

Optical fibre in the BT inter-exchange network

Wednesday 8th October April 2025

Welcome

The lecture and webinar will start at 7:00pm

Introduction: Kevin Foster FIET, Chairman, Anglian Coastal Local Network

Presenter: Russell Davey CEng. FIET, Principal Network Architect, BT Fellow

Questions: Live in the Atrium & via Q&A Messaging in Teams. In Teams, please type in your questions and these will be taken in a Q&A session at the end of the presentation.

Close: Approximately 8:15pm



A solid pink horizontal bar.

Optical Fibre Research at BT's Adastral Park

Russell Davey

russell.davey@bt.com

3rd October 2025

A solid teal horizontal bar.

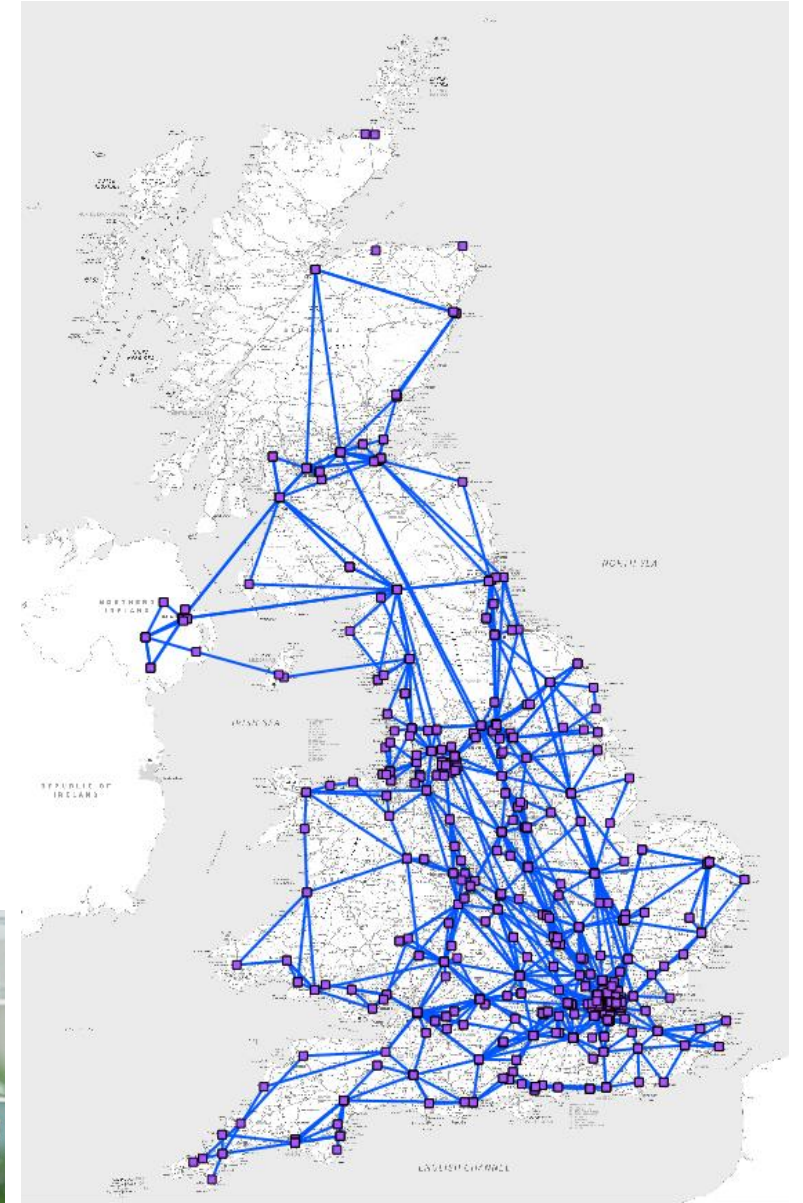
Optical fibre connects our cities

– and is vital to the internet we all use every day



Key enabling technologies:

- Single mode optical fibre
- Semiconductor optical sources
- Semiconductor optical detectors
- Optical amplifiers
- Coherent WDM
- All-optical wavelength switching

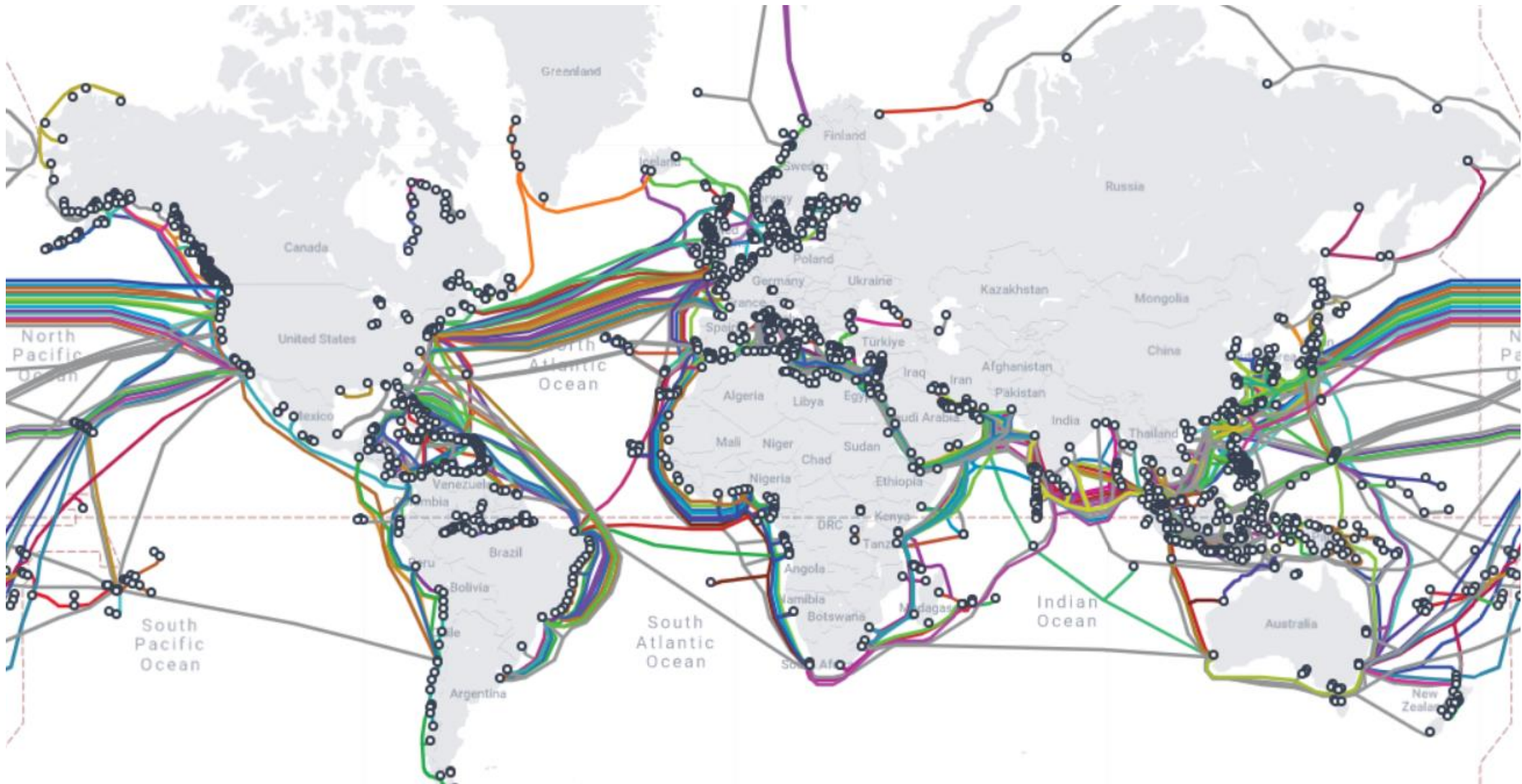


Optical fibre connects countries

4

Map of subsea optical fibre cables

www.submarinecablemap.com



Increasingly Fibre goes to our homes



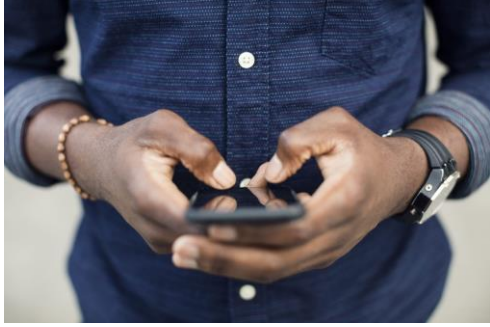
openreach

- Fibre FTTP passes over 20 million premises⁽¹⁾
- Fibre passing 81,000 new premises per week
- Build to 25 million premises by end 2026
- £15 billion network investment
- Today ~38% of passed premises connected

Key enabling technologies:

- Single mode optical fibre
- Semiconductor optical sources
- Semiconductor optical detectors
- Passive Optical Networks
- Blown fibre

Fibre connects 4G and 5G mobile basestations

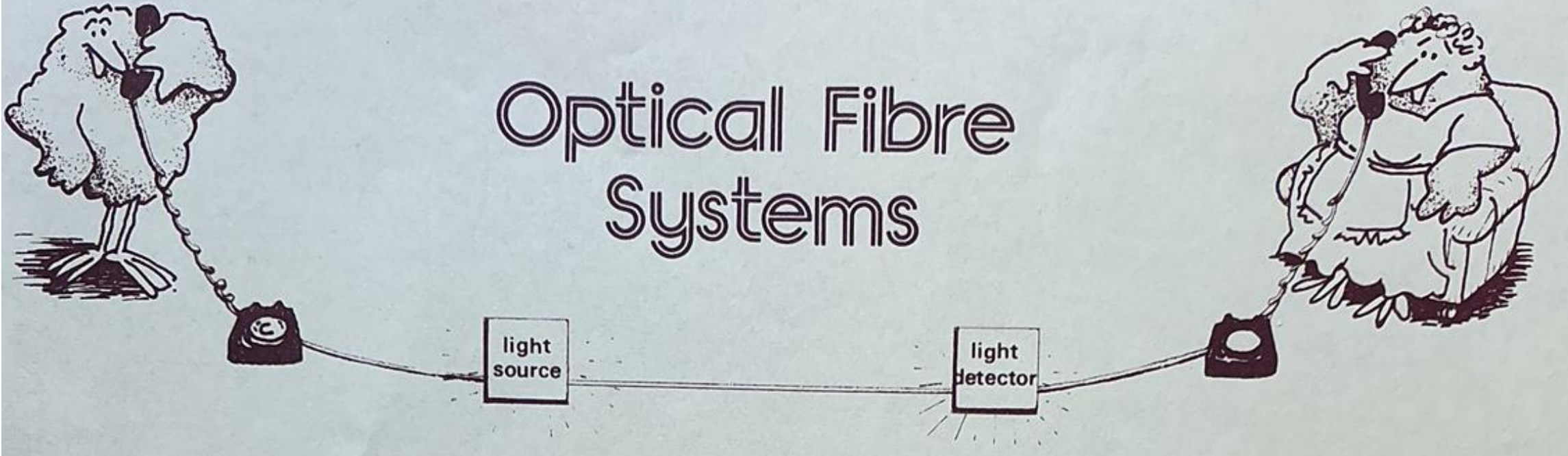


- >6,000 (~30%) of mobile basestations directly connected to fibre
- Even where the basestation is connected to the telephone exchange with microwave radio rather than optical fibre, fibre is used for the onward journey from the telephone exchange

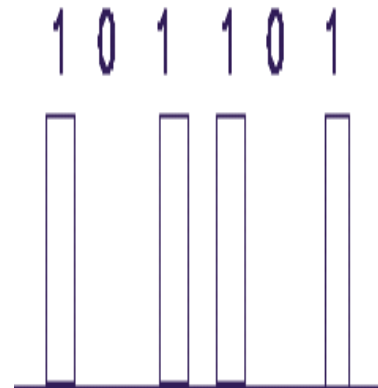


Post Office Telecommunications

Optical Fibre Systems



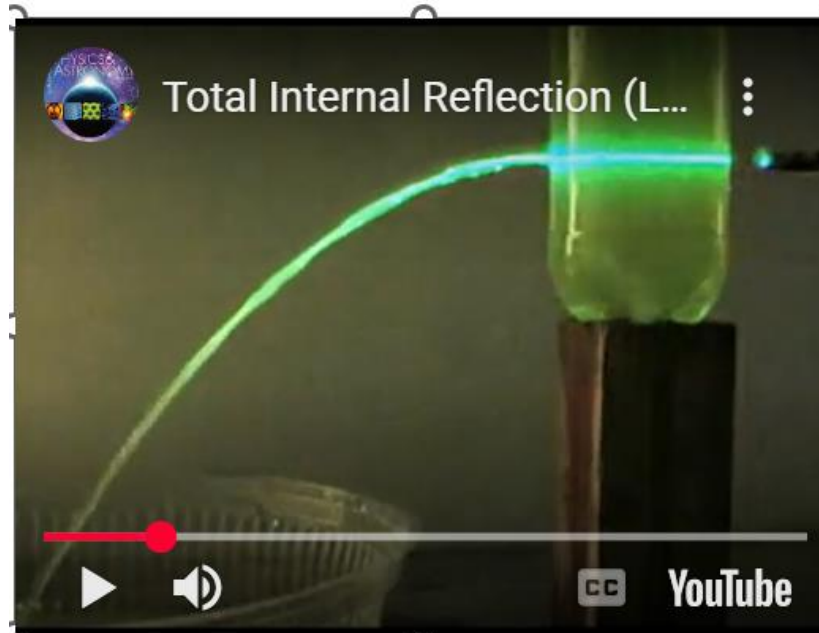
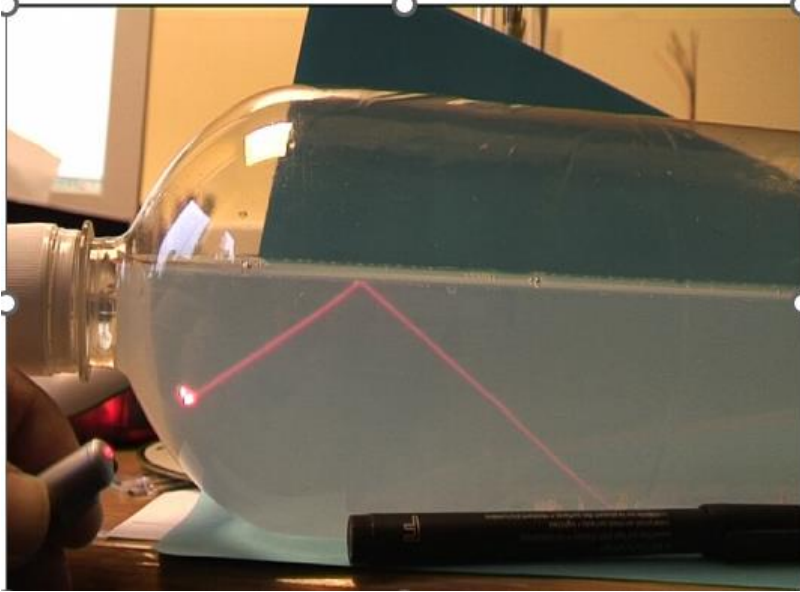
For 10 Mbit/s the light source (laser) is turned on and off 10 million times a second to give the sequence of 1s and 0s (binary digits or bits) carrying your Netflix along the fibre and across the country



- 1 Mbit/s (Megabit per second) is 1 million bits per second
- Your broadband at home will probably be tens of Mbit/s
- A good quality video needs 2Mbit/s to 10 Mbit/s

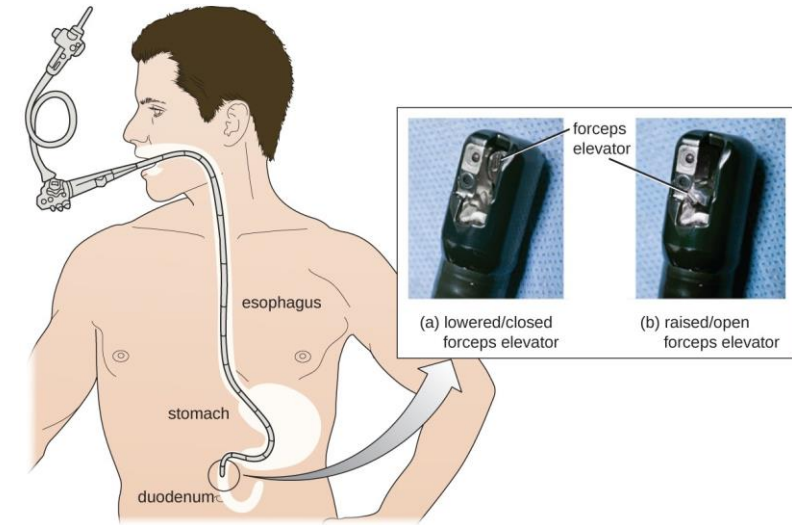
Physics and early history of “light pipes”

Total internal reflection



19th Century scientists (e.g. Tyndall) guided light within jets of water as a party piece

First practical application: Fibre optic gastroscope invented 1950s



1966 – the birth of optical fibre communication

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Dielectric-fibre surface waveguides for optical frequencies

K. C. Kao, B.Sc.(Eng.), Ph.D., A.M.I.E.E., and G. A. Hockham, B.Sc.(Eng.), Graduate I.E.E.

Synopsis

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.

