Swansea University
Prifysgol Abertawe

# Optical Communication at IAT


Michel Marhic

Professor



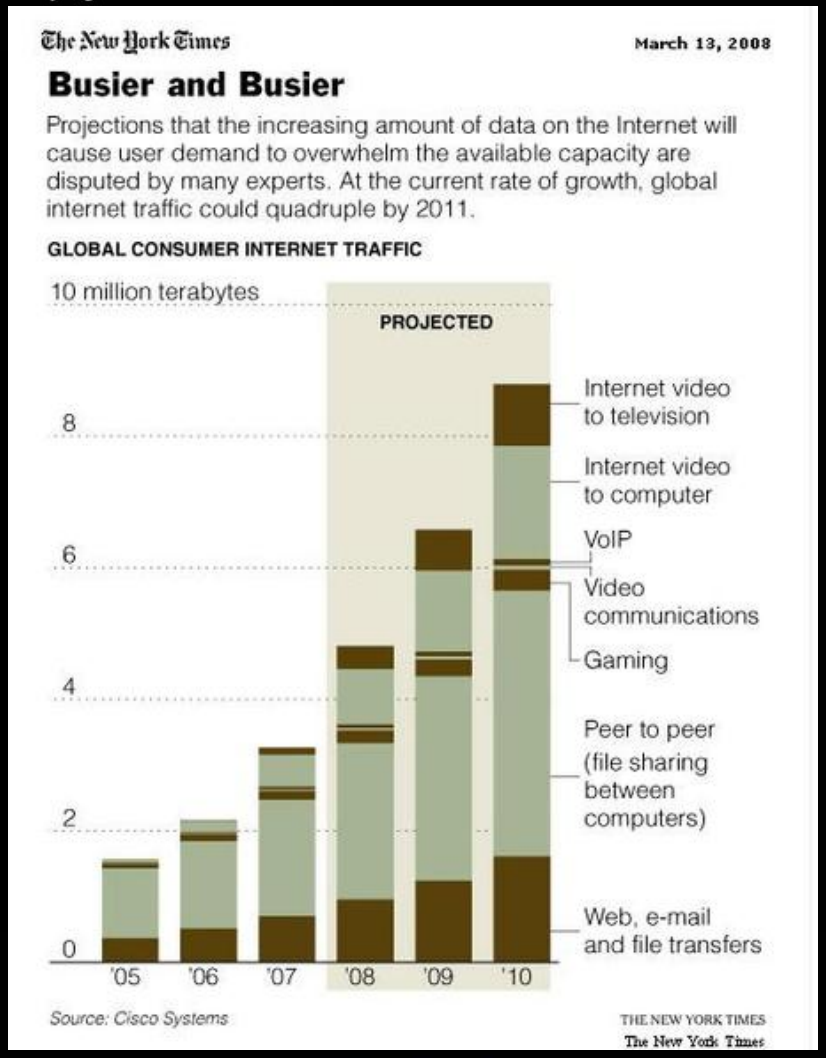


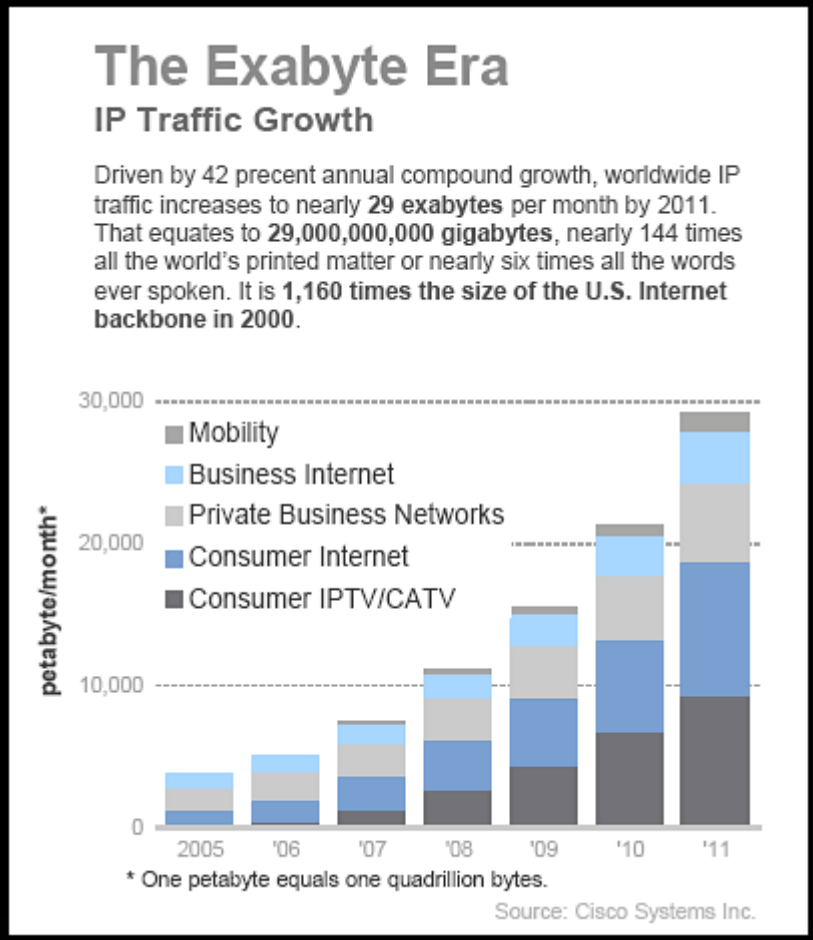


IAT
Institute of Advanced Telecommunications

