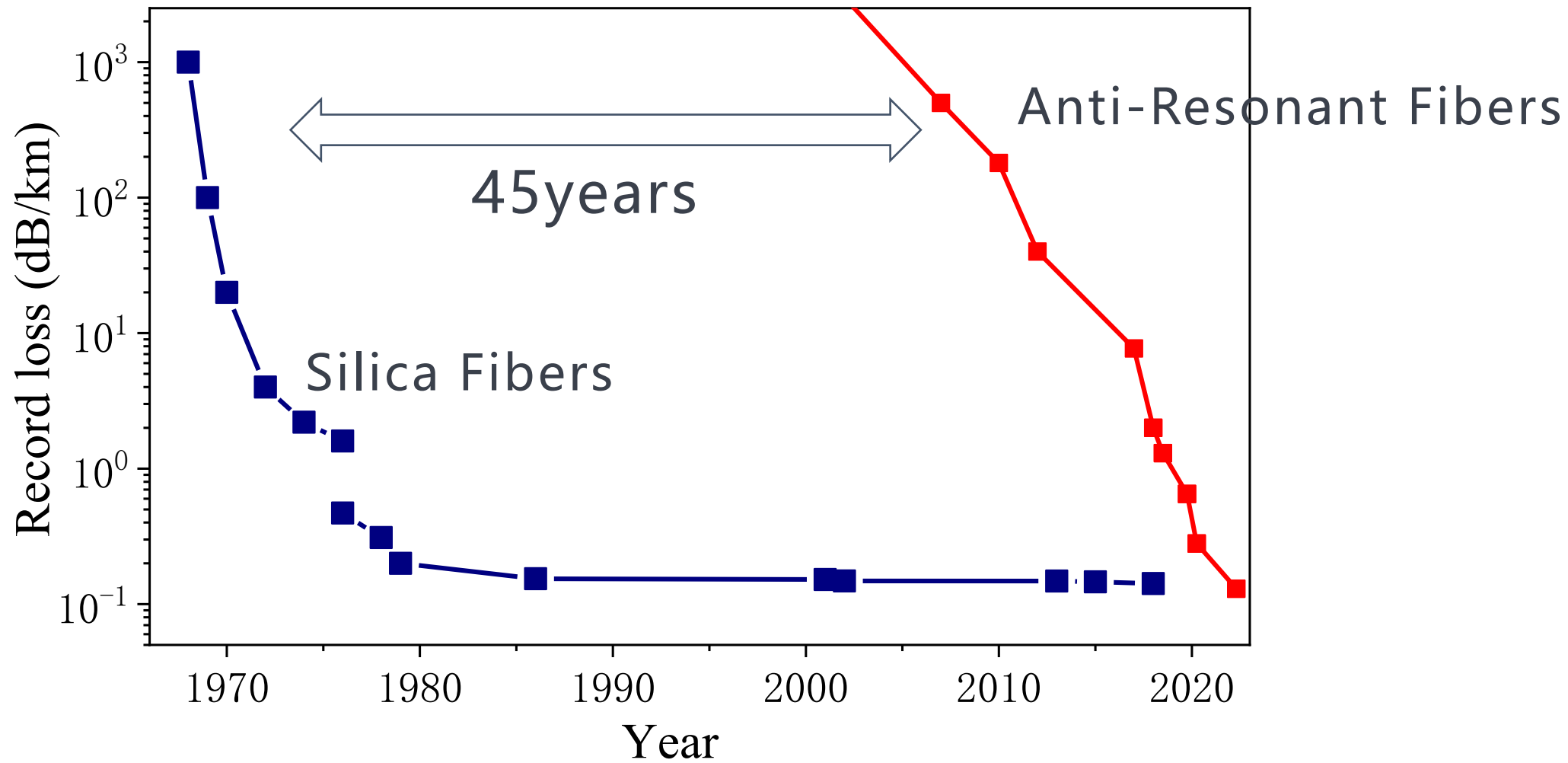




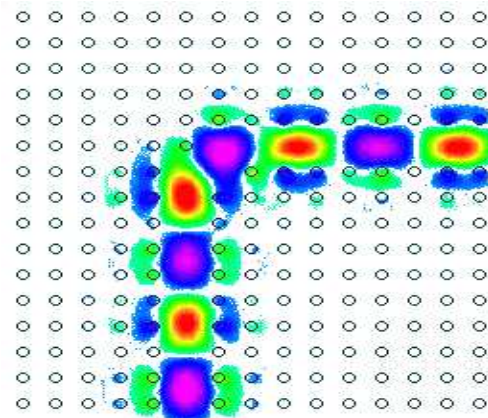
# Microstructured Fibers



# Low Loss Anti-Resonant Fibers



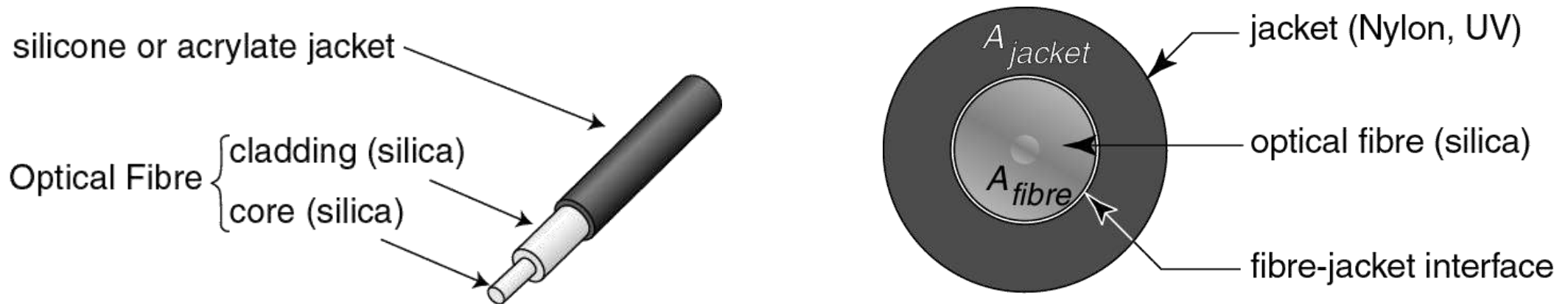




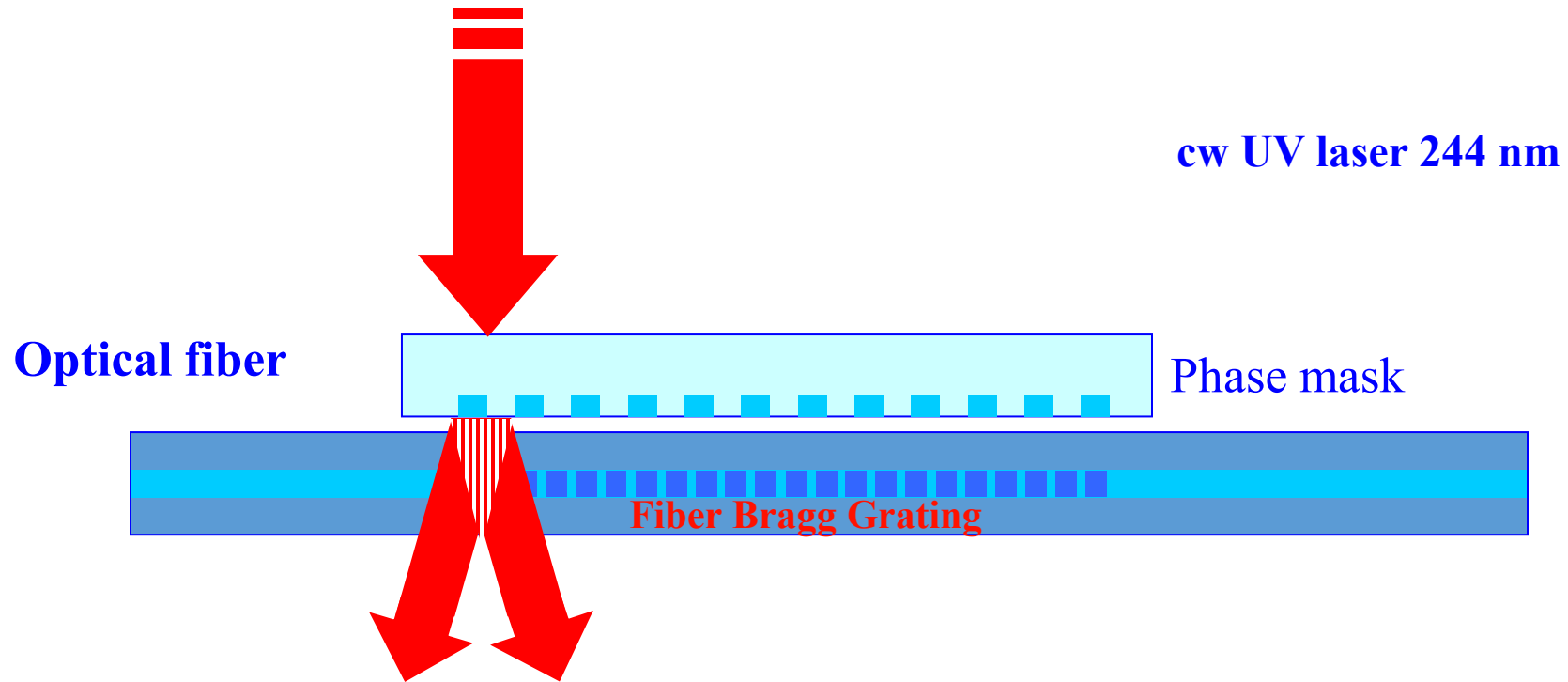