List of principal symbols

J_n = n th-order Bessel function of the first kind
 K_n = n th-order modified Bessel function of the second kind
 $\beta = \frac{2\pi}{\lambda_g}$, phase coefficient of the waveguide
 J'_n = first derivative of J_n
 K'_n = first derivative of K_n
 h_i = radial wavenumber or decay coefficient
 ϵ_i = relative permittivity
 k_0 = free-space propagation coefficient
 a = radius of the fibre
 γ = longitudinal propagation coefficient
 k = Boltzman's constant
 T = absolute temperature, deg K
 β_c = isothermal compressibility
 λ = wavelength
 n = refractive index
 $H_n^{(j)}$ = n th-order Hankel function of the i th type
 H'_n = derivation of H_n
 ν = azimuthal propagation coefficient = $\nu_1 - j\nu_2$
 L = modulation period

Subscript n is an integer and subscript m refers to the m th root of $J_n = 0$

1 Introduction

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. This form of structure guides the electromagnetic waves along the definable boundary between the regions of different refractive indexes. The associated electromagnetic field is carried partially inside the fibre and partially outside it. The external field is evanescent in the direction normal to the direction of propagation, and it decays approximately exponentially to zero at infinity. Such structures are often referred to as open waveguides, and the propagation is known as the surface-wave mode. The particular type of dielectric-fibre waveguide to be discussed is one with a circular cross-section.

2 Dielectric-fibre waveguide

The dielectric fibre with a circular cross-section can support a family of H_{0m} and E_{0m} modes and a family of hybrid HE_{nm} modes. Solving the Maxwell equations under the

boundary conditions imposed by the physical structure, the characteristic equations are as follows:

for HE_{nm} modes

$$\frac{n^2 \beta^2}{k_0} \left(\frac{1}{u_1^2} + \frac{1}{u_2^2} \right)^2 = \left(\frac{\epsilon_1 J'_n(u_1)}{u_1 J_n(u_1)} + \frac{\epsilon_2 K'_n(u_2)}{u_2 K_n(u_2)} \right) \times \left\{ \frac{1}{u_1} \frac{J'_n(u_1)}{J_n(u_1)} + \frac{1}{u_2} \frac{K'_n(u_2)}{K_n(u_2)} \right\} \quad (1)$$

for E_{0m} modes

$$\frac{\epsilon_1 J'_0(u_1)}{u_1 J_0(u_1)} = - \frac{\epsilon_2 K'_0(u_2)}{u_2 K_0(u_2)} \quad (2)$$

for H_{0m} modes

$$\frac{1}{u_1} \frac{J'_0(u_1)}{J_0(u_1)} = - \frac{1}{u_2} \frac{K'_0(u_2)}{K_0(u_2)} \quad (3)$$

The auxiliary equations defining the relationship between u_1 and u_2 are

$$\begin{aligned} u_1^2 + u_2^2 &= (k_0 a)^2 (\epsilon_1 - \epsilon_2) \\ h_1^2 &= \gamma^2 + k_0^2 \epsilon_1 \\ -h_2^2 &= \gamma^2 + k_0^2 \epsilon_2 \\ u_i &= h_i a, i = 1 \text{ and } 2 \end{aligned}$$

where subscripts 1 and 2 refer to the fibre and the outer region, respectively.

All the modes exhibit cutoffs except the HE_{11} mode, which is the lowest-order hybrid mode. It can assume two orthogonal polarisations, and it propagates with an increasing percentage of energy outside the fibre as the dimensions of the structure decrease. Thus, when operating the waveguide in the HE_{11} mode, it is possible to achieve a single-mode operation by reducing the diameter of the fibre sufficiently. Under this condition, a significant proportion of the energy is carried outside the fibre. If the outside medium is of a lower loss than the inside dielectric medium, the attenuation of the waveguide is reduced. With these properties, HE_{11} mode operation is of particular interest.

The physical and electromagnetic aspects of the dielectric-fibre waveguide carrying the HE_{11} mode for use at optical

Charles Kao
STL, Harlow, UK



7 Conclusions

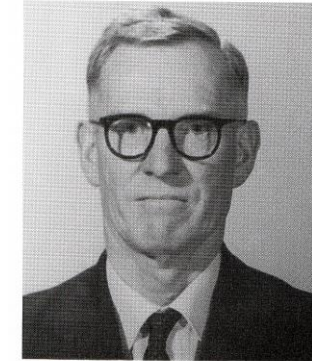
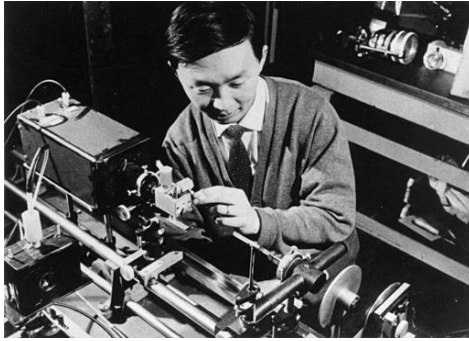
Theoretical and experimental studies indicate that a fibre of glassy material constructed in a clad structure with a core diameter of about λ_0 and an overall diameter of about $100\lambda_0$ represents a possible practical optical waveguide with important potential as a new form of communication medium. The refractive index of the core needs to be about 1% higher than that of the cladding. This form of waveguide operates in a single HE_{11} , E_0 or H_0 mode and has an information capacity in excess of 1 Gc/s. It is completely flexible and calls for a mechanical tolerance of around 10%, which can be readily met in practice. Thus, compared with existing coaxial-cable and radio systems, this form of waveguide has a larger information capacity and possible advantages in basic material cost. The realisation of a successful fibre waveguide depends, at present, on the availability of suitable low-loss dielectric material. The crucial material problem appears to be one which is difficult but not impossible. Certainly, the required loss figure of around 20 dB/km is much higher than the lower limit of loss figure imposed by fundamental mechanisms.



Receiving Nobel
prize for physics
2009

Post Office Research involved from the start

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FF Roberts,
Post Office Research

Kao in his Nobel lecture in 2009 said:

CONVINCING THE WORLD

The substance of the paper was presented at an IEE meeting on January 27, 1966 [7]. Most of the world did not take notice – except for the British Post Office (BPO) and the U.K. Ministry of Defence, who immediately launched major research programs [8, 9]. By the end of 1966, three groups in the U.K. were studying the various issues involved: I myself at STL; Roberts at BPO; Gambling at Southampton in collaboration with Williams at the Ministry of Defence Laboratory [10].



TOPICAL MEETING ON OPTICAL FIBRE TRANSMISSION II - WILLIAMSBURG,
22-24 FEBRUARY 1977

OPTICAL FIBRE TRANSMISSION SYSTEM STUDIES IN THE UK POST OFFICE

F F Roberts

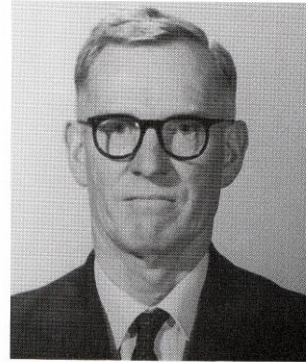
Post Office Research Centre, Martlesham Heath, Ipswich, Suffolk, IP5 7RE,
England

Background

The present writer became aware in late 1965 of the studies then being pursued by K C Kao at STL. A parallel interest (1, 2, 3) in high purity crystalline dielectric materials led (10) to a critical evaluation of the high purity glass problem and to the conclusion that low loss optical fibres could be produced. A PO target loss of less than 20 dB/km was set early in 1966 and quoted to all interested parties, which included Corning Glass through their UK associate Electrosil. A Ministry of Technology contract was set up with Sheffield University and PO contracts were let during 1967 with British Titan Products Company, with STL and with Barr and Stroud Ltd. A Ministry of Defence contract was already supporting the development of promising gallium arsenide lasers at STL and direct PO contract support has been added there in recent years aimed at a reliable laser for fibre transmission systems.

1966 & 1967 FF Roberts mobilises UK

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FF Roberts' internal memo shows in March 1966 he visited the following UK companies to talk about fibre optics

- 1st March. Signals Research and Development Establishment (MOD). Charles Kao present as well
- 4th March. Ministry of Aviation
- 7th March. Imperial College, London
- 10th March, Glass Developments Ltd, Battersea, London
- 11th March. Sheffield University

FF Roberts sets up contracts for Low Loss Optical Fibre Consortium:

- STL, Harlow (where Kao was working)
 - Barr & Stroud, Glasgow
 - British Titan Products
 - Sheffield University
-
- In 1967 Post Office Research makes its first optical fibre in a laboratory.
 - “Run Jacquie Run!”.
 - Loss 30dB/m !
 - Continued to make (good!) fibres until 1990s



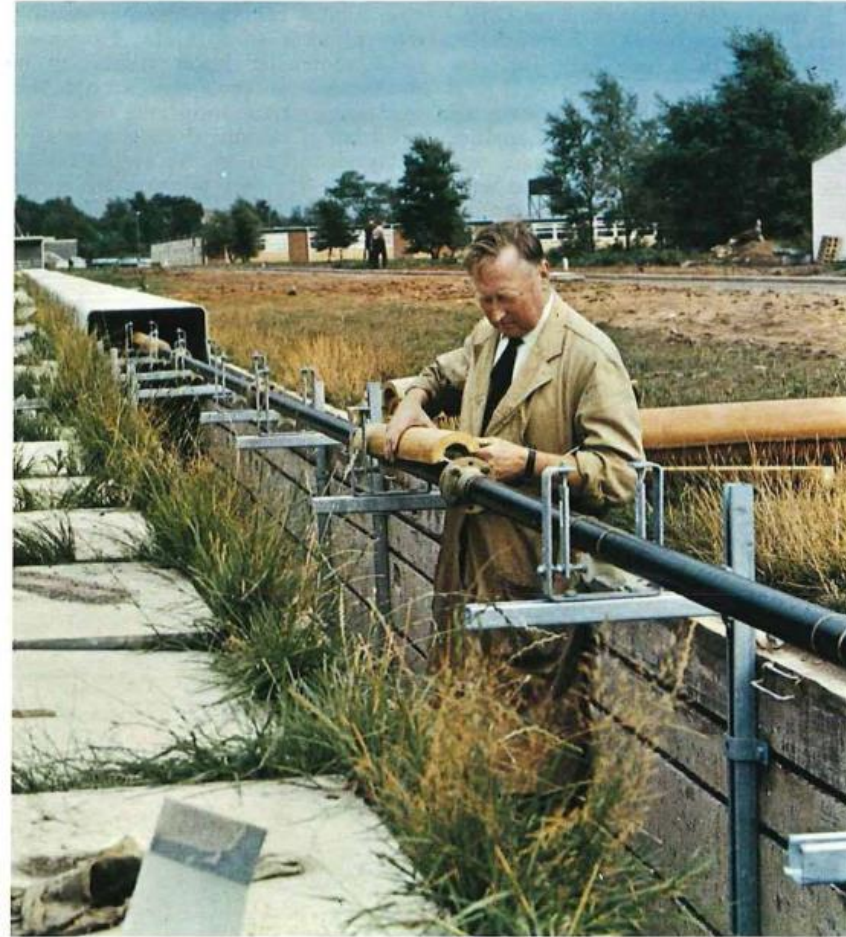
The preferred solution before fibre came along

Post Office Telecommunications Journal. Autumn 1970.

A new type of trunk telecommunications system in which radio signals are transmitted through hollow copper tubes buried in the ground is to undergo a full-scale field trial. The tubes, called waveguides, are just 50 mm in diameter, little thicker than a car's exhaust pipe, and are capable of transmitting signals of very short wavelength.

Although loss of signal strength is very low, amplifying stations are needed at intervals. If the waveguide route is fairly straight and level these repeaters may be 20 km or more apart. In built-up areas where the waveguide must bend to avoid pipes and cables already in the ground, there are additional losses and repeater spacing may be 10 km or less.

The field trial equipment will be capable of carrying over 300,000 two-way telephone conversations or 200 television circuits or the equivalent in other forms of traffic. If successful, waveguides could be laid from city to city to



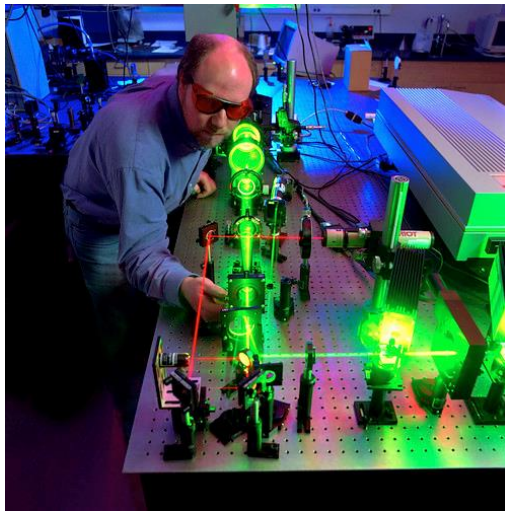
- Field trial between Martlesham and Wickham Market ran until 1977

1970 – optical fibre breakthrough

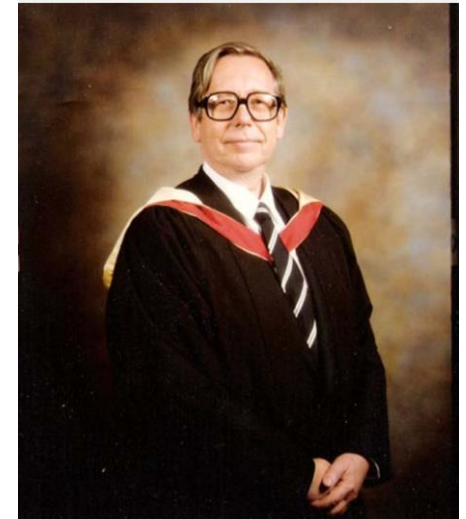
IEE Conference on Trunk Telecommunications London in October 1970



- Most papers about the hollow copper waveguides
- Handful of papers on optical fibre
- Corning announced they had made an optical fibre with loss below 20 dB/km
- Dick Dyott of Post Office : “we can wait for the waveguide to be laid in the ground and then come along and fill it with optical fibres”



- 9th November 1970 Corning took a sample to Post Office Laboratories, Dollis Hill
- **Loss 15 dB/km!**
- In 2001 IEEE dedicated a Milestone plaque in Corning, USA to recognise the achievement.....