Swansea University
Prifysgol Abertawe

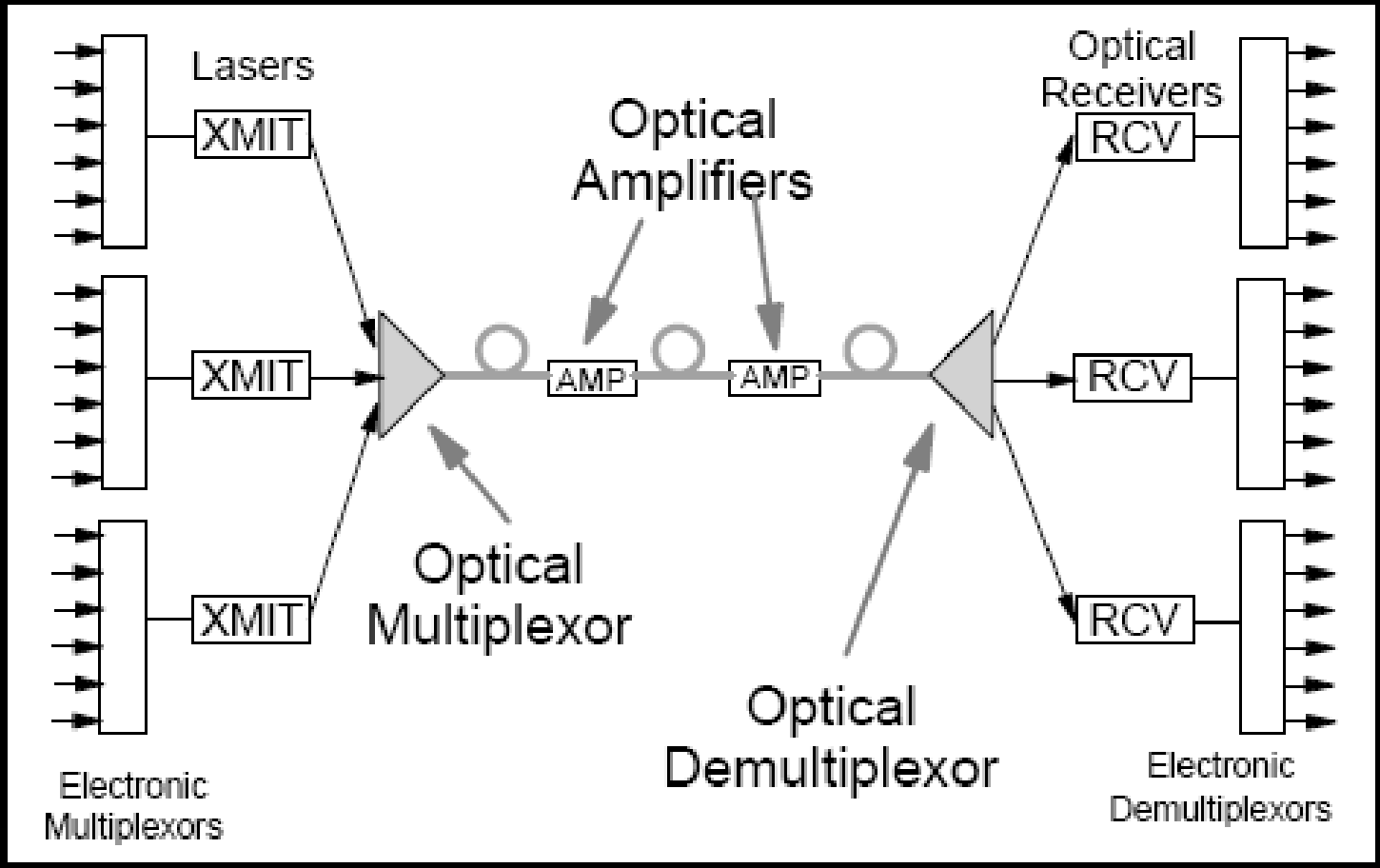
# Growth of Internet Traffic



Swansea University
Prifysgol Abertawe

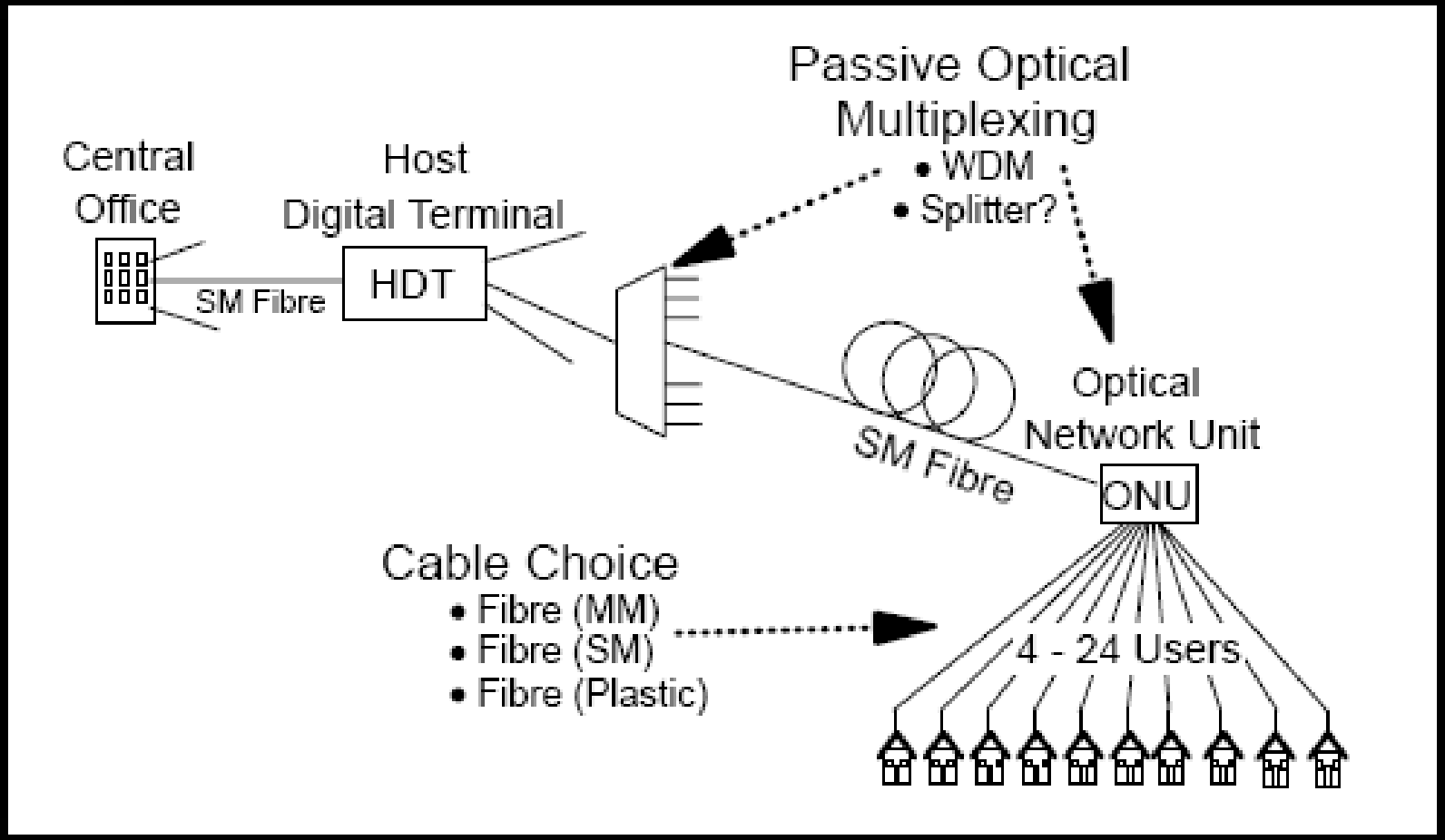
# Long-Haul Optical Communication System




