Communication Networks II

BMEVITMA310 in English

Tibor Cinkler (**3.**) April 25, 2018

Wednesday 14:15 – 15:45 (I.E.219)

http://opti.tmit.bme.hu/~cinkler/TNS

Administration

- Repeated MidTermExam?
  - May 4 Friday 12:00-14:00 IB210
- Measurements:
  - opti.tmit.bme.hu/~cinkler/TNS/2017/LabMeasurements/
  - May 11 IPTV (Ivett)
  - May 18 MPLS (Levente)
  - Fridays 12:15-16:00 (IB142,IB141)

Optical Networks: 3 Generations

- 1. G: only transmission links are optical
- 2. G: whole transmission paths are optical
- 3. G: even the control is optical

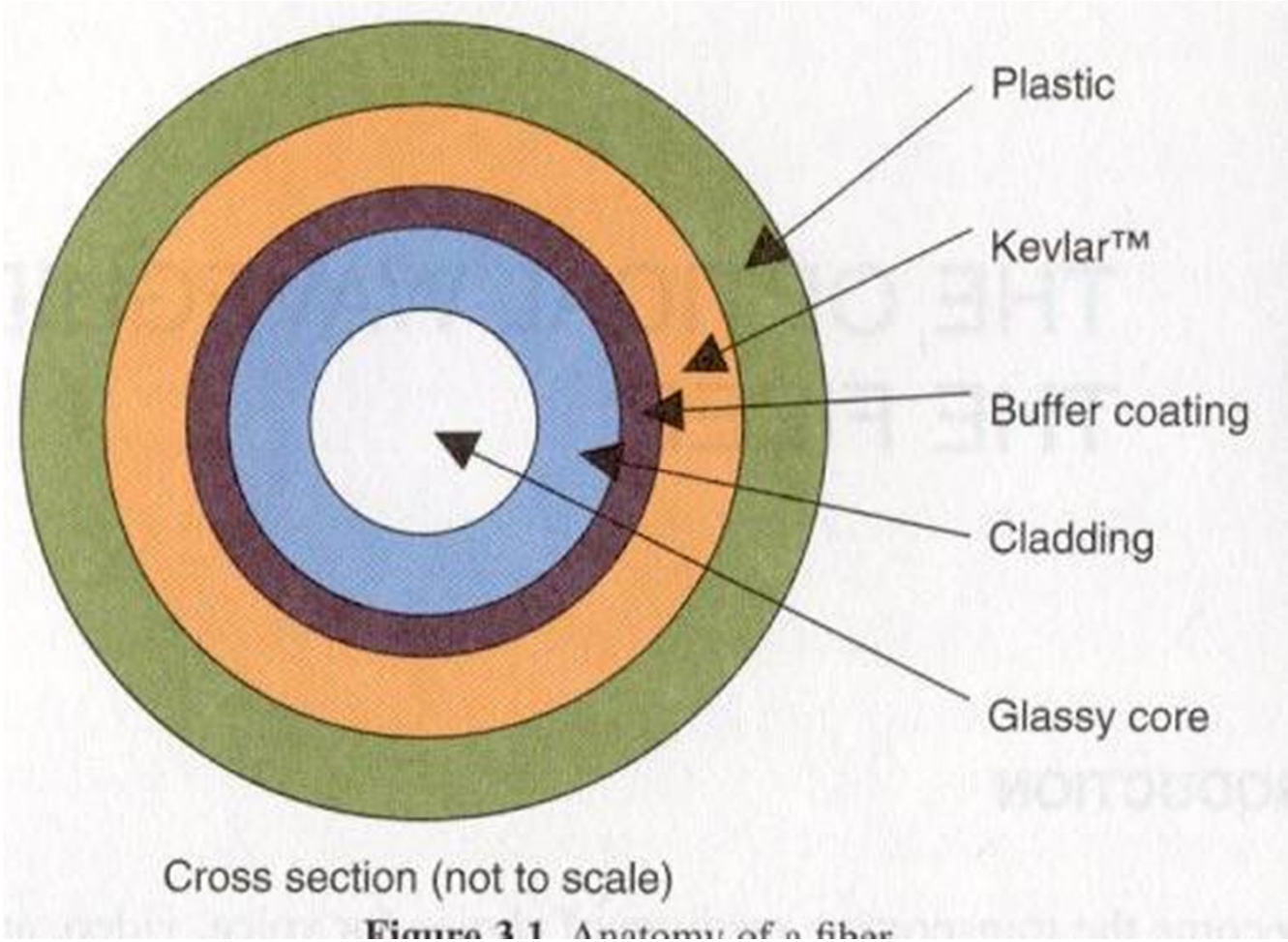
Multiplexing Solutions

- Space (OSDM)
  - Multifiber & Multicore
- Wavelength (WDM)
  - CWDM & DWDM
- Time (OTDM)
  - Packets & Pulses (ultrashort)
- Code (OCDM)
- OOFDM (Optical Orthogonal FDM)
- NDWDM (Nyquist WDM)