IEEE Milestone Plaque for Corning

With
due
credit
given to
Post
office

The Worlds First Low-Loss Optical Fiber for Telecommunications, 1970

In 1970, Corning scientists [Dr. Robert Maurer](#), [Dr. Peter Schultz](#), and [Dr. Donald Keck](#) developed a highly pure optical glass that effectively transmitted light signals over long distances. This astounding medium, which is thinner than a human hair, revolutionized global communications. By 2011, the world depended upon the continuous transmission of voice, data, and video along more than 1.6 billion kilometers of optical fiber installed around the globe.

During the mid-1960s, members of the British Post Office came to Corning seeking assistance in creating pure glass fiber optics. Their design required a single-mode fiber (100 micron diameter with a 0.75 micron core) having a total attenuation of about 20 dB/km. The very best bulk optical glasses of the day had attenuations of approximately 1,000 dB/km. This meant Corning's scientists had to see an improvement in transparency of 1,098 in order to reach the 20 dB/km goal. It seemed impossible, but they did it, inventing an optical fiber with attenuation of 17 dB/km. As a result, Corning's invention of the first low-loss optical fiber and the manufacturing process used to produce it revolutionized the telecommunications industry and changed the world forever. The explosion of the Internet and other information technologies would not have been possible without optical fiber. Only optical fiber provides the bandwidth required for high-speed transmission of voice, data, and video the world depends upon for the way we live, work, and play. Today, there are more than 1.6 billion kilometers of fiber installed around the globe.

This breakthrough work established the optical fiber category. There were no similar achievements at the time of the invention. In recognition of this achievement, the three scientists responsible for inventing low-loss optical fiber – Dr. Robert Maurer, Dr. Peter Schultz, and Dr. Donald Keck – have been inducted into the Inventors Hall of Fame and were awarded the National Medal of Technology.

IEEE Regions

1

IEEE sections

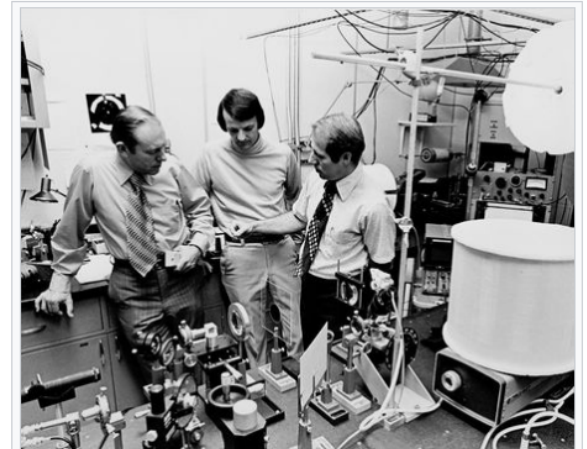
Rochester

Additional IEEE section information

Milestone sponsored by the IEEE
Photonics Society

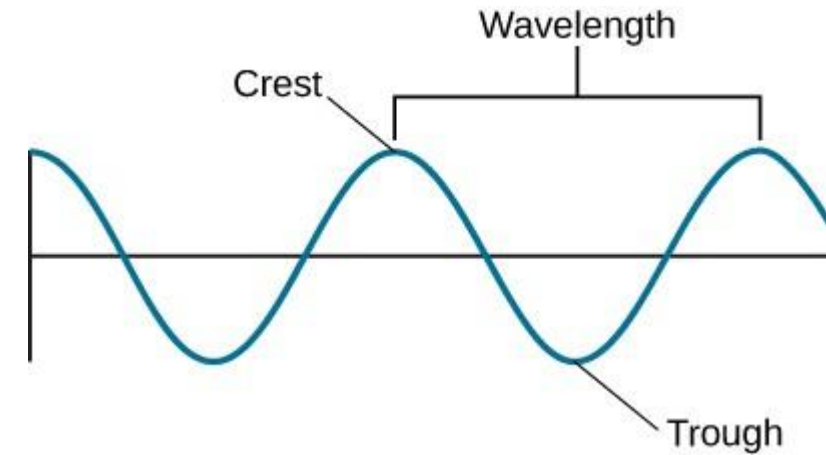
Achievement date range

1970-1970

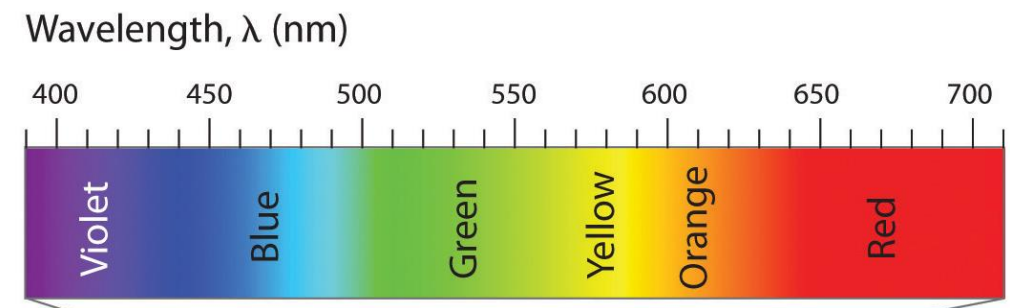


1972. Dr. Robert Maurer, Dr. Peter Schultz, and Dr. Donald Keck. Sullivan Park Archive, Corning, N.Y.

Light is a wave

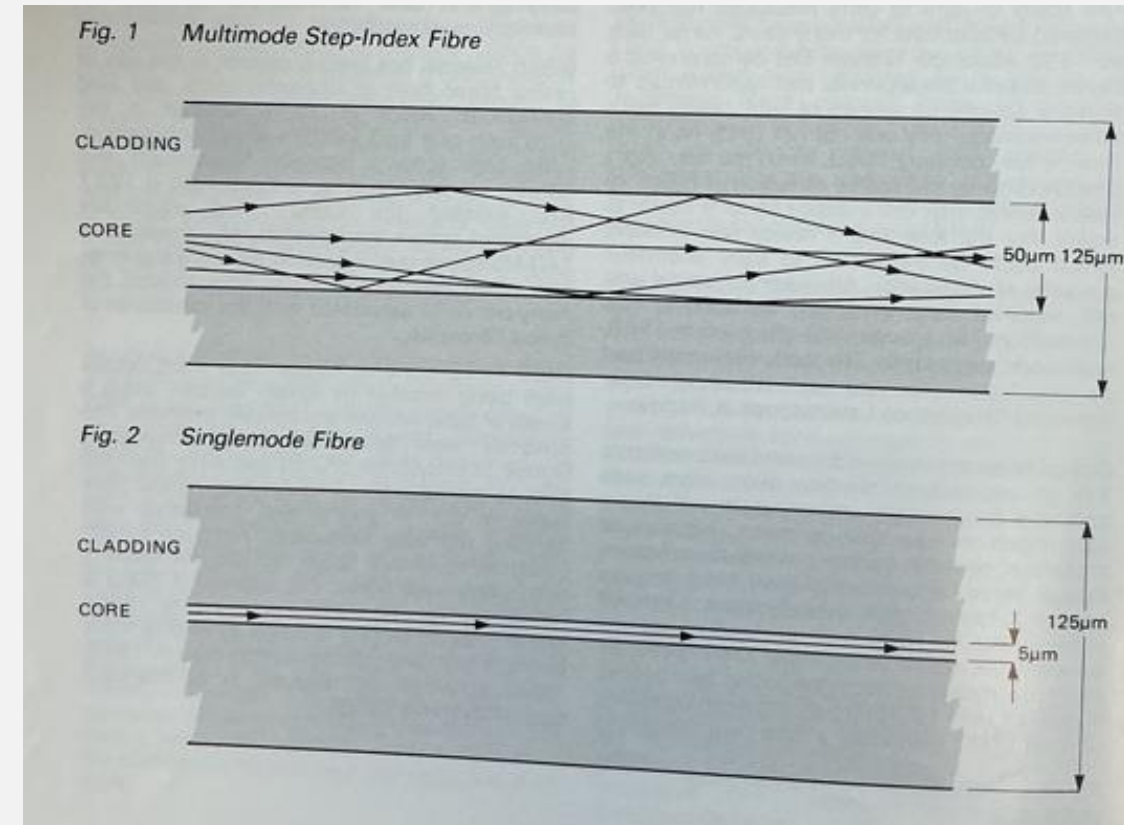
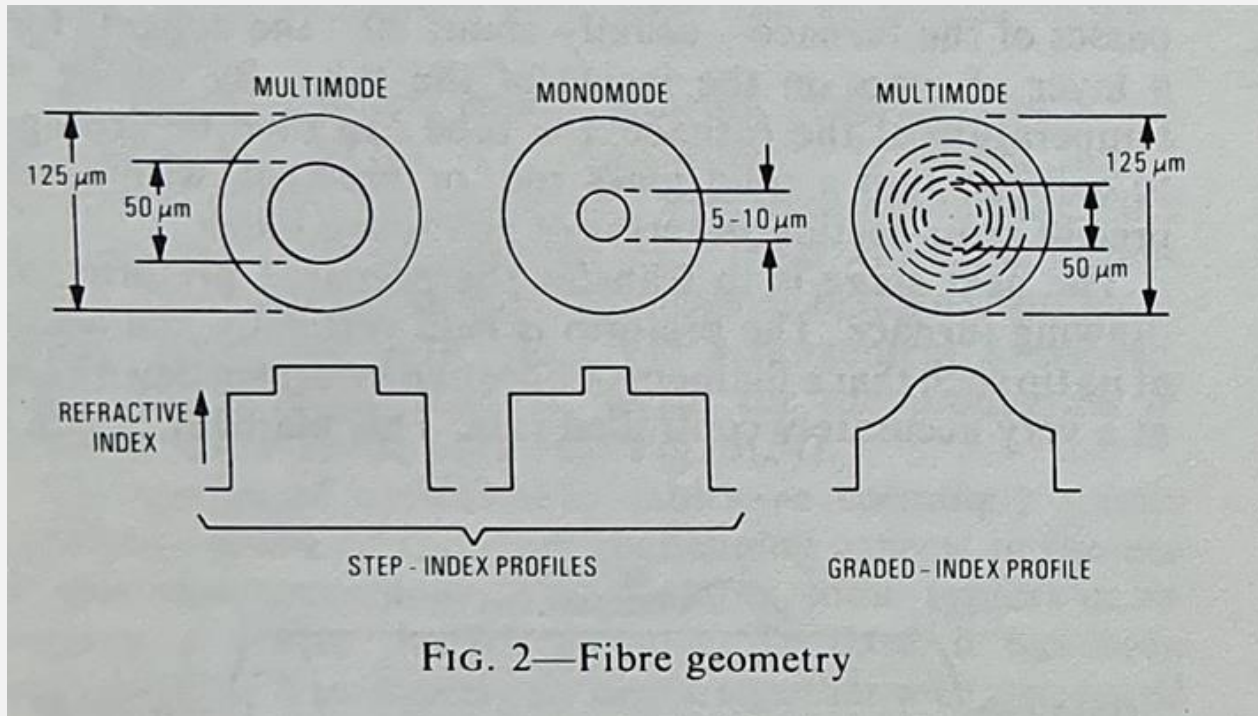


1 st Telecoms window	850 nm
2 nd telecoms window	1300 nm
3 rd telecoms window	1550 nm



1 nm = 1 nanometre = 0.000000001 metres

Multimode versus single mode



- Kao's 1966 paper and the 1970 Corning breakthrough were single mode fibre
- Through the 1970s the world moved towards using multimode fibre because easier to get light into the larger core and join fibres together

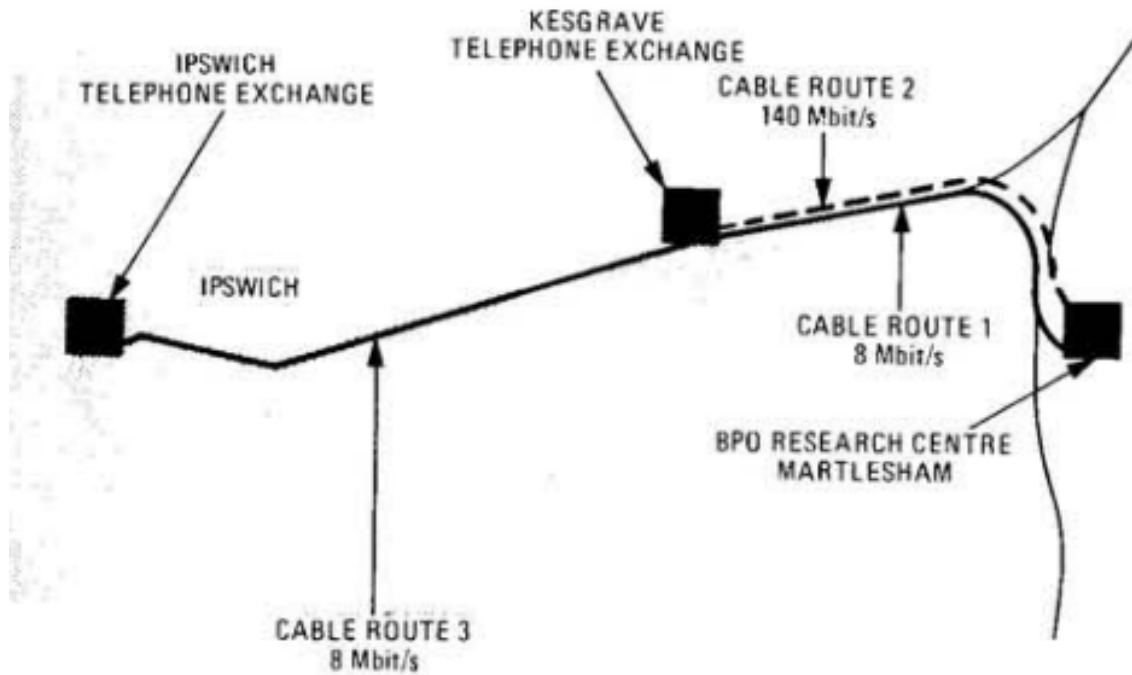
20th November 1975

- Technical improvements made since 1970
 - In the fibre itself and the semiconductor sources and detectors
- At the opening of Martlesham laboratories there was a demonstration of 8Mbit/s over 6km of multimode fibre