**Ultra-tight confinement**

- **Optical fiber as a sensing element**

- Measurement of the modification of the propagation path (delay, attenuation, polarization,...)
- Measurement of the interaction of light with the propagation medium



## Fabrication of Fiber Gratings

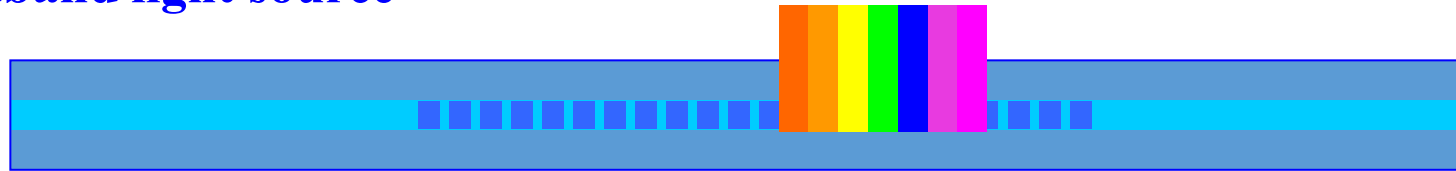




# Fiber Bragg Grating-based Sensors

**Illuminates FBG with  
a broadband light source**

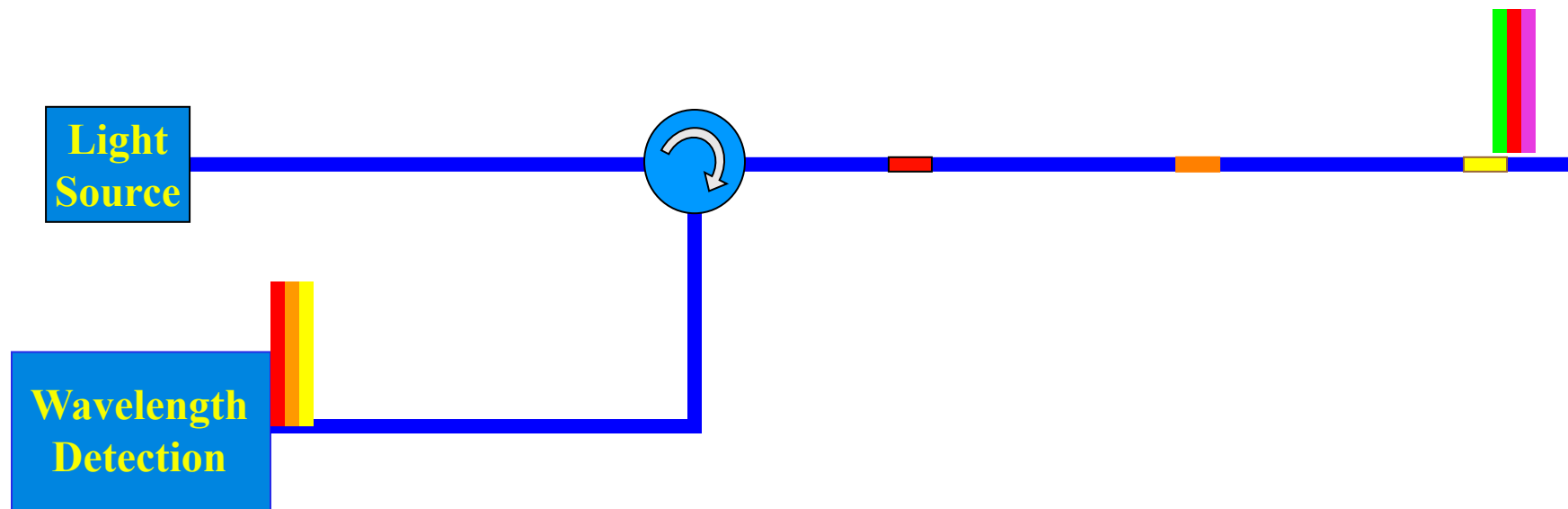
**The rest of the spectrum is transmitted**