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

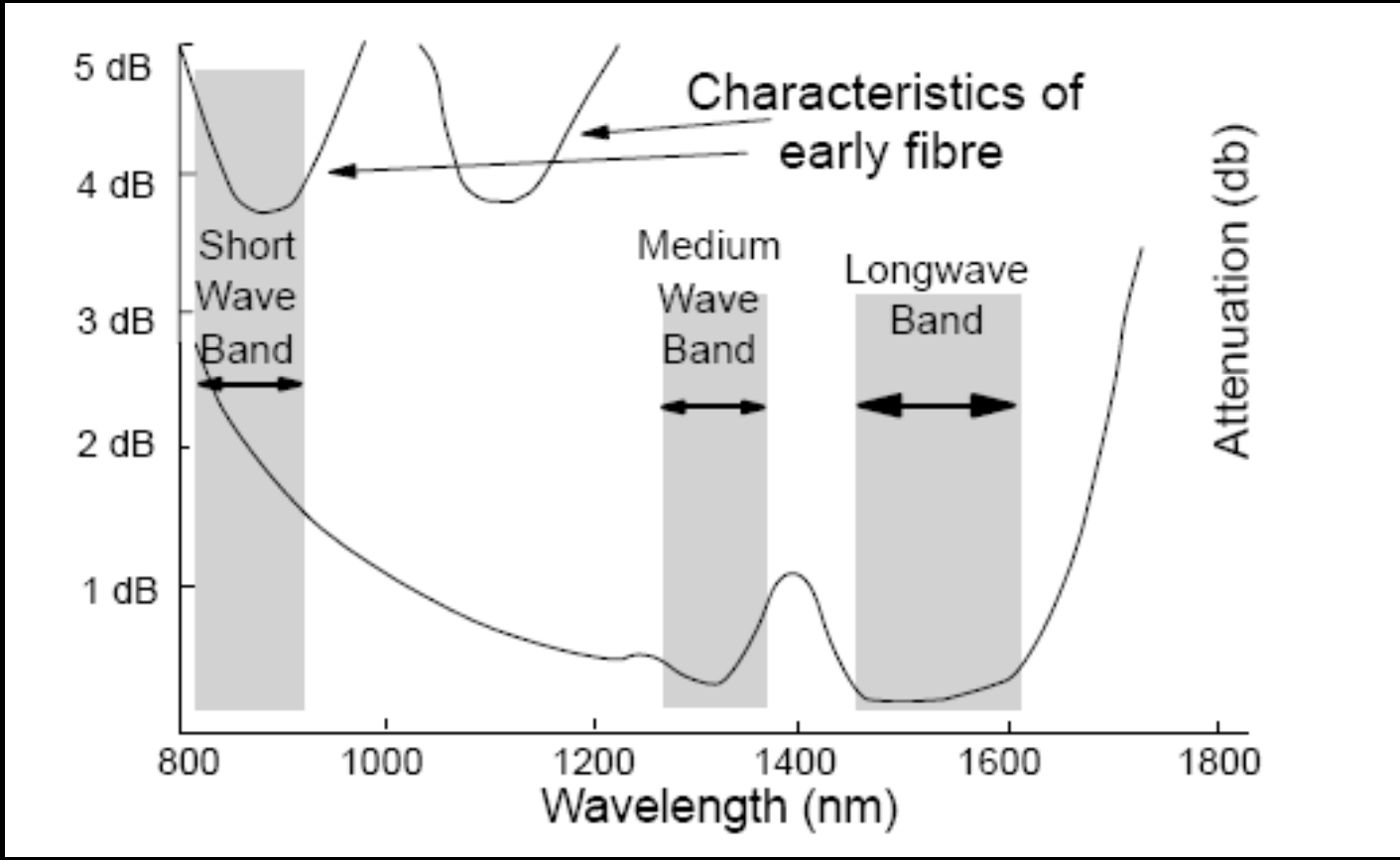
# Passive Optical Network (PON)