1977: First Post Office fibre trial

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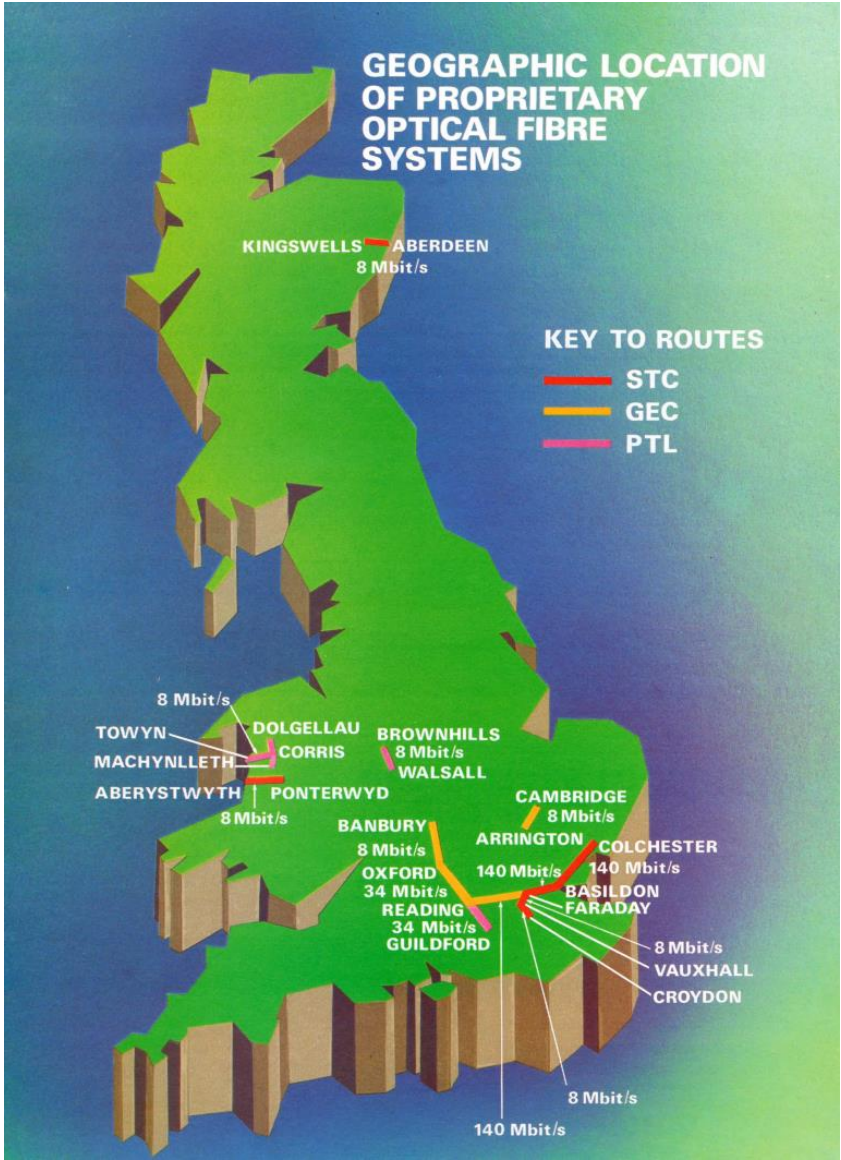


- Adastral Park- Kesgrave- Ipswich telephone exchange
 - Graded index **multimode** fibre
 - 140 Mbit/s over 5.75km from Adastral to Kesgrave
 - 8 Mbit/s over 13 km Adastral to Ipswich link – no repeaters
 - Corning made the fibre with **loss ~5dB/km** at the operating wavelength ~840nm
 - BICC put the fibre into cables which local Post Office field engineers installed into ducts
 - Carried Europe's first public phone calls over optical fibre
 - Post Office work on the Martlesham-Wickham Market copper waveguide trial now stopped
- *In the same year STL deployed 140Mbit/s on a 9km route between Hitchin and Stevenage telephone exchanges*
 - *3km repeater spacing which was deemed uneconomic*

1978: BT starts deployment of multimode fibre

- 1978: BT plans for operational optical network on 15 routes. Proprietary Optical Line Systems (POLS)
- 1979: contracts placed with 3 vendors
- 1980: 1st deployment between Brownhill and Walsall

System	Prime Contractor	Route	No. of Systems	Network Application	Ready for Service	Power Feeding	Route Length km
140 Mbit/s	STC	London-Basildon Basildon-Colchester	2	T	1982	✓	47
			2	T	1982	✓	61
	GEC	London-Reading	2	T	1980	✓	74
34 Mbit/s	GEC	Oxford-Reading	2	T	1981	✓	48
	PTL	Guildford-Reading	2	T	1982	✓	53
8 Mbit/s Long Haul	GEC	Banbury-Oxford	2	T	1981	✓	39
8 Mbit/s Short Haul	STC	Aberystwyth-Ponterwyd	2	J	1981	X	20(A)
		Aberdeen-Kingswells	2	J	1981	X	12
		Croydon-Vauxhall	2	J	1980	X	15
		London-Vauxhall	2	J	1981	X	4
	PTL	Corris-Dolgellau	4	J	1981	✓	16(A)
		Corris-Towyn	2	J	1981	X	23(A)
		Corris-Machynlleth	4	J	1981	X	9(A)
		Brownhills-Walsall	2	J	1980	X	9
	GEC	Arrington-Cambridge	2	J	1981	✓	17
	Total		34				447

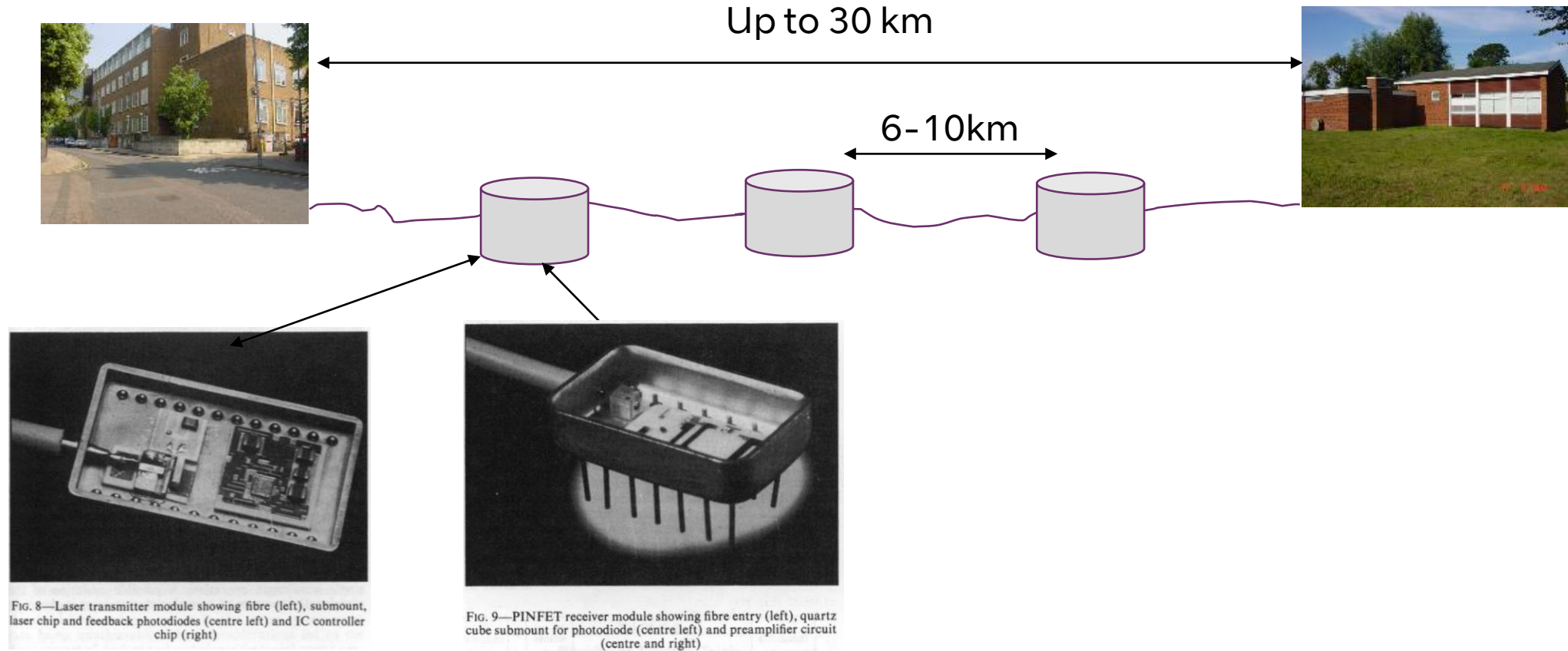


Meanwhile in Martlesham.....

Martlesham led the world to single mode fibre

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- Dave Payne of BT Labs showed a significant cost saving if could get a repeater spacing of 30km or more and bit rates of 140Mb/s or more

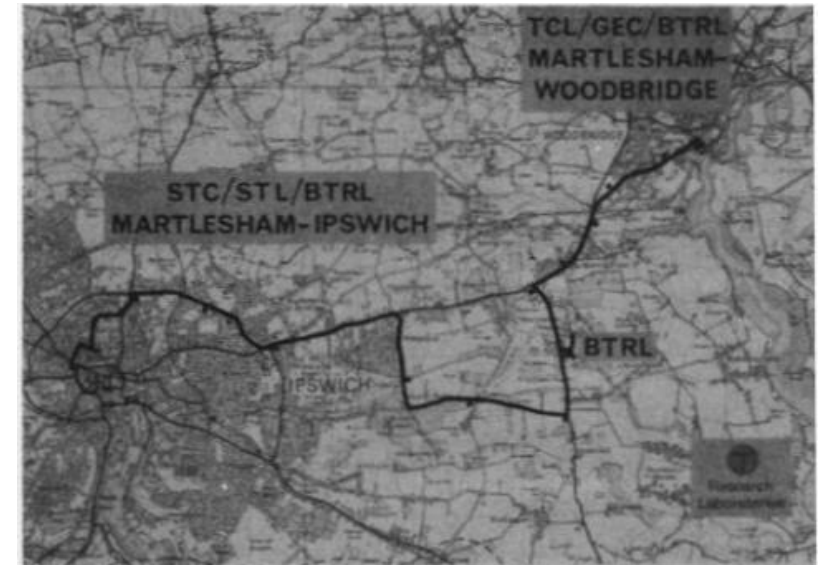
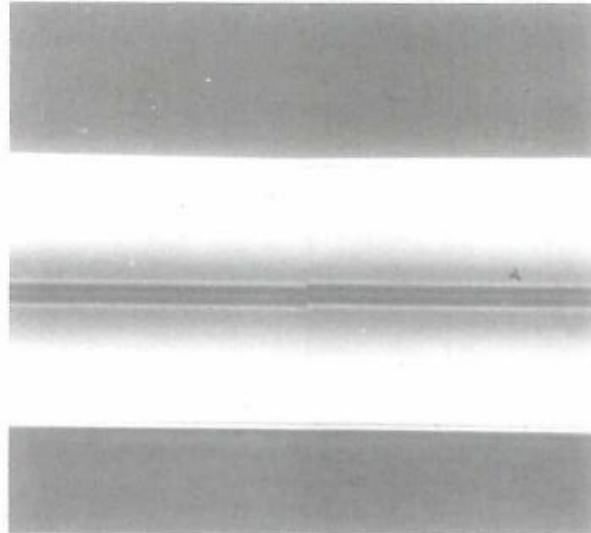


- Single mode was lower loss than multimode, was cheaper to produce and did not suffer mode dispersion which limited the bit rate and regenerator spacing on multimode fibre systems.
- BUT more difficult to get light into the smaller core of single mode fibre
- Sydney O'Hara (Deputy Director Research) chaired an internal workshop at Martlesham which decided the future was single mode
- First Martlesham open week in 1980: lab demo of 37km unrepeated 140Mbit/s single mode fibre link

1982 BT labs World first field trials of single mode fibre

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- February 1982: BT Labs does world-leading single mode fibre field trial between Martlesham and Woodbridge (7.5km)
- splicing/joining fibres in real-world is key aspect
- 140Mbit/s and 650 Mbit/s over 37.5km unrepeated (1300 nm wavelength)
- 140Mbit/s over 62km unrepeated (1300 nm wavelength)
- A second trial link deployed Martlesham - Ipswich



TELECOM

News release

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DW111

October 21, 1983

FIRST SINGLEMODE OPTICAL FIBRE LINK

Another world first in optical fibre communications has been notched up by British Telecom.

Optical fibres are strands of glass as thin as a human hair. Phone calls travel along these filaments as pulses of light.

This form of communications offers significant cost savings over conventional long-distance coaxial telephone cable.

In this new achievement, British Telecom has successfully tested the world's first 140 Mbit/s commercial optical fibre link using the technique known as singlemode transmission.

The link runs 27 km (17m) between Luton and Milton Keynes, without intermediate regenerators (which boost the light along the route).

In general, singlemode systems can span distances of at least 30 km without regenerators. By contrast, using the less advanced multimode alternative, regenerators have to be installed - usually in manholes - at 6 to 10 km intervals.

mf

OPTICAL FIBRE LINK IS A UK FIRST

THE FIRST monomode optical fibre communications systems for operational use in the UK network have been supplied by STC to British Telecom.

In a major technological step two 140 Mbit/s systems cover the 27.3km (17 miles) between Luton and Milton Keynes without signal regenerators along the route.

The order for the systems was won by STC Telecommunications' Transmission Products Division, Basildon which also installed the equipment at the terminals.

The fibre was manufactured at Harlow and cabled by Cable Products Division, Newport. The electro-optic devices were made at STC Components, Paignton.

The optical fibre cable on the Luton to Milton Keynes route, following the Watling Street Roman road (the A5), was installed and joined in existing cable ducts by British Telecom engineers. Training and oversight of the whole operation was a joint STC/British Telecom undertaking.

The ability of the monomode optical fibre system

to operate over such long distances without needing signal regenerators stems from its far greater efficiency compared with the previous multimode 140 Mbit/s systems.