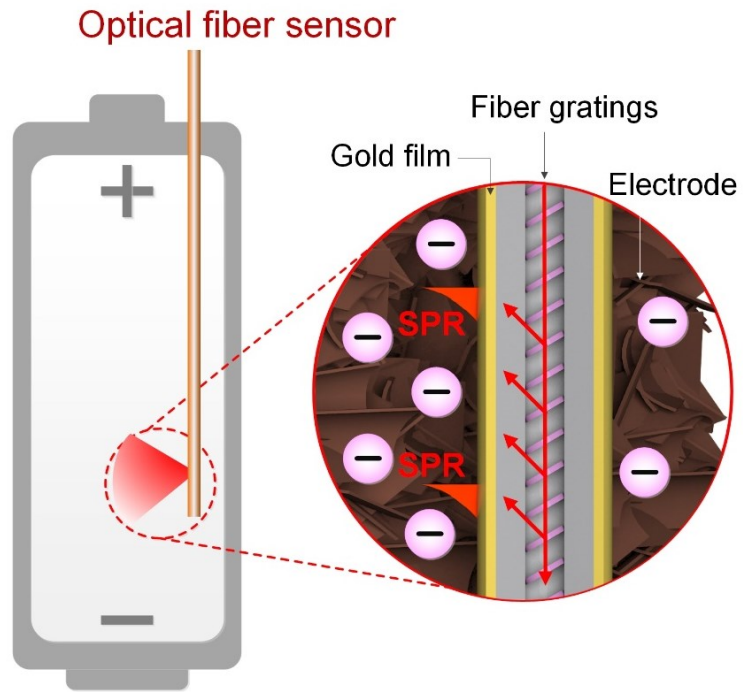
**Fiber Bragg Grating Optical fibre**

**A narrowband of light  
reflected by the FBG**

## Wavelength-Division Multiplexing of FBG Sensors



# In situ monitoring state-of-charge of battery



Tuan Guo\*, *Light: Science & Applications*, (2018) 7: 34

## Sound frequencies

Infrasound

Voice frequency

Ultrasound



0~20Hz

20Hz~20kHz

>20kHz





# Applications



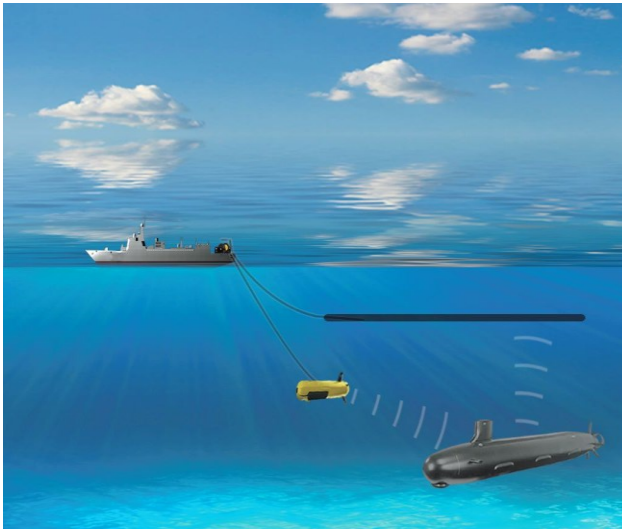
Biochemical detection



Structural health monitoring



Pipeline leakage detection



Antisubmarine monitoring



Nondestructive testing



Seismic wave monitoring

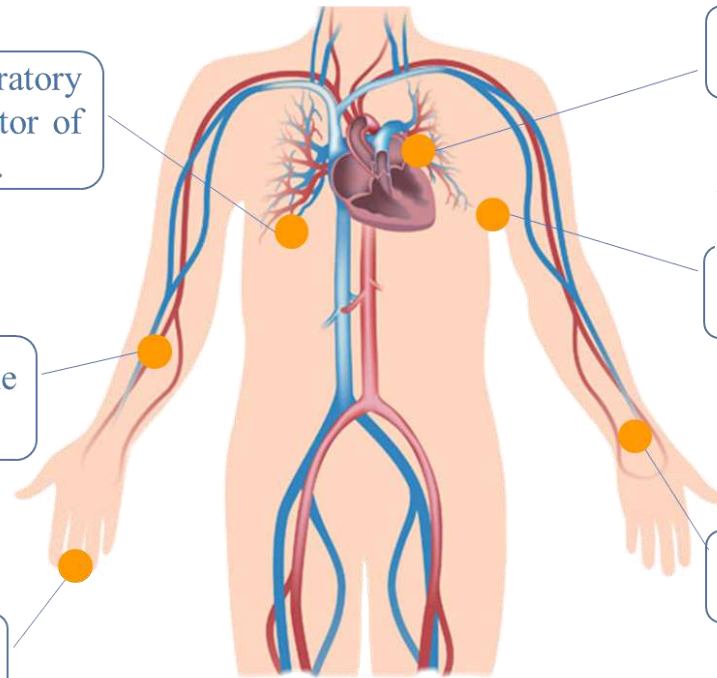


# Human vital signs monitoring

➤ **Breath Rate**  