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

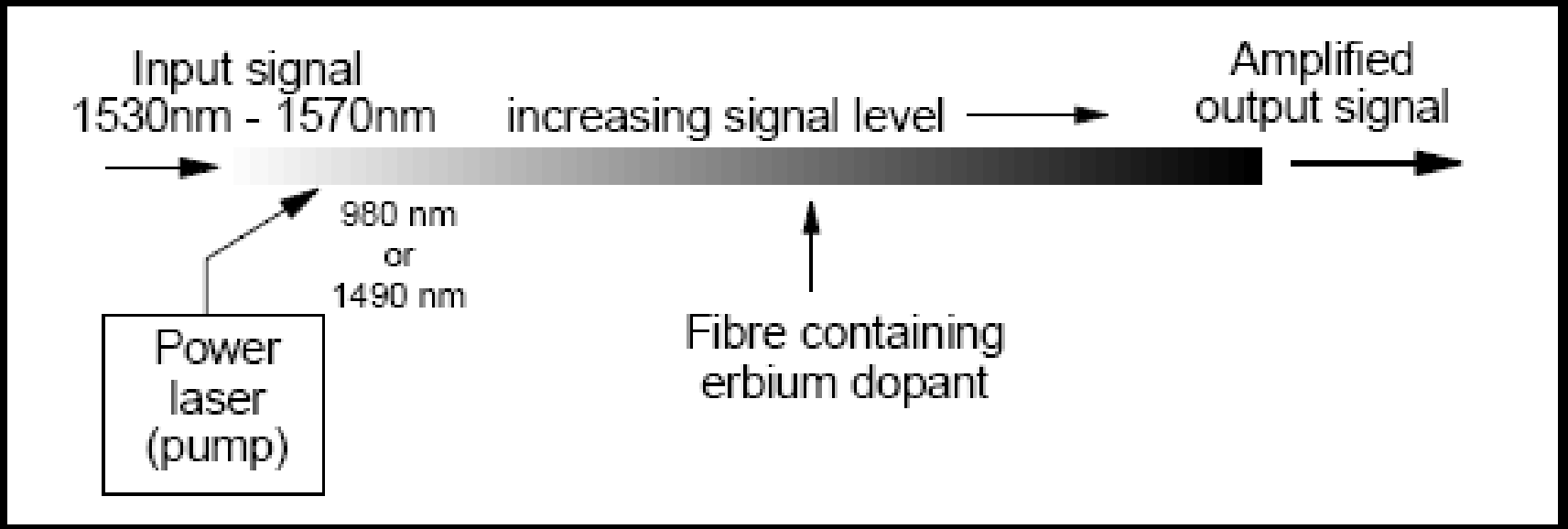
# Transmission of Silica Fibers




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

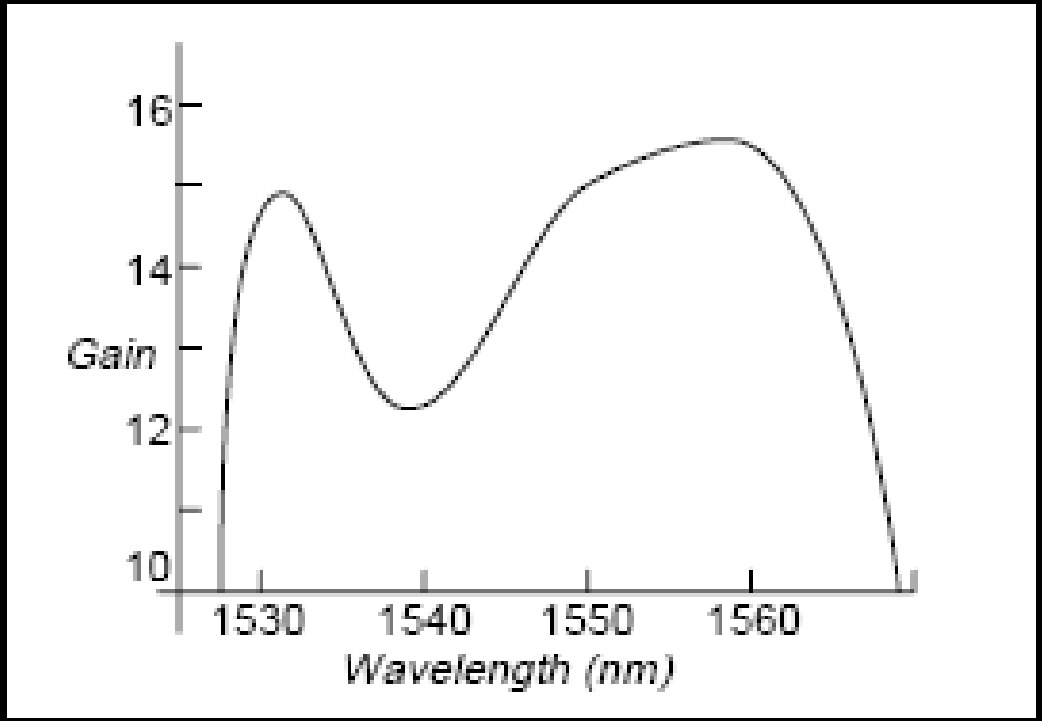
# Erbium-Doped Optical Amplifiers




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

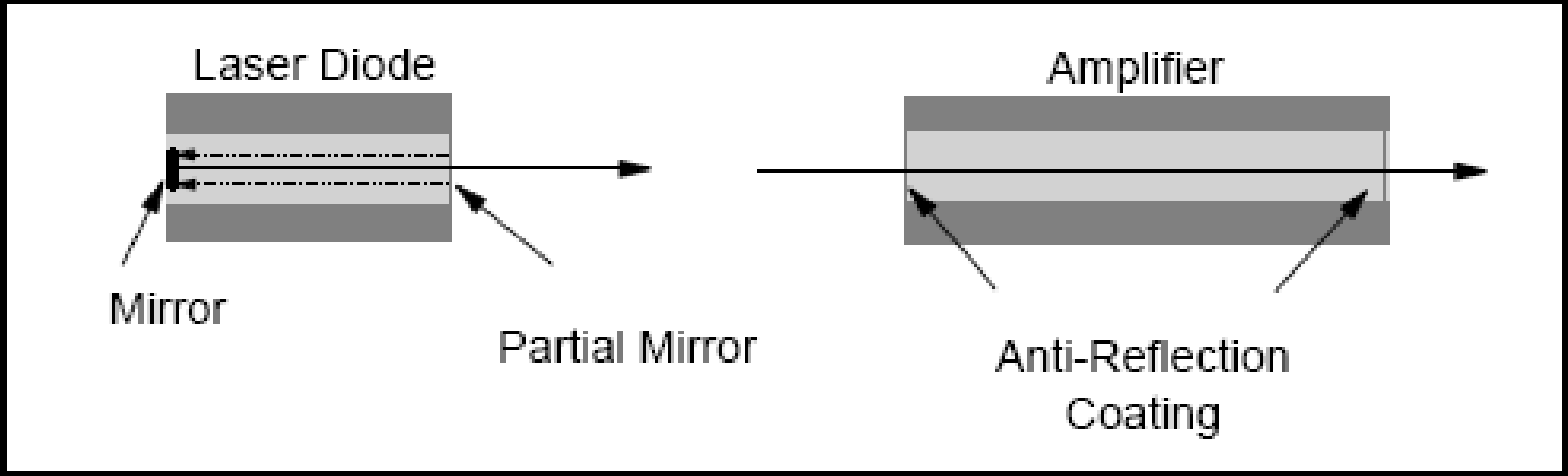
# Gain Spectrum of EDFAs




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

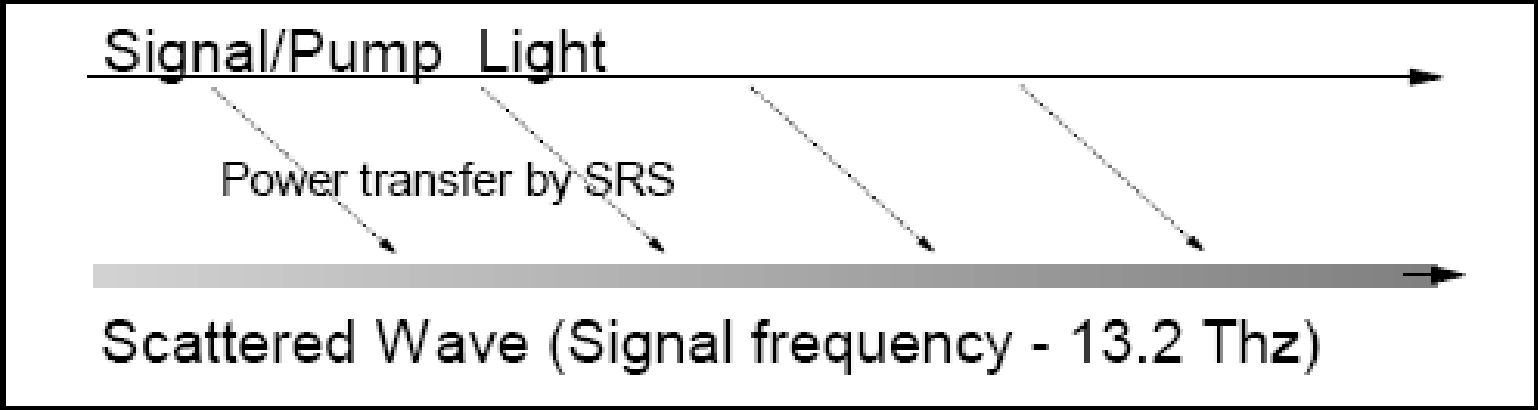
# Semiconductor Optical Amplifiers (SOAs)




Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

# Raman Amplification




Used for amplification along transmission fibers

Source: H. J. R. Dutton, Understanding Optical Communications

Swansea University
Prifysgol Abertawe

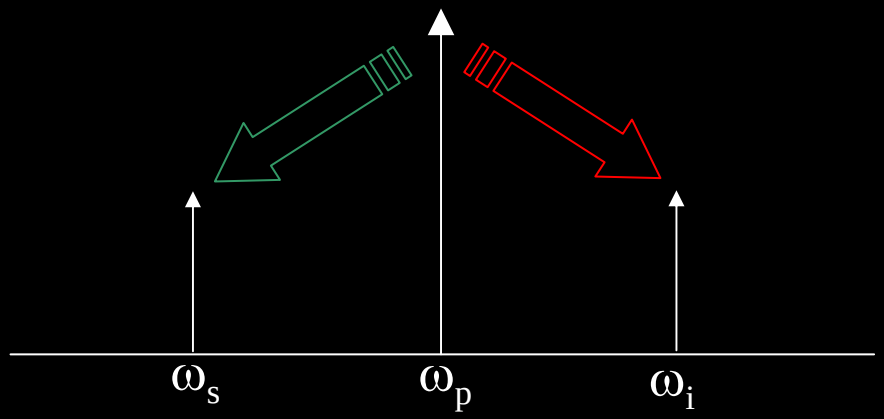
# Fiber Optical Parametric Amplifiers (OPAs)

M. Marhic, H. Lu, A. Vedadi, C. Braimiotis
R. Malik, M. Jamshidifar

- Based on fiber third-order susceptibility $\chi^{(3)}$
- Two versions: 1 or 2 pumps
- Involves four-wave mixing (FWM), aided by pump cross- & self-phase modulation (XPM & SPM)
- Energy transferred from pump(s) to signal and idler.

Swansea University
Prifysgol Abertawe

# One-pump OPA




$$\omega_s + \omega_i = 2\omega_p$$

Signal & idler are symmetric w.r.t. pump frequency $\omega_p$

Swansea University
Prifysgol Abertawe

# Continuous-wave fiber optical parametric amplification in bismuth-oxide fiber

A. Vedadi, M. Jamshidifar and M. E. Marhic
IAT, Swansea University



IAT
Institute of Advanced Telecommunications

Swansea University
Prifysgol Abertawe

# Characteristics of Bismuth Fiber

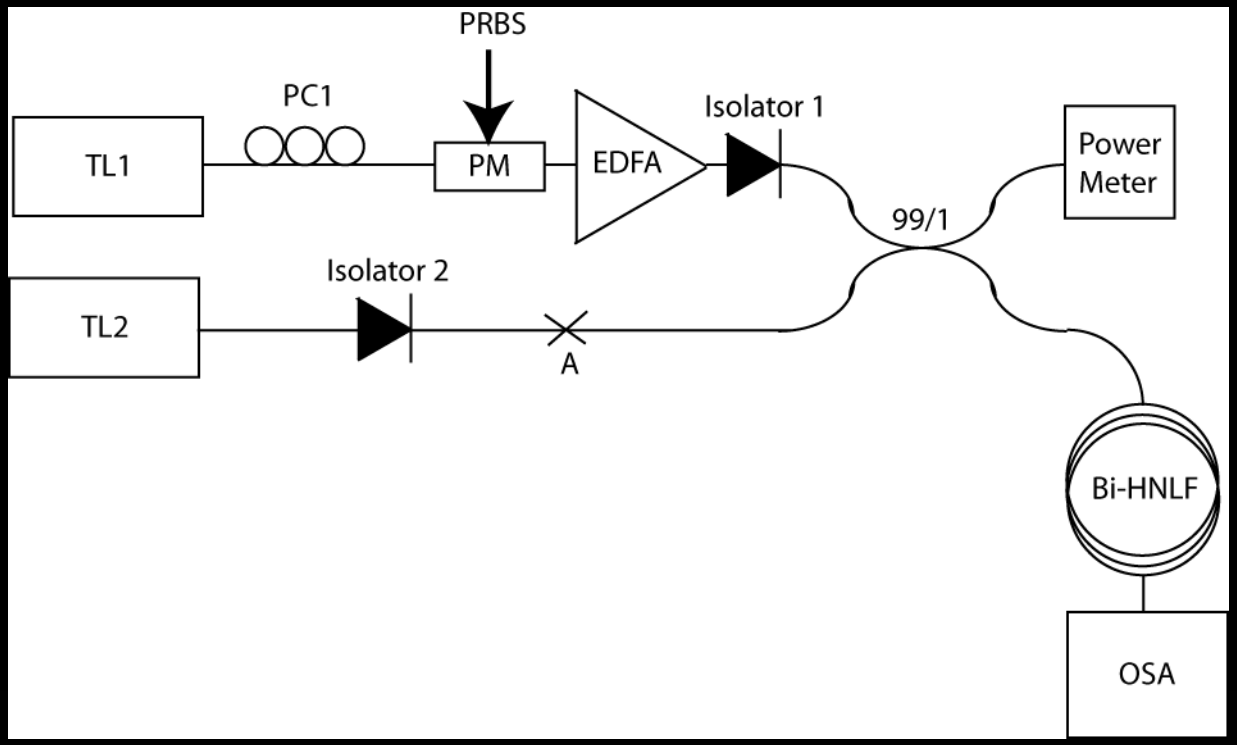
- High index: n ≈ 2.2
- High nonlinearity: $\gamma \approx 1000\ W^{-1}km^{-1}$
- High loss: 2 dB/m
  → Short *L*eff : a few meters
  → Need watt-level pump for significant OPA gain
- High normal dispersion: D=-240ps/(nm*km).
  → Phase matching only possible close to pump (assuming no birefringence).