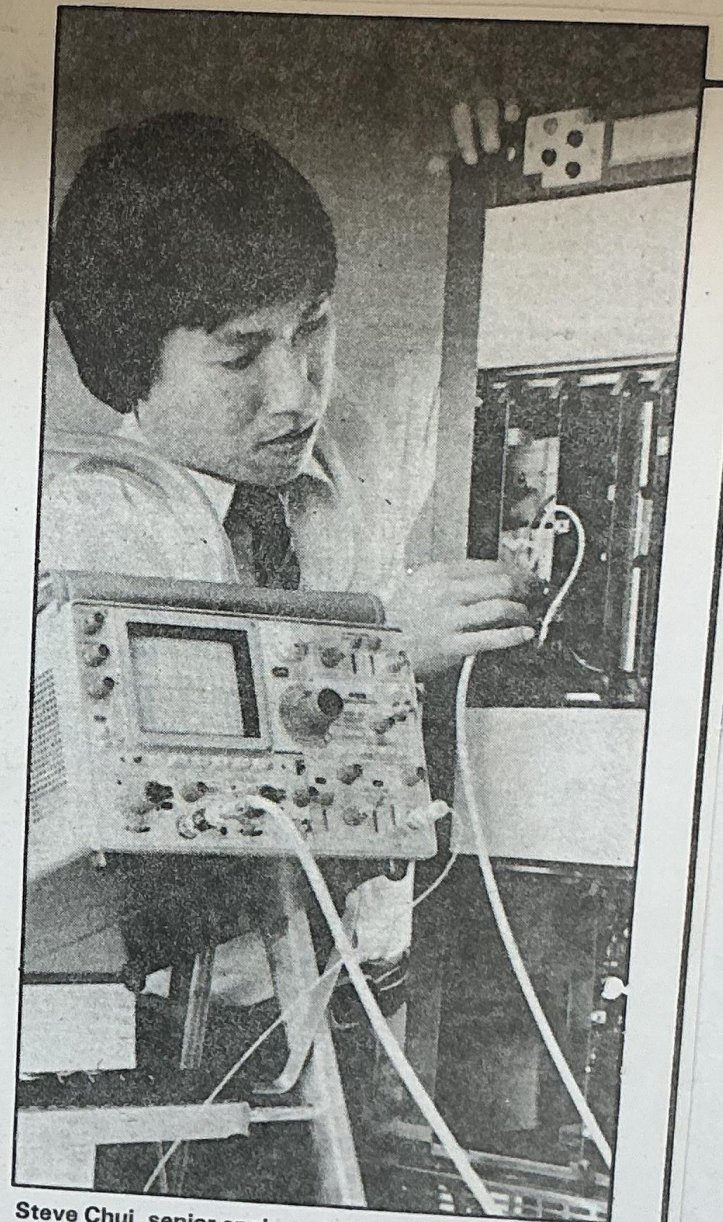
They have needed, instead, regenerators at intervals of 6-8 km along the cable route.

Installed

Two such multimode systems were installed on the 47 km route between London and Basildon and handed over to British Telecom by STC in March this year.

Trials of the new monomode operations were carried out by STC and British Telecom between Ipswich and Martlesham, Suffolk last year.

The news of the historic Luton-Milton Keynes link helped boost considerable worldwide interest shown in STC's 140 Mbit/s optical transmission systems at Telecom 83 in Geneva last month.

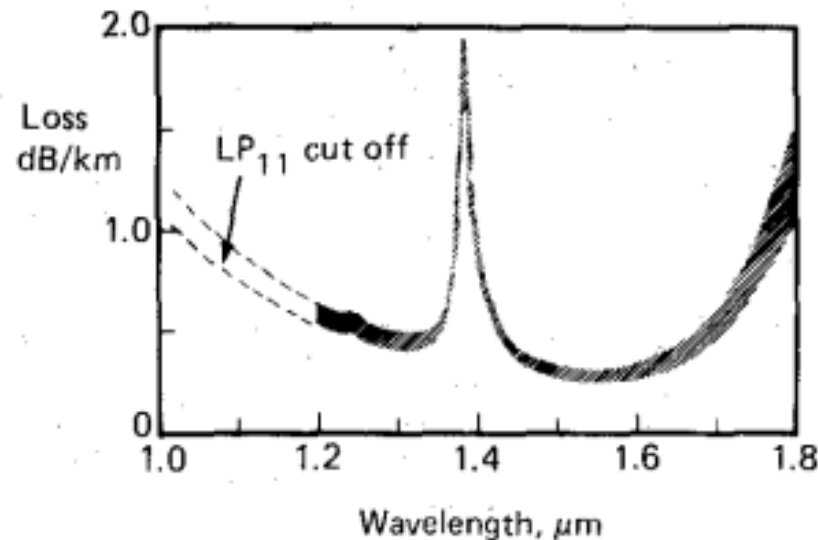


Steve Chui, senior engineer in TPD's optical development laboratory, Basildon tests the STC 140 Mbit/s line system used for the Luton-Milton Keynes link.

Martlesham world experts on design of single mode fibre

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- In 1982 Jim Ainslie & Clive Day have plenary paper at world-leading Optical Fibre Communications conference: “Current world-wide status of single-mode fibers”
- Their results⁽¹⁾ below show low loss operation at both 1300nm and 1550nm wavelengths as is widely deployed today
- BT Labs licensed their fibre to GEC and Ericsson in 1982

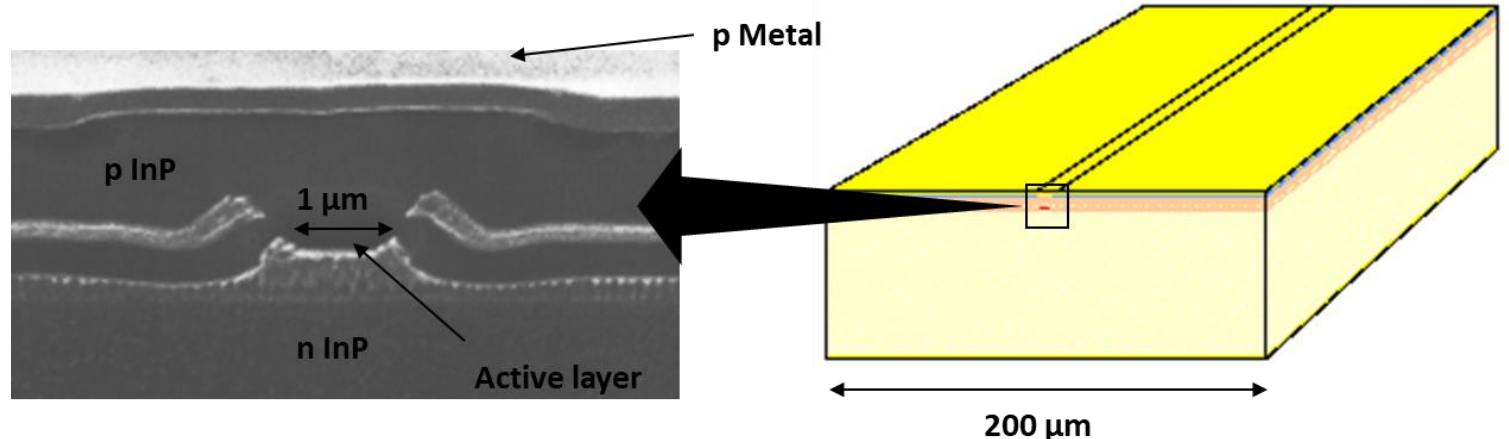
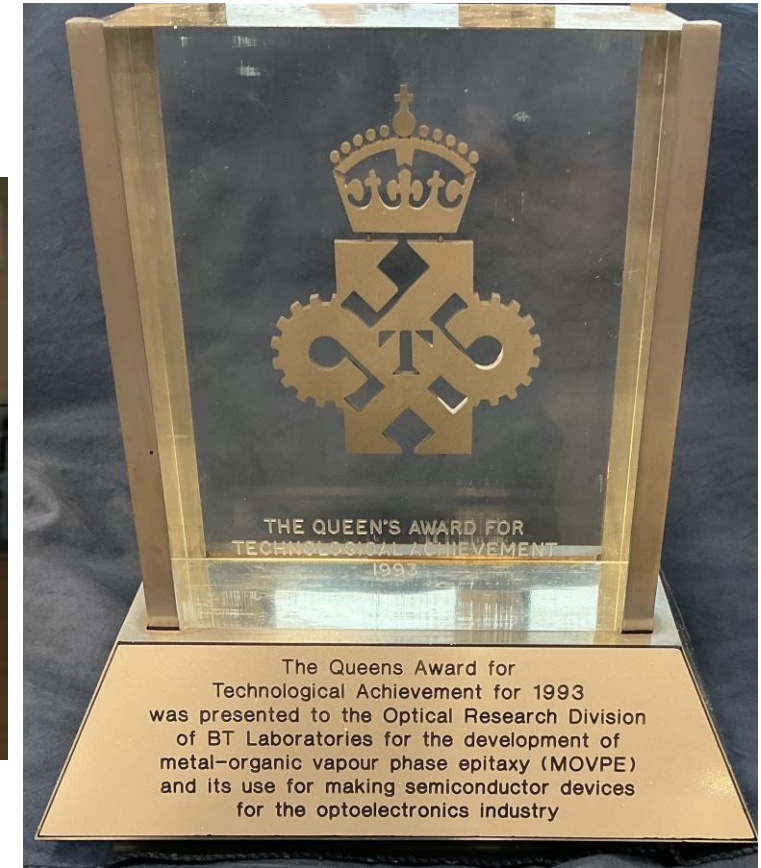


(1) IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. MTT-30, NO. 4, APRIL 1982. Ainslie, Day, Beales & Rush

Another Queen's Award 1993

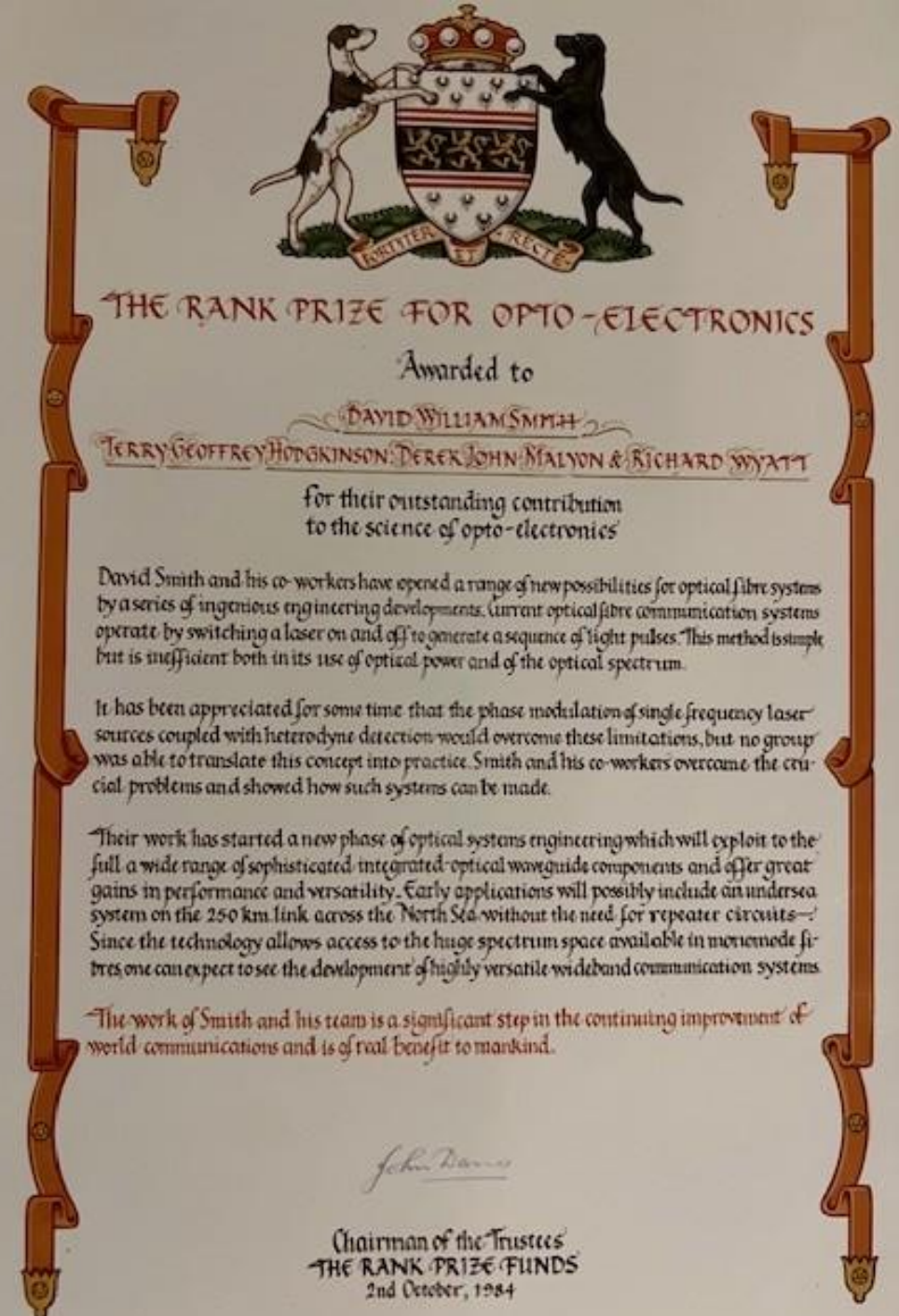
MOVPE technique used to make semiconductor optical components

- Post Office Research was involved from the outset in research to make suitable light sources and receivers for the new field of optical fibres
- In 1970s & 1980s, Metal Organic Vapour Phase Epitaxy (MOVPE) was being developed across the world for various applications
- Post Office worked collaboratively on MOVPE with universities and companies like Plessey and STL
- Commercialised MOVPE through BT&D joint venture with Du Pont
- MOVPE used ubiquitously today to make the semiconductor optical components that are connected to optical fibres today



Coherent transmission Rank Prize 1984

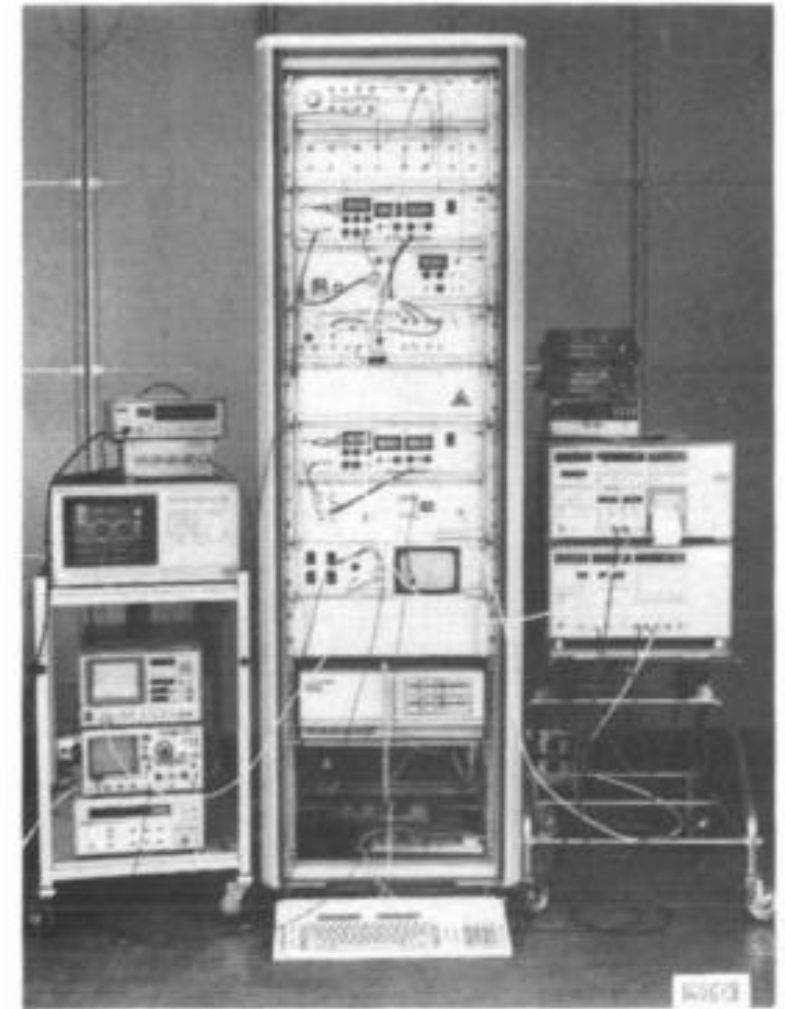
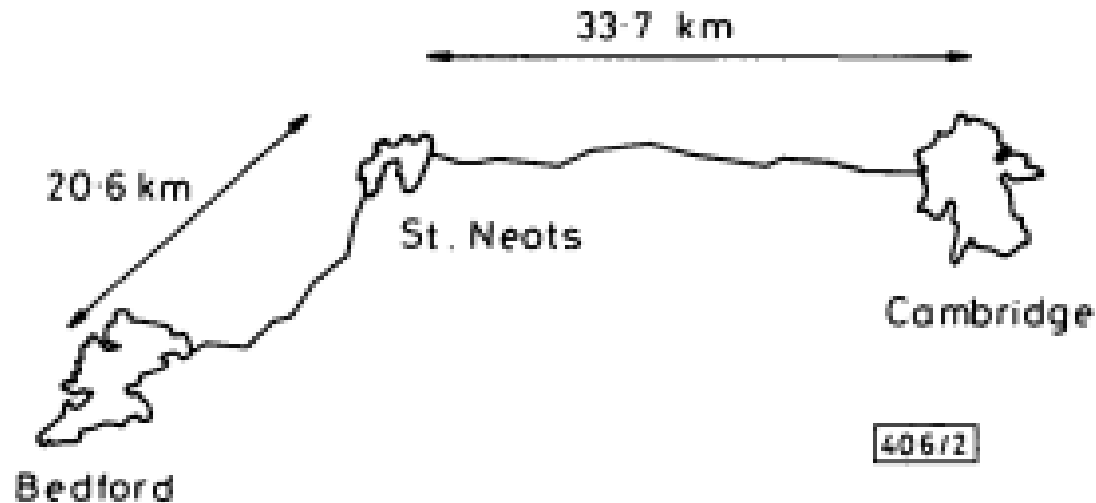
- Coherent is a technique to increase reach and bandwidth carried in an optical fibre through
 1. using the fact light is a wave and
 2. Electronic signal processing
- “..no group were able to translate this concept into practice. Smith and his co-workers overcame the crucial problems and showed how such systems can be made. The work is a significant step in the continuing improvement of world communications and is of real benefit to mankind