A major parameter of respiratory physiology and an important indicator of acute functional respiratory disorder.

➤ **Radial augmentation index**  
An important indicator implies the risk of cardiovascular diseases.

➤ **Blood Oxygen Saturation**  
A indicator of cardiovascular and cerebrovascular diseases.



➤ **Heart Rate**  
The most direct indicator of heart health level.

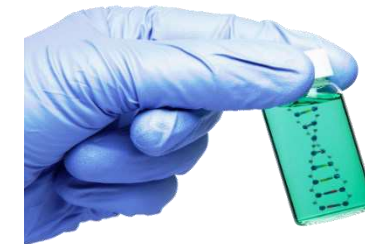
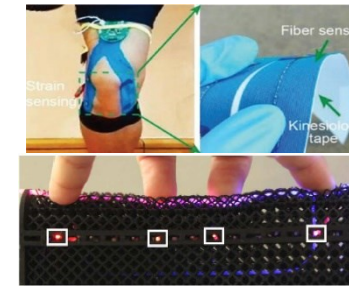
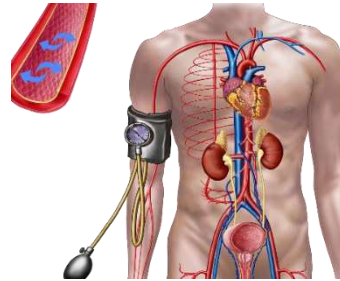
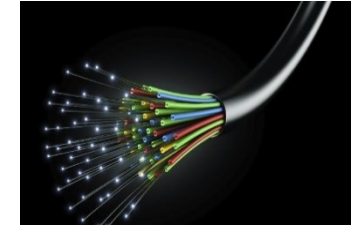
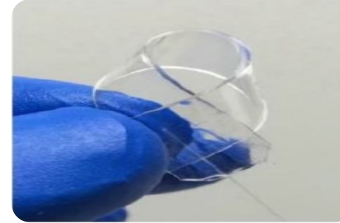
➤ **Body Temperature**  
One of the most direct and obvious signs of the human health.

➤ **Blood Pressure**  
A indicator of cardiovascular and cerebrovascular diseases.