# Parametric gain close to the pump

Swansea University
Prifysgol Abertawe

European Conference on Optical Communications
22-25 Sept. 2008, Brussels

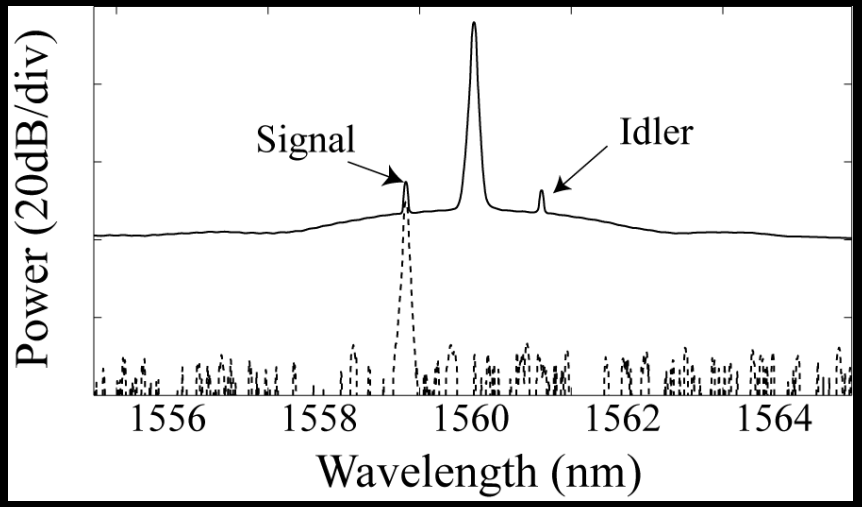
Paper P.1.20.

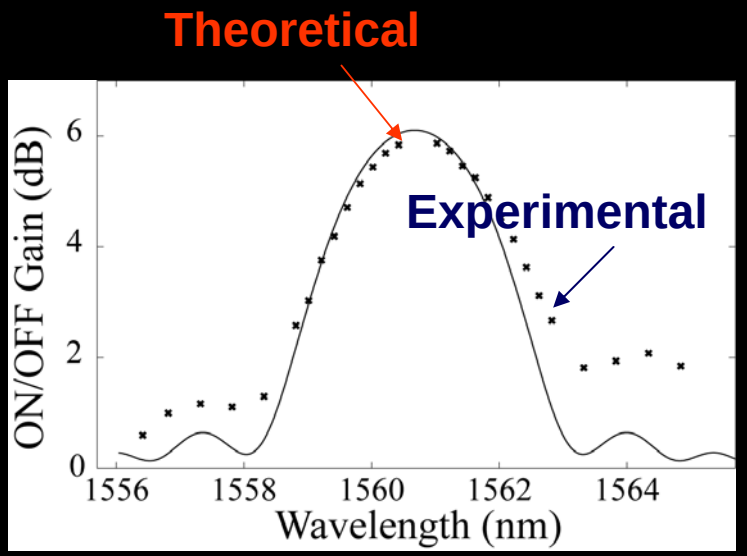


Swansea University
Prifysgol Abertawe

# Experimental Results

**ON/OFF output spectra**






IAT
Institute of Advanced Telecommunications

Swansea University
Prifysgol Abertawe

# Quantum-limited Amplification in a Fiber Optical Parametric Amplifier

P. Kylemark and M. E. Marhic

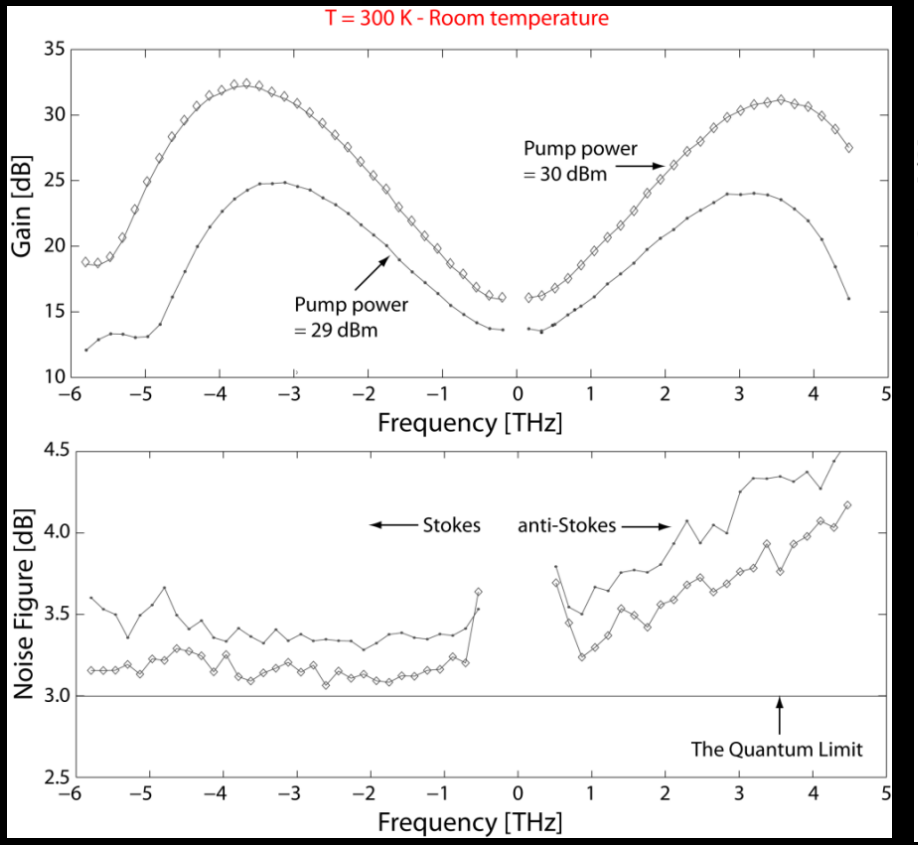
European Conference on Optical Communications
22-25 Sept. 2008, Brussels
Paper Tu.3.B.3.