1988. BT first in world to deploy coherent in the field

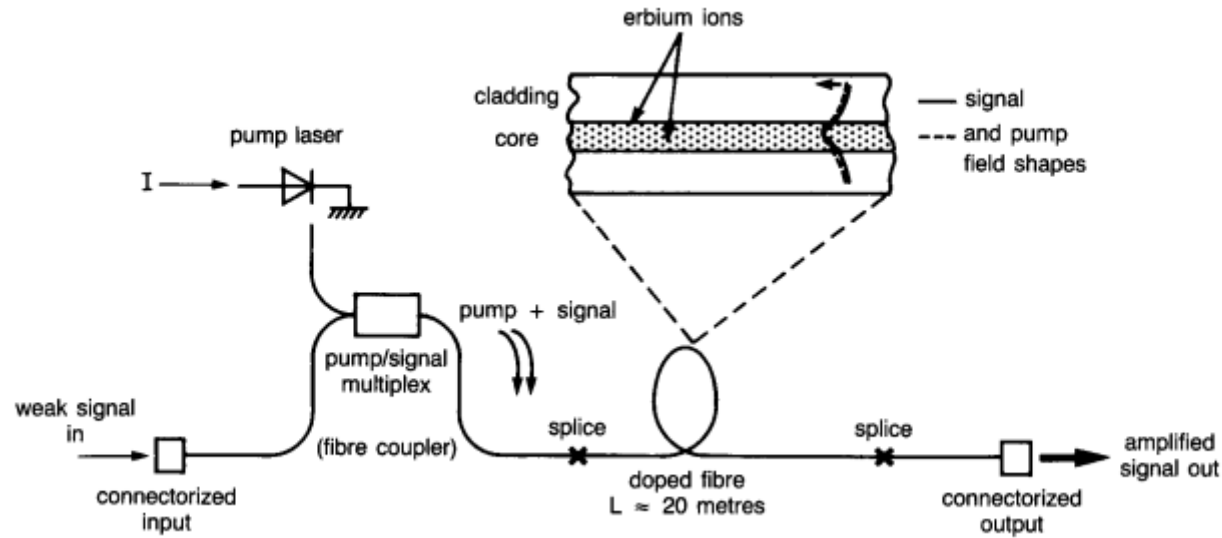
26

- Taking the optical reach to 176km
- 565 Mbit/s

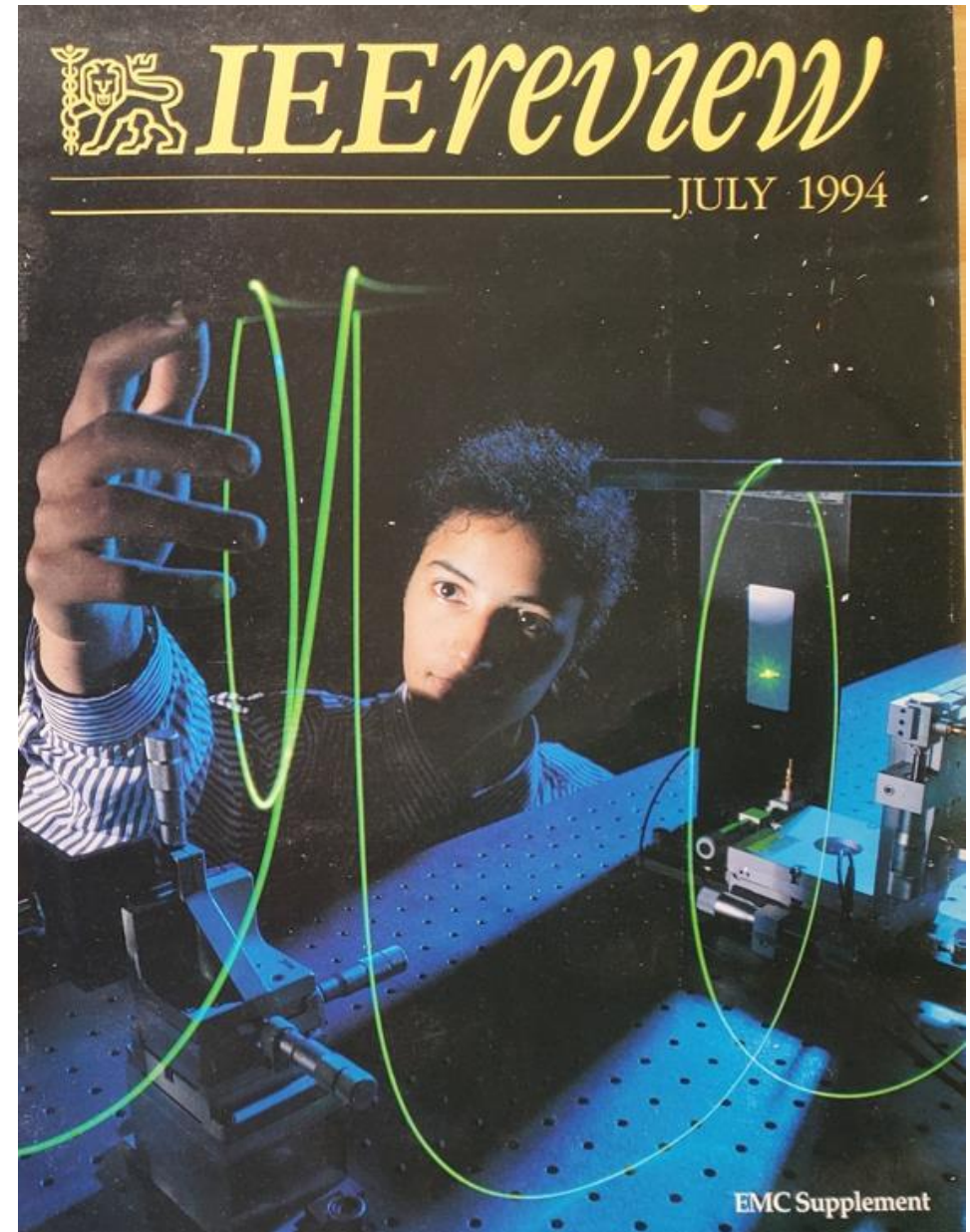


- Today coherent widely used in inter-city fibre transmission to deliver hundreds of thousands of Mbit/s over hundreds and thousands of kilometres
- In combination with optical fibre amplifiers.....

Optical fibre amplifiers



- Erbium fibre amplifiers first reported by Southampton University in 1987
- Tim Whitley of BT reported 1st laser diode pumped operation in 1988
- Commercial device by 1990 – see next slide
- Erbium fibre amplifiers now widely used in our inter-city fibre networks
 - Total reach >1000 km
 - Amplifiers every ~80km
 - They work in 1530-1565 nm wavelength range where single mode fibres have lowest loss (~0.2dB/km)



Invention on Tomorrow's World



Award-winning Dr. Colin Millar (left) and Dr. Paul Wheatley receive their certificate from Prince Charles.

The development of a prototype erbium fibre amplifier has led to engineers Paul Wheatley and Colin Millar of RT21 being featured on *Tomorrow's World* in the presence of HRH Prince Charles.

As two of the seven finalists in this year's Prince of Wales Award for Innovation and Production, they were featured in the show on Thursday, 14th June. Filming took place at Sandringham House. The engineers, with their technicians Mike Hunt and Jodie Ward, spent three days at the Royal home. They had to set up a demonstration of the device — the world's first all-fibre packaged fibre amplifier.

It will be two years before they know if it has won the award. The Prince's organisation, Business in the Community, will evaluate the development in 1992, judging it on a combination of technical innovation and potential for commercial success.

Colin Millar led the speculative research carried out between 1985-8 that was corporately sponsored. Paul managed the product development,

sponsored by BTI for application in submarine systems. Mike Hunt helped with fabrication work during the research phase, while Jodie made a significant contribution to development and production.

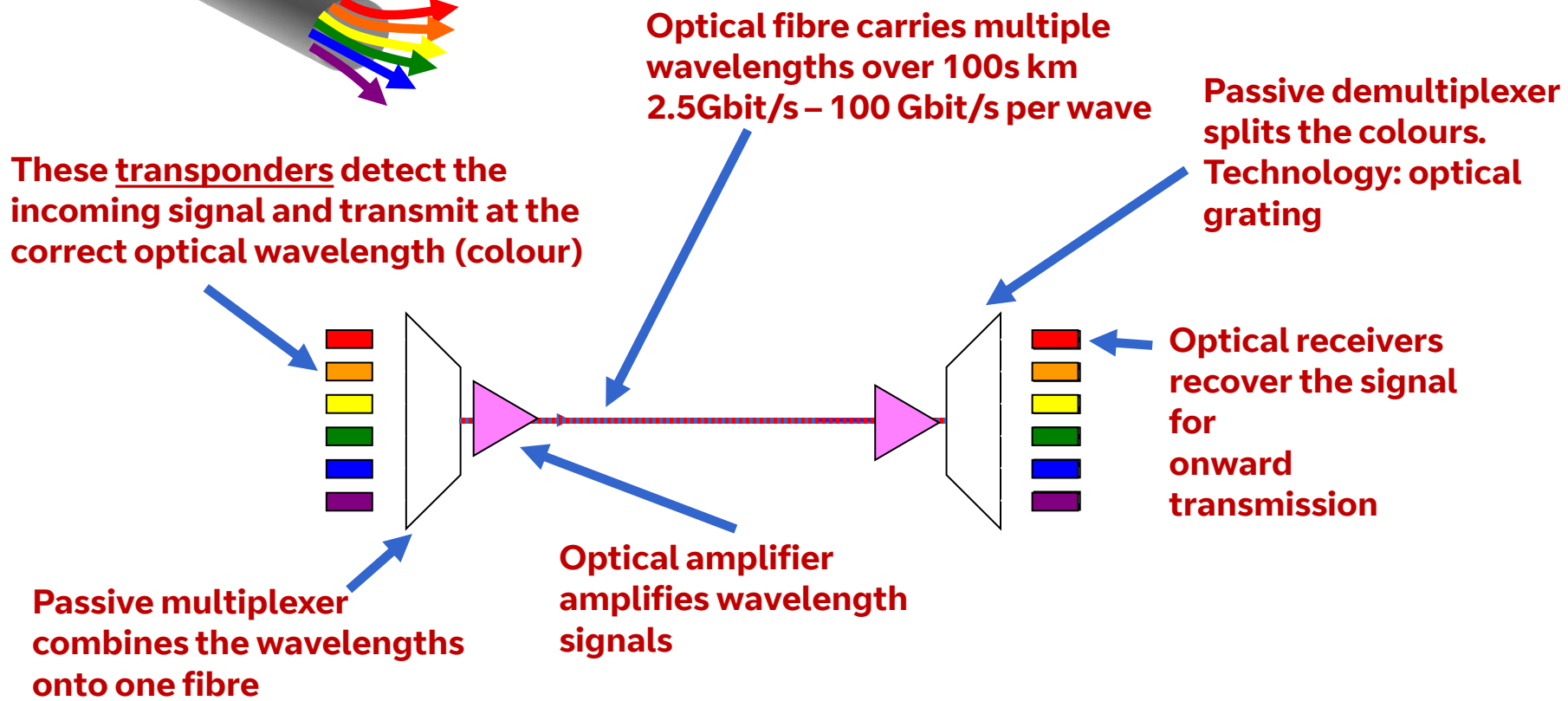
The device has been supplied to most optical groups on the Martlesham Heath site, and is now commercially marketed by BT&D.

Technical explanation

Signals sent down optical fibre communications systems, without amplifiers, degenerate to such an extent that they eventually become completely unintelligible. The special 'doped' fibre inside the amplifier has the chemical, erbium, incorporated into it during manufacture. Lasers within the amplifier 'pump' energy into the erbium. The incoming signal is then amplified by the energy transferred into it, to remain intelligible over a long distance. The amplifiers are likely to be used in telephony and data transmission systems by 1995.

WDM one slide tutorial

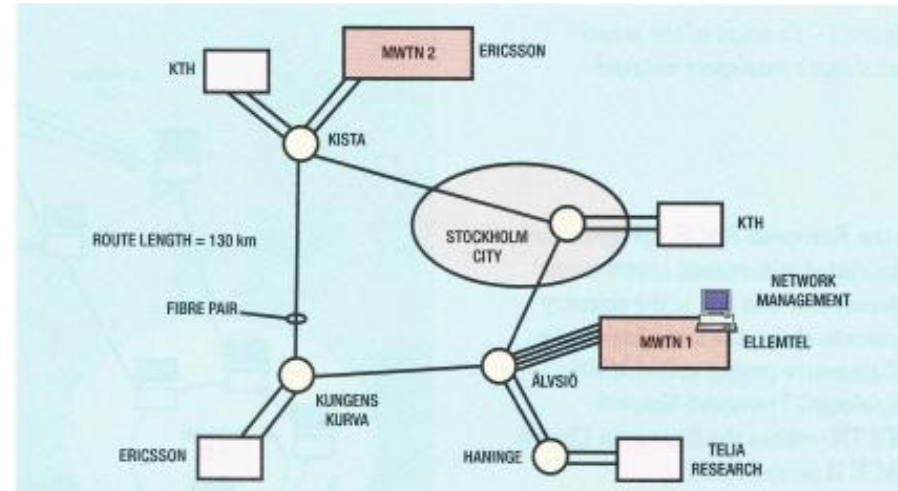
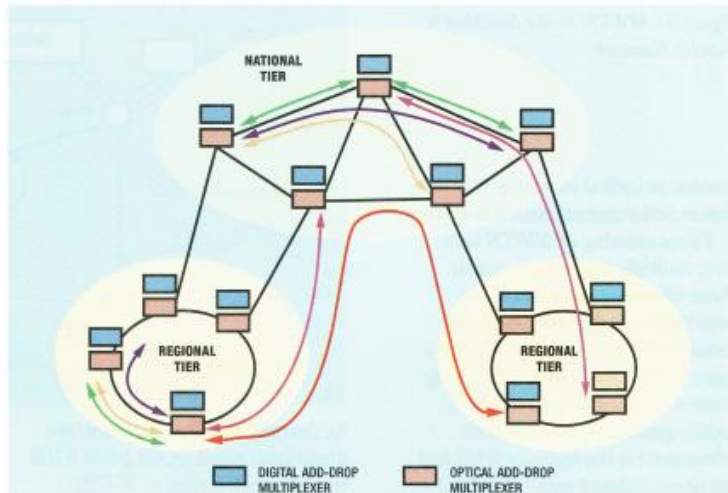
Wavelength Division Multiplexing



- Above is a fixed point-to-point line system carrying a number of wavelengths between two exchanges
- BT first deployed the above in late 1990s
- What we have today is a national network of managed wavelength switches – routing wavelengths all optically between any two cities....