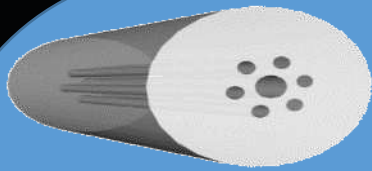


- **Flexible and human friendly**
- **Highly sensitive**
- **Multifunctional**
- **Integrated and wearable**
- **Robust and reusable**
- **Noninvasive and continuous measurement**

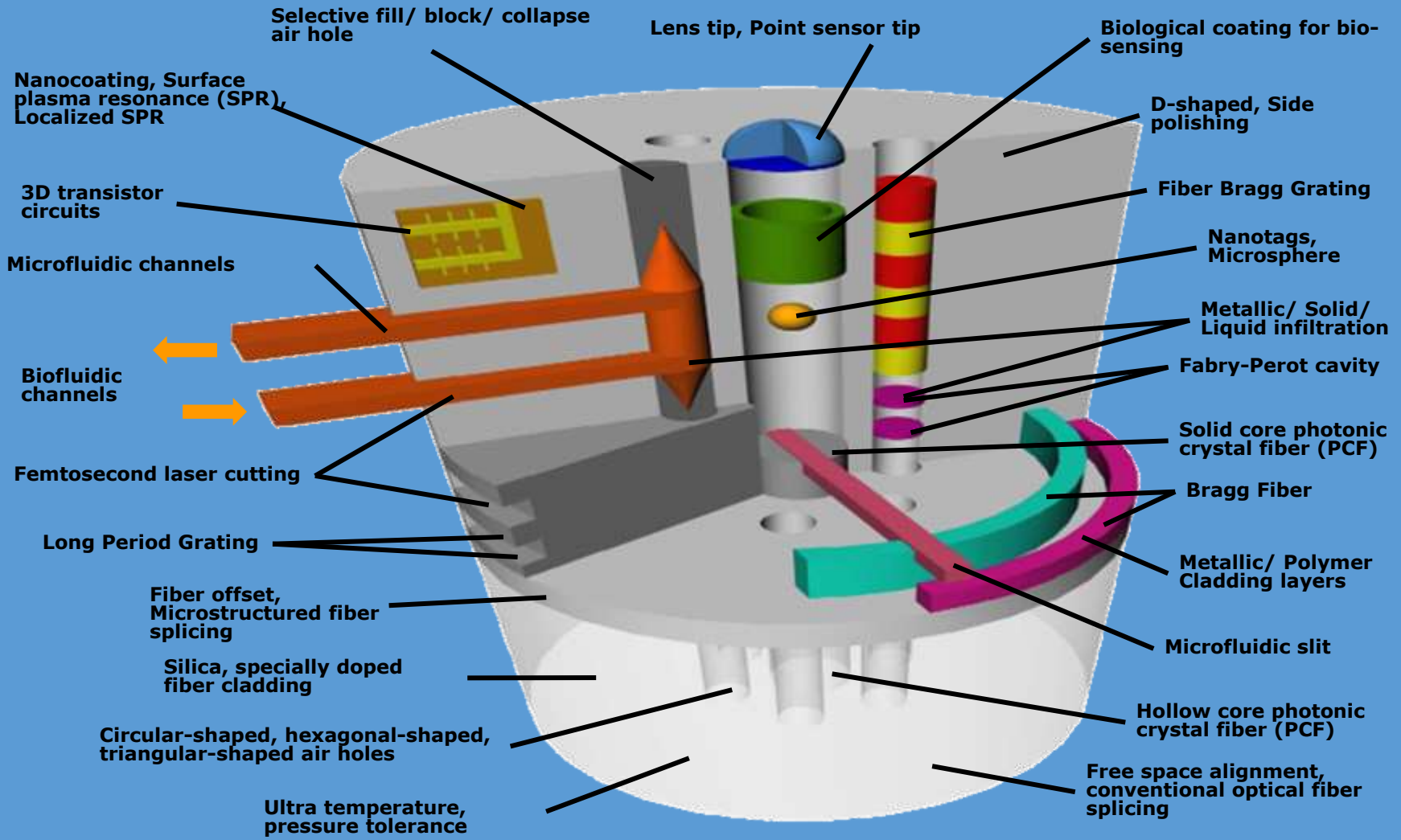


[1] "Ultrasensitive hybrid optical skin", 2018  
[2] Adv. Mater. 2018, 30, 1704229  
[3] Sci. Robot. 4, eaaw6304, 2019





# Fibre Sensors



For further information please contact Prof. Perry Shum  
Email: shum@ieee.org





# Perry Shum

SUSTech



**SUSTech**

Southern University  
of Science and  
Technology