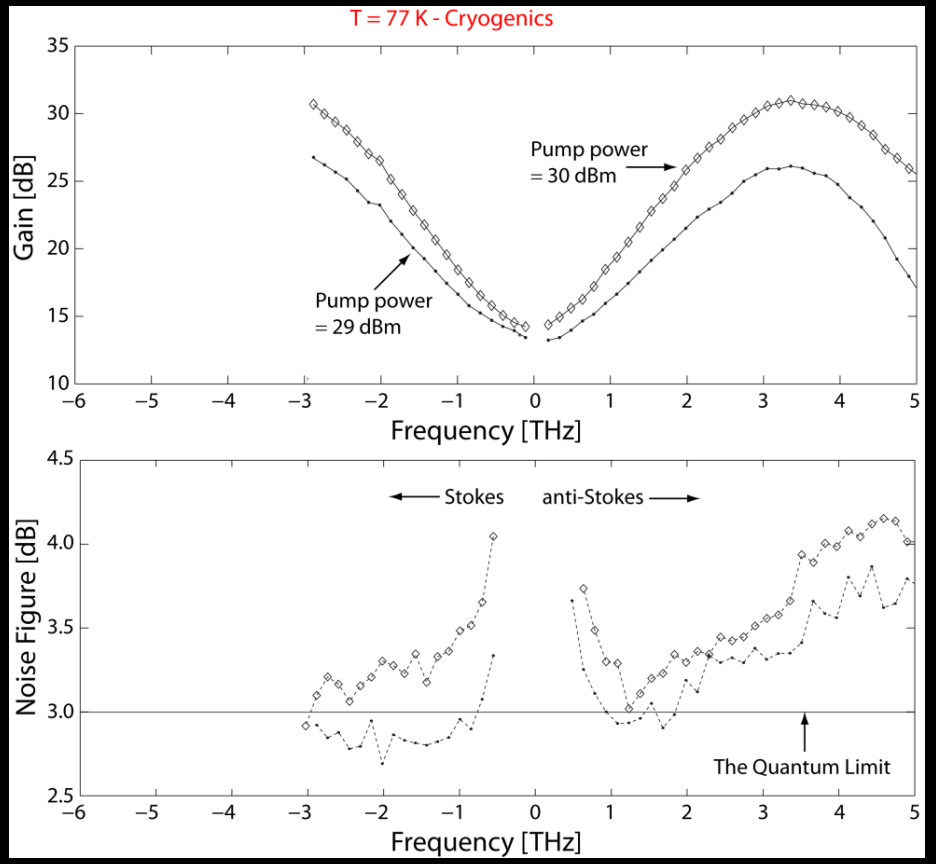


IAT
Institute of Advanced Telecommunications

Swansea University
Prifysgol Abertawe

# Experimental results

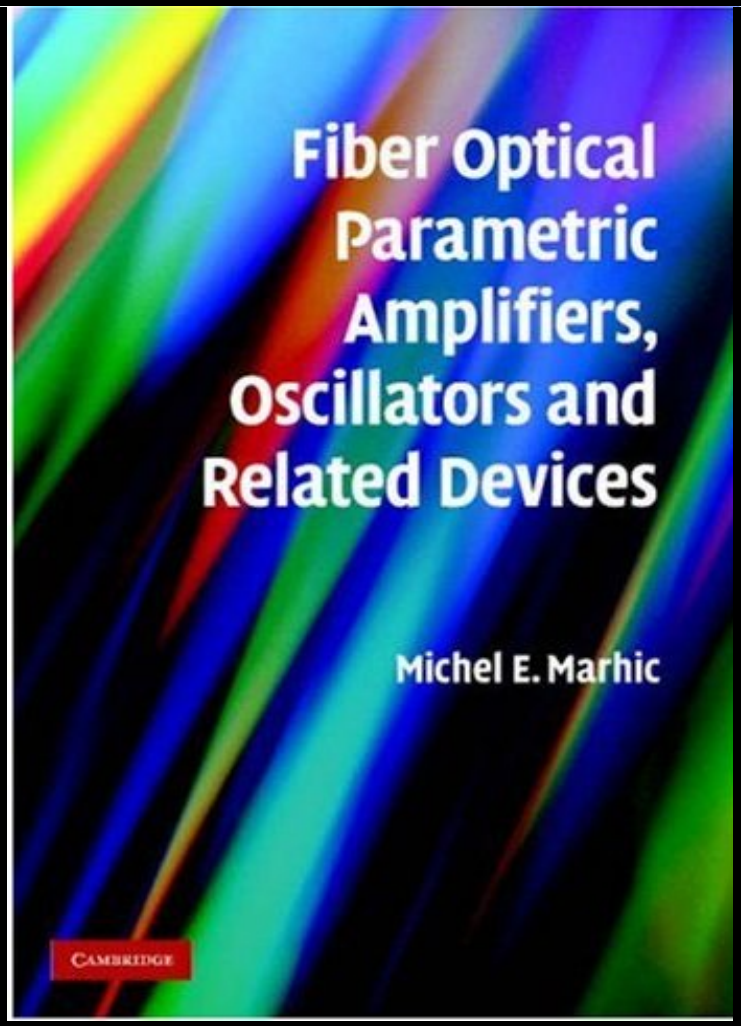



Conclusion: OPAs can operate at the 3 dB quantum limit

Swansea University
Prifysgol Abertawe

# First Book on Fiber OPAs



Swansea University
Prifysgol Abertawe

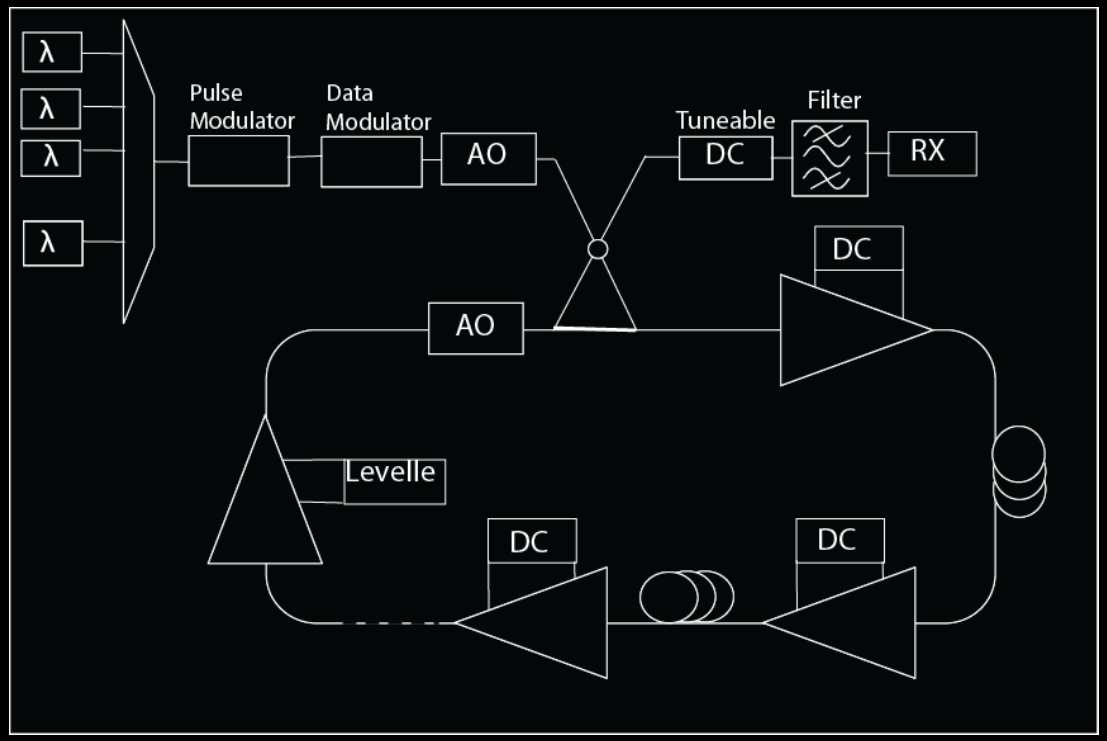
# DWDM Transmission

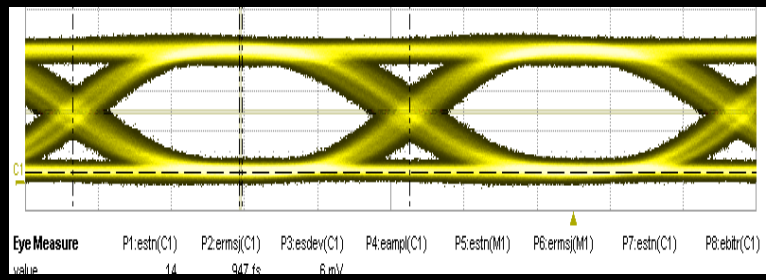
**N.J. Doran, D. Govan, T. Widdowson**

- 40 channel DWDM testbed.
  - Currently 10 Gb/s per-channel up to 56 Gb/s soon
  - Channel rates >100 Gb/s possible with advanced modulation formats
- Numerical modelling facilities
- Main areas of research
  - High speed (>40 Gb/s) long haul DWDM transmission
  - Advanced modulation formats
  - Improved tolerance to penalties, i.e Partial DPSK for improved dispersion tolerance

Swansea University
Prifysgol Abertawe

# Recirculating Loop Test Bed




Our recirculating loop test bed allows us to transmit multiple wavelength channels over long distances to test different fibre dispersion maps, modulation formats and new components.

# Components and Networks Research

Dr. Karin Ennser

Swansea University
Prifysgol Abertawe

- **Optical Regeneration, Wavelength Conversion and WDM sources:**
  - Use of nonlinear effects in optical fibre to develop photonic components for key all-optical functions.
- **Advanced Erbium-doped Amplifier:**