Managed wavelength switching

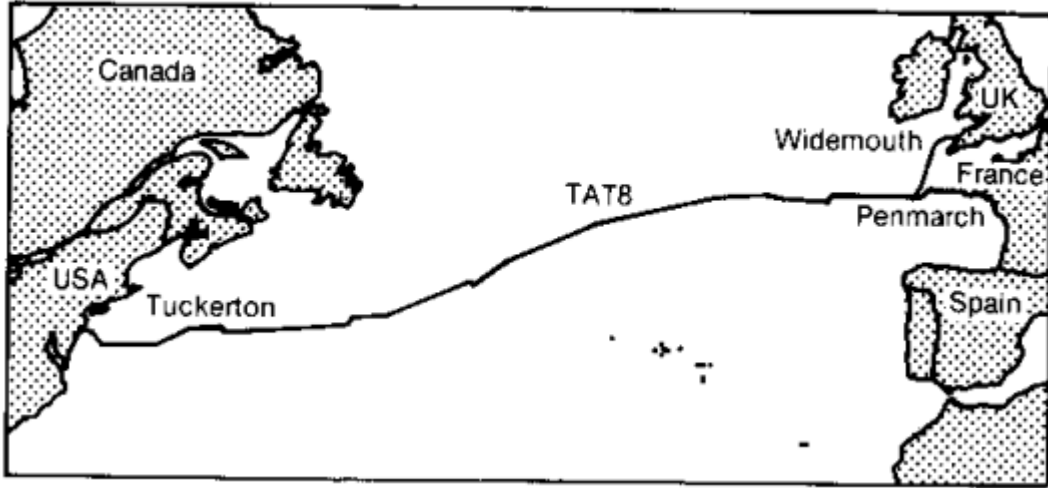
- Goff Hill of BT Labs first proposed the idea of a managed, wavelength switched network at a conference in 1988
- As part of the EU-funded RACE programme, BT Labs then led a ten partner collaborative project MWTN (Multi-Wavelength Transport Network) from 1992-95
 - to demonstrate a managed, transparent, multi-wavelength optical transport layer
 - Successful field demonstration in Sweden in 1995 (world-first)
 - In 1995, BT Laboratories received the RACE Award for Technological Progress in recognition of MWTN's achievements—a significant milestone at the close of the decade-long RACE programme.



- This concept is used today in the inter-city network of BT and other operators

TAT8 – 1st transatlantic subsea fibre cable

31



- In service 1988
- 280 Mbit/s carrying 8,000 voice channels
- Wavelength 1310nm
- BT Labs developed an interconnection cable joint enabling a three-way split

TeMart

An internal newspaper of Technology Executive

NO. 2 FEBRUARY 1986

MAJOR STC ORDER FOR MARTLESHAM RECEIVERS

STC, the world's largest submarine systems manufacturer, has called upon Martlesham to design a new set of integrated circuits, and an optoelectronic receiver to meet the complex compatibility demands of TAT8. Martlesham have also now won a contract for the on-site manufacture of all the optical receivers for STC's segment of TAT8.

Dr Tom Rowbotham, Head of Optical Transmission Systems Division, told *TeMart News*: "Although renowned for its highly reliable transistors and ICs, this is the first time the site has made optoelectronic components for the submarine world. It is a reflection of the esteem in which the optical excellence of BTRL is held by STC. We are recognised world leaders in optical technology."

TAT8, the first optical fibre transatlantic submarine telecommunications cable, has 26 owners. The largest is AT&T and the second largest, BT. Each of the three major participating countries — Britain, the USA and France — has a landing point and an interest in manufacturing and in view of this, the owners decided on three

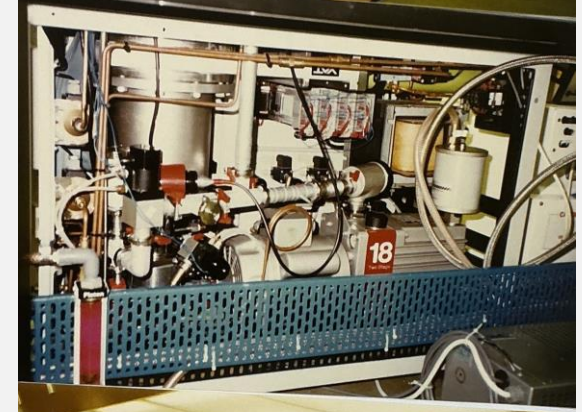
alterations to the STC and Submarcom systems, so that they can all use the same coding. The necessary expertise in IC and receiver design lies at Martlesham, and has won for BTRL a £3½m STC contract for this work. Derek King has spearheaded its progress. This contract has led to a further £2m commitment from STC for all the optical receivers for their segment.

Demanding

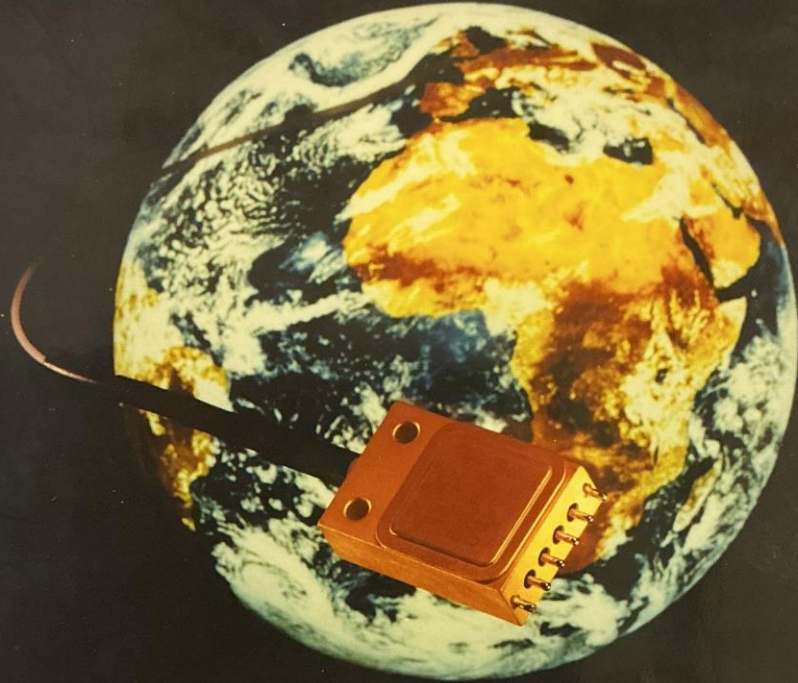
Their long-haul NL2 system is now based on this new receiver design. Submarine technology is probably the most demanding anywhere in terms of reliability — even more so than defence electronics, or satellite communications, where the life of the equipment is generally expected to be less than ten years. The TAT8 system is specified to work for 25 years, with allowance made for only three cable ship repair operations. Yet, there are 250 repeaters in the combined system. "If Moses had laid a system with these design margins in the Red Sea," remarked Dr



A laser welder being used in TA5.2.1 to assemble receivers for TAT8, the first transatlantic optical cable system.



The 1990 Queen's Award for Technological Achievement has been presented to Research & Technology for the design and manufacture of a receiver for the world's first optical transatlantic cable system, TAT-8



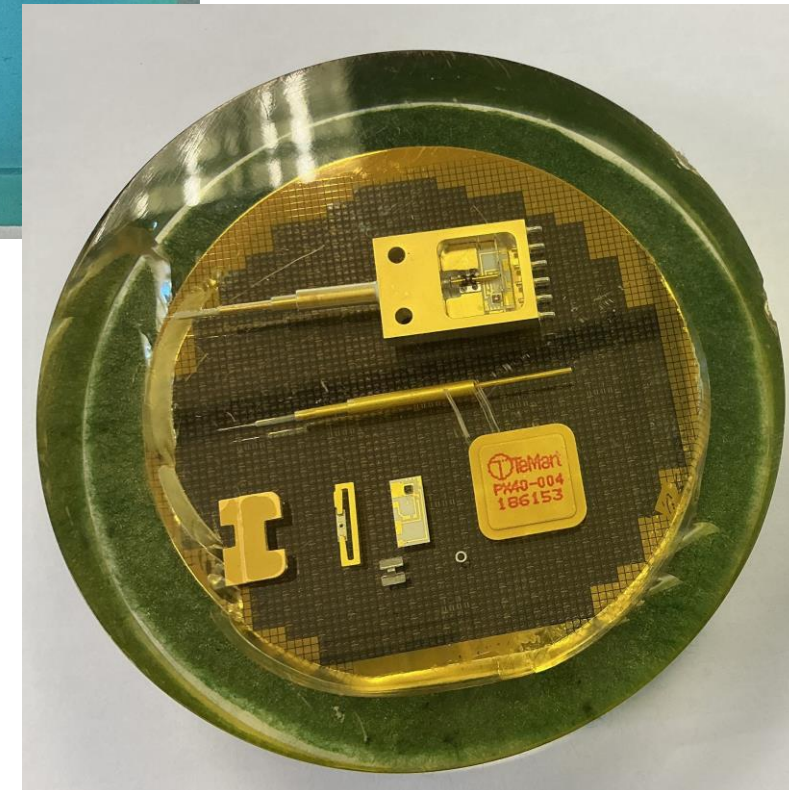
Over 2700 of two generations of receiver have since been made at BTRL and used worldwide

PINBIP 280

1988 UK-France-USA
(TAT-8)
1988 UK-Denmark
(UK-Denmark 4)
1989 Spain-Majorca
(PENBAL 3)

PINBIP 440

1989 UK-Ireland-USA-Bermuda-Caribbean
(PTAT-1)
1990 Hong Kong-Taiwan
(HONTAI)
1990 Japan-Alaska-USA
(NPC)
1991 UK-Spain
(UK-Spain 4)



1982. First BT Fibre-to-the-Home

33

Presented to participants in

British Telecom's Fibrelevision Cable TV Trial at Milton Keynes 1982-1984



Eighteen customers in the Oldbrook area of Milton Keynes were the first in the United Kingdom to have television pictures brought into their home by optical fibre.

This (pioneering) switched-star network carried interactive services and a Pay TV channel, as well as standard broadcast TV channels.



B.T.R.L.
R9.3

Designed and Printed by BT Reprographics

Fibre-to-the home

Passive Optical Networks (PONs)

- Concept of a Passive Optical Network (PON) for Fibre-to-the-Home was first published by BT Labs (Jeff Stern et al) in 1987
- BT then deployed a trial in Bishop's Stortford in 1991 to delivery telephony initially (TPON)
 - with the option to later add video on a separate wavelength
- BT deployed TPON to several tens of thousands of customers
- But when BT launched broadband in 2000 high speed copper (DSL) access was used not fibre

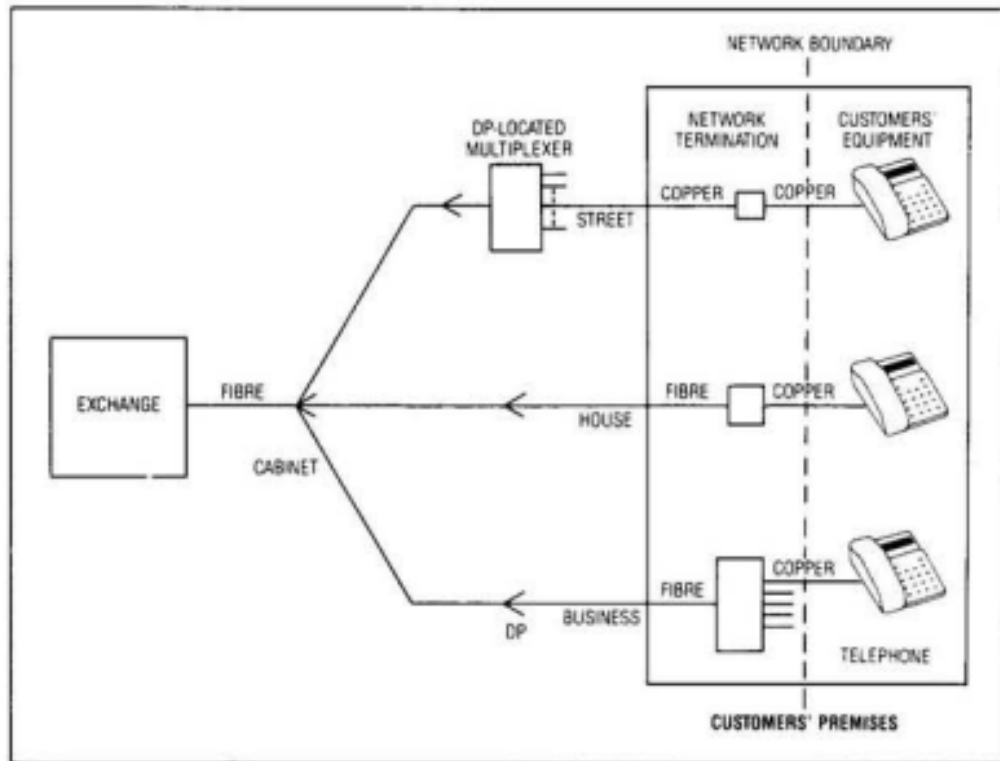
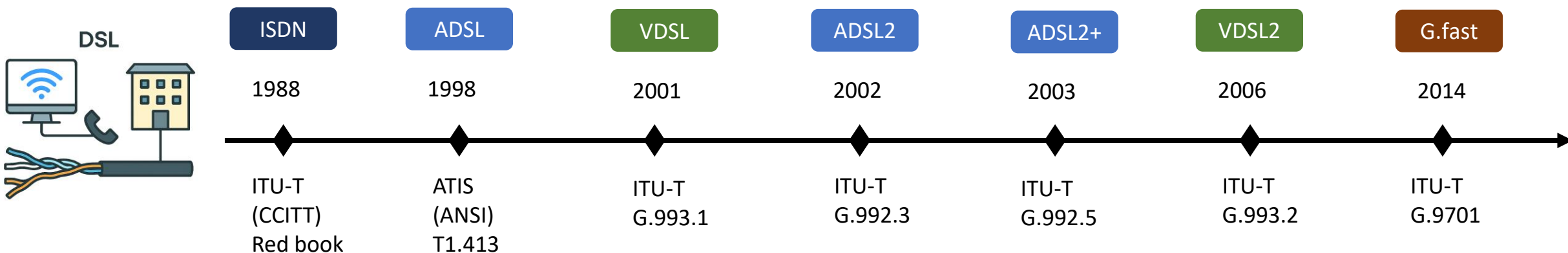


Figure 8—TPON network termination

BT Labs at forefront of copper broadband (DSL) too³⁵

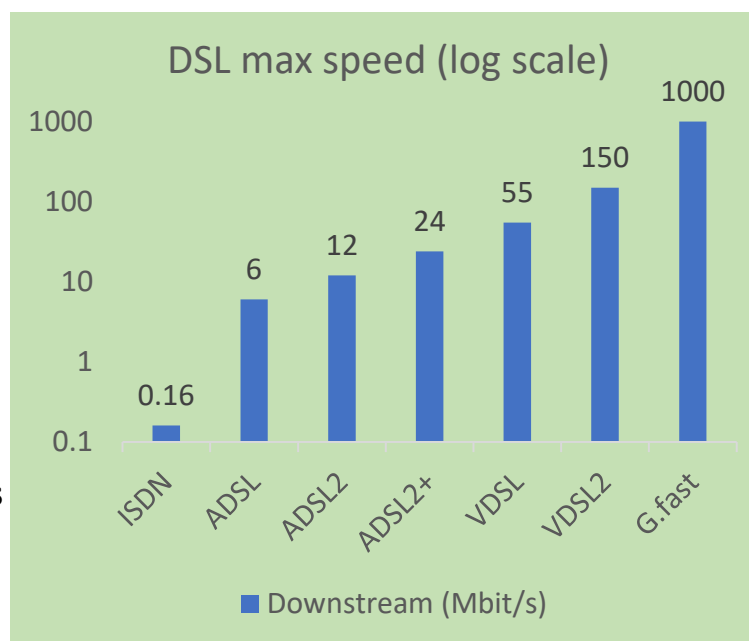


DSL evolved rapidly to provide mass market broadband access over existing twisted pair telephone wires.

Key enabler was cheap and powerful digital signal processing (DSP).

The Shannon (information) capacity of the twisted pair channel could start to be realised.

Many key DSL related innovations and patents filed by BT labs over 40+ years.



Examples of BT labs' impact on DSL globally:

- 2B1Q ISDN line code (Adams/Cox, 1986).
- Impulsive noise and RFI ingress characterisation of phone wires in UK (Cook, Foster & Humphrey).
- Novel DSL splitter design for ADSL and VDSL (Cook).
- ADSL and VDSL Olympic line code testing using BT labs' LNEL (Foster/MacDonald, 1993 & 2003).
- Press demo of ADSL for VoD in real home (Foster, 1993).
- Identified potential for VDSL which we use today for FTTC (Foster BT MSc thesis, 1995).
- Dynamic Line Management (DLM) for optimisation of DSL (Cook/Linney/Croot/Pickering/Everett, 2005).
- 30+ years of International DSL standards contributions & leadership from BT labs (NICC, ETSI, ATIS, BBF, ITU-T).

FTTP today

GPON and 10Gbit/s XGS-PON coexist on same fibre using different wavelengths/colours of light

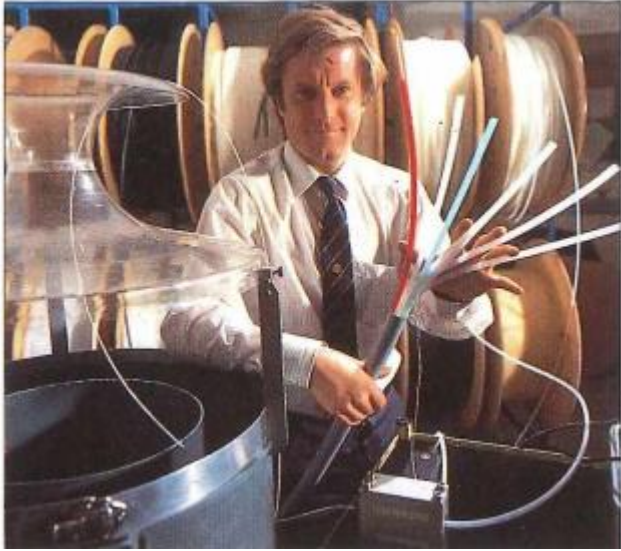
BT exchange building



- Openreach are deploying PON and have passed 20 million homes with FTTP
- Many other companies in UK and overseas also deploying PON.



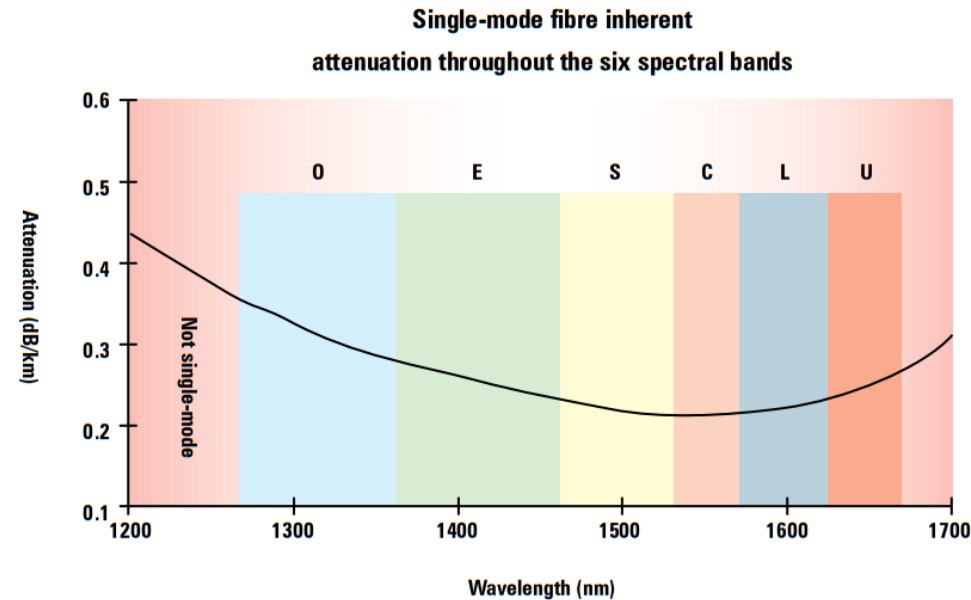
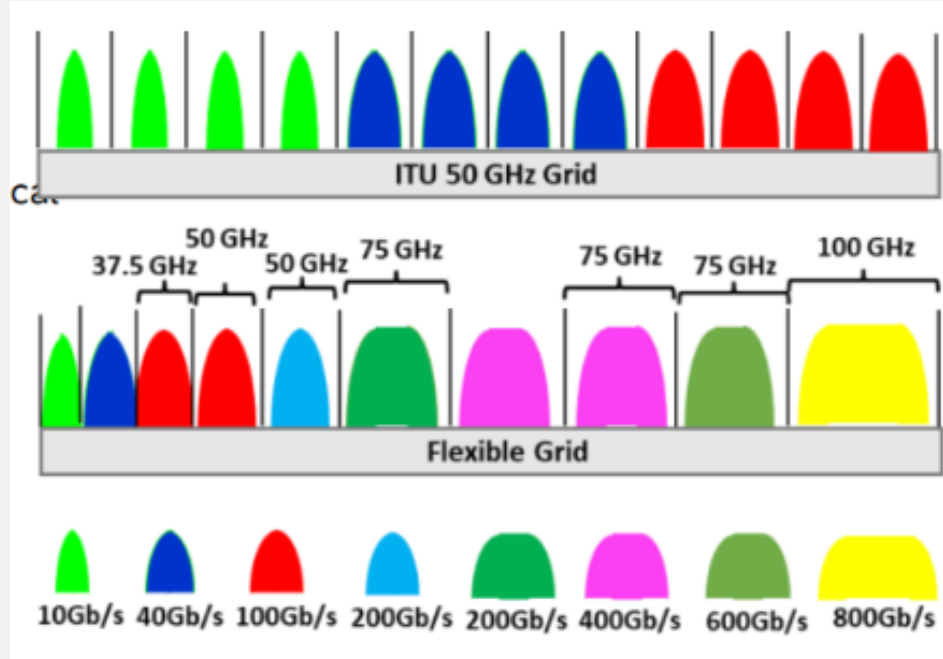
Blown fibre



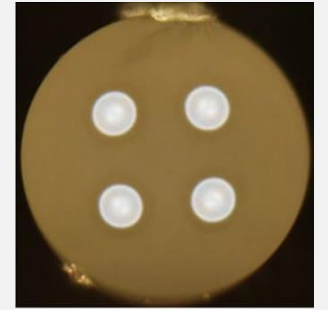
- In 1982 Steve Cassidy and Mick Reeve of BT Labs were investigating ways to install fibre in ducts without putting it under strain
- They tried blowing fibre along a tube with air by attaching a parachute at the end
- It worked – but worked even better when the parachute came out of the end
- This prompted them to study the physics and work out the air was pushing the fibre along the tube (viscous drag)
- Patents followed plus a field trial in Leeds in 1984 and licensing to suppliers in 1986
- Used in Bishop's Stortford deployment
- Now widely used by Openreach to install optical fibres

What about 2030+ ?

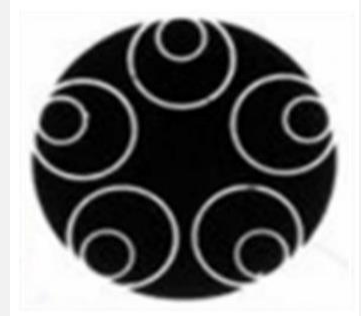
- How many homes will have FTTP and how much bandwidth will they generate?
- What will widespread use of AI do to traffic in our core network?



Multi- core fibre

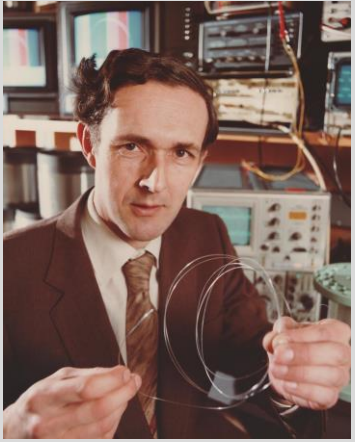


Hollow core fibre



- As we go faster we are using most of the spectrum supported by erbium fibre amplifiers (C-band)
 - Shannon limit
- For faster than 800 Gbit/s use new amplifiers to support more spectrum?
 - Use new fibre types like hollow core or multi-core fibre?
- Or do we just use lots of fibre in parallel?

Quantum networks?



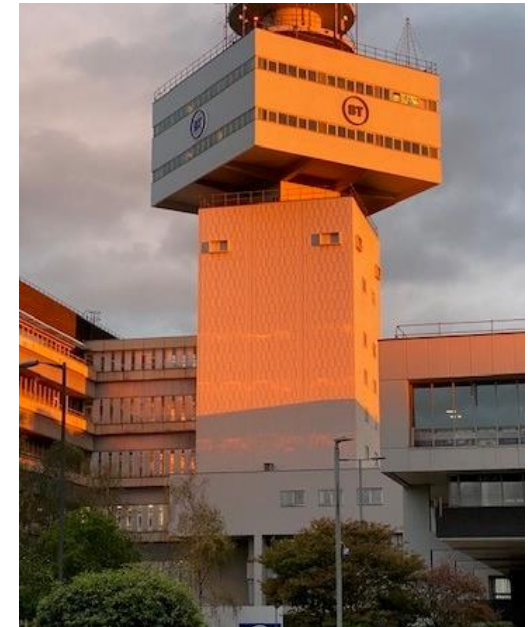
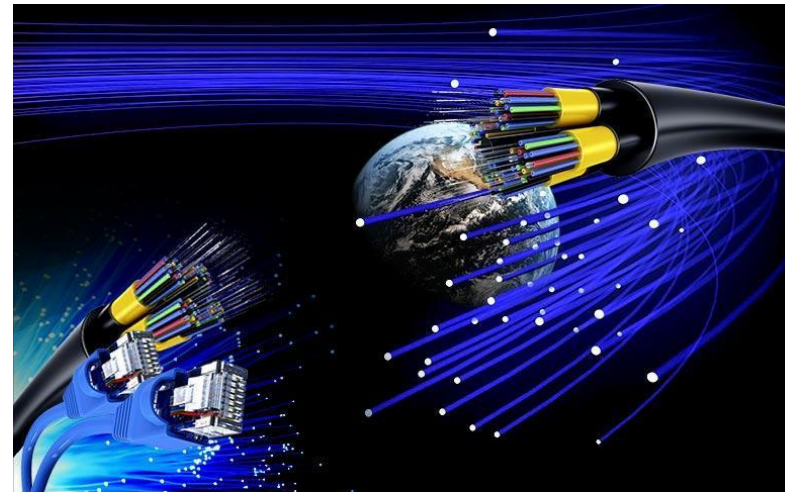
“Looking back, the period 1977 to 1984 during which I was Head of the Optical Communications Division seems like a golden age.”

Professor John Midwinter OBE FRS

Key technologies that made the internet possible and changed the world:

- Single mode optical fibre
- Semiconductor optical sources
- Semiconductor optical detectors
- Optical amplifiers
- Coherent WDM
- All-optical wavelength switching
- Passive Optical Networks
- Blown fibre

All pioneered at Martlesham





Thank you for your attendance

Future Anglian Coastal Webinars & face-to-face meetings:

6 November (hybrid event), **Point-to-point Microwave**, Prof. Andy Sutton MBE, BT Fellow

For more details and how to register please visit:

<https://engx.theiet.org/local-networks/ea1>

Event CPD Certificate and Slides/Video (with permission) will be posted on this site.

Anglian Coastal



The volunteers of the IET Anglian Coastal Network organise events and other activities covering engineering and technology topics for engineers and also members of the public who have an interest in engineering and technology. Even if you're not a member of the IET, you're still welcome to join us at any of our events.

We cover the areas of Norfolk, Suffolk and north Essex. Over the past few years we have organised a large number of highly successful Webinars when face-to-face meetings have not been possible. We are now able to resume face-to-face events. We aim to retain many of the benefits of the Webinar format where practical. Most of the lecture events will be hybrid offering both face to face attendance or online options. We also organise occasional visits to places of engineering interest (e.g. Bentwaters Cold War and Bawdsey Radar museums).

Blogs and Articles (New!)

This is a new feature. Please visit [Blogs and Articles by Anglian Coastal LN](#) to view our blogs and articles on IET EngX.

Contact us

We're always looking for ideas and suggestions for events and visits etc so if there is something you would like us to organise, or to help you to organise, please get in touch: angliancoastalln@ietvolunteer.org.

Was this helpful?

👍 Yes (28) 👎 No

In this Article

- Blogs and Articles (New!)
- Contact us
- Car parking in Ipswich (face to face event)
- Foothold (needs your help)
- Watch one of our event videos
- CPD Certificates for our events
- Previous event information (slides and videos)
- Our committee

Created over 4 years ago

Updated 3 months ago

Upcoming Events

Optical Fibre in the BT inter-exchange Network – where we are and how we got here
8 Oct 2025 7:00 PM to 8:45 PM

Point to Point Microwave Radio Systems
6 Nov 2025 7:00 PM to 8:45 PM