  - Optical gain control techniques
  - Inhomogeneous medium (SHB effect).
  - Ultra-high-concentration doped fibre and waveguides.
  - Amplifier performance for optical burst/packet switching.
- **Transmission impairment compensation and monitoring:**
  - Advanced modulation formats
  - Impairment compensation techniques.
  - Techniques to monitor network degradation due to (non-)linear impairments.

Swansea University
Prifysgol Abertawe

# New active components for telecom, sensing and biomedicine

**Stefano Taccheo**

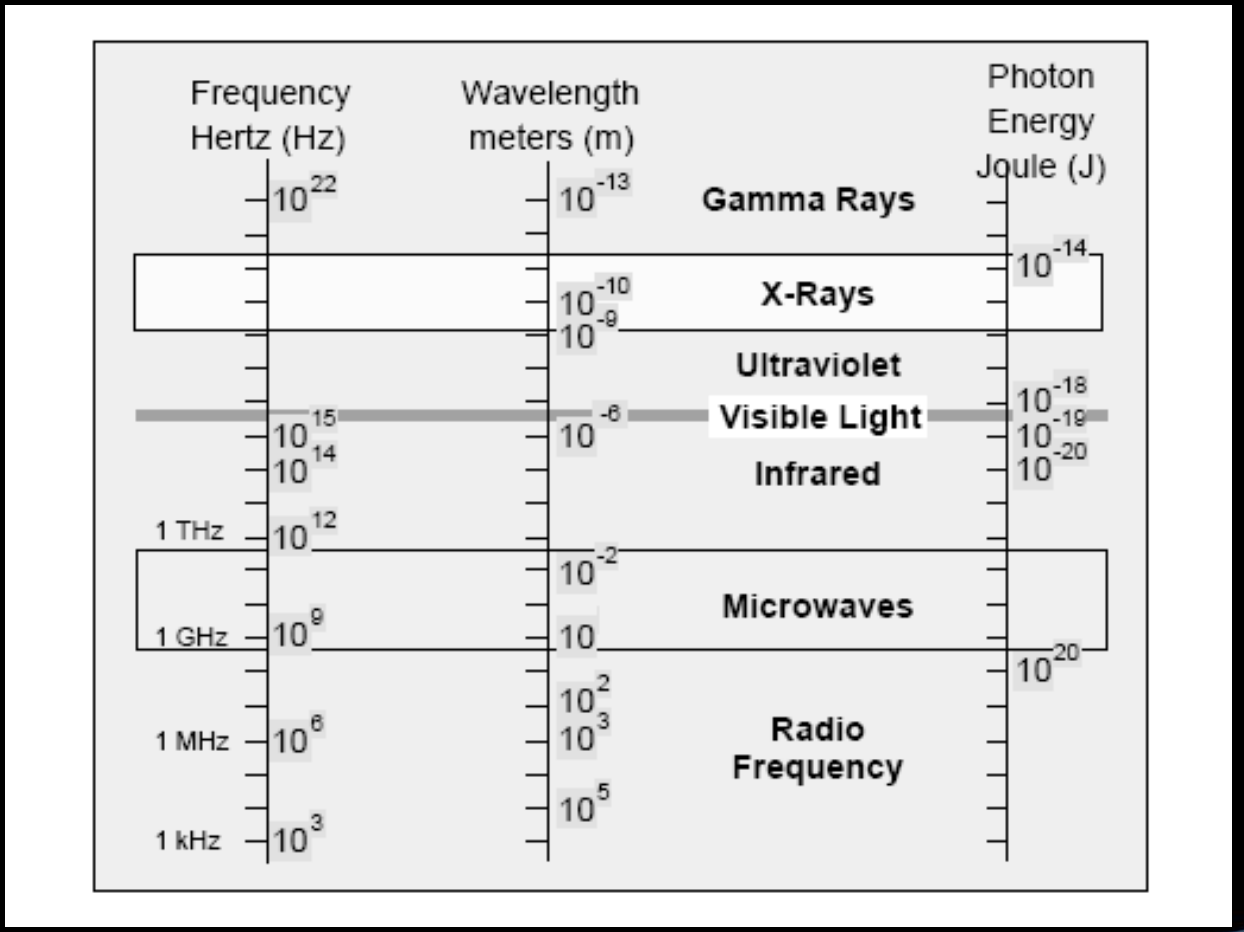
- **Optical communications:**
- Fibre lasers and amplifiers, Raman amplifier
- Waveguide laser and amplifier
- Non-linear processing (l-conversion, optical regeneration, slow-light)

- **Sensing and security/defence:**
- High-power narrow-linewidth single frequency laser
  - range-finder, 100 km, sub-1m resolution
  - High-resolution spectroscopy
  - Hydrophones
  - THz- and mm-wave generation
- 2-micron laser for advanced LIDAR
- Mid-infrared sources for chemical detection (“fingerprint” infrared region)
- Rugged waveguide/fiber laser/amplifiers for airborne and satellite applications

- **Biomedicine:**
- UV and visible light generation for time resolved spectroscopy
- All-fiber light sources for clinical use

Swansea University
Prifysgol Abertawe

# The Electromagnetic Spectrum




Source: H. J. R. Dutton, Understanding Optical Communications