Optical Technologies

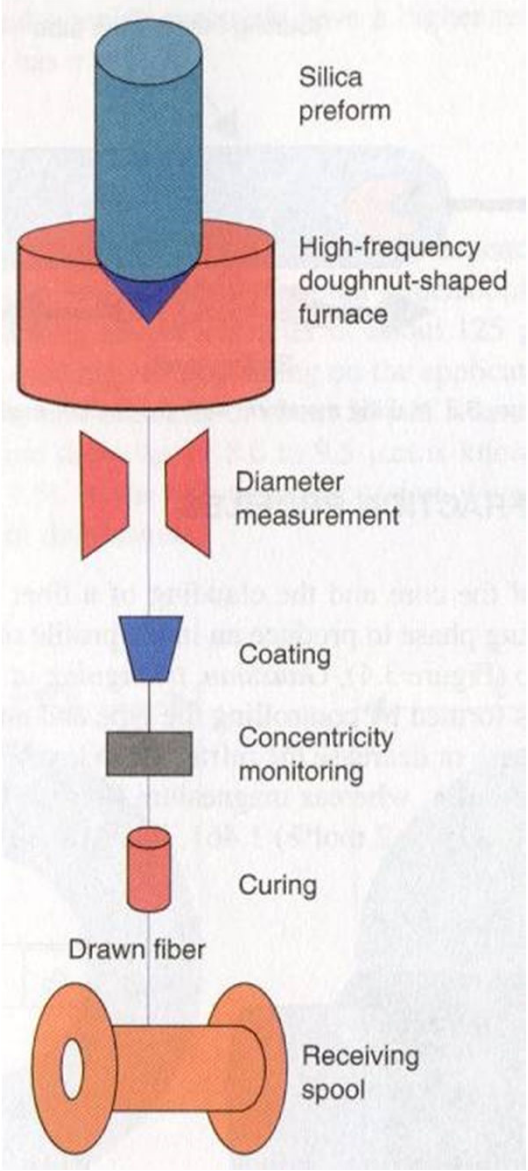
- Fibers (SMF, MMF, etc)
- AWG - Arrayed Waveguide Grating
- Transmission Impairments, transmitters, receivers, filters
- Optical Amplifiers (SOA, EDFA, RamanA)

Fiber Anatomy



Source: Shivkumar Kalyanaraman

Fiber Manufacturing

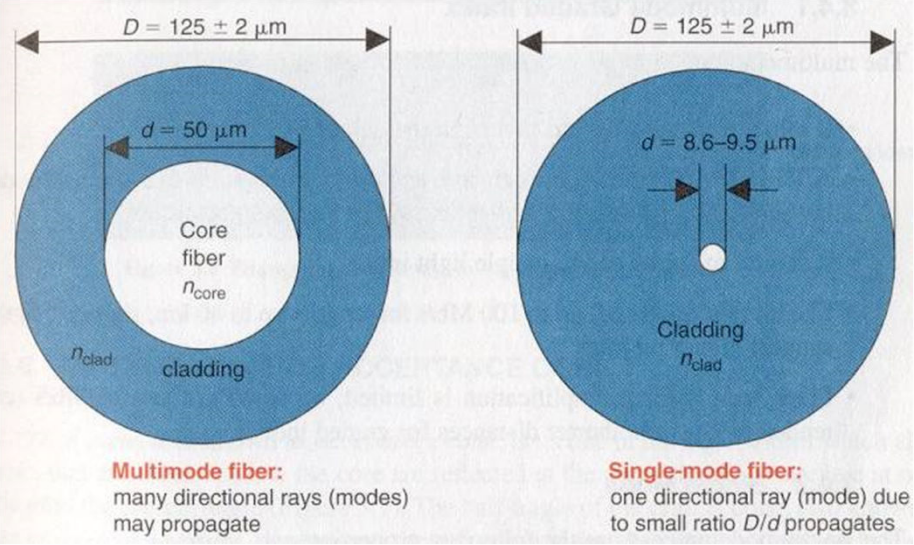


- Dopping by rare earth elements
  - Graded index
  - (Step Index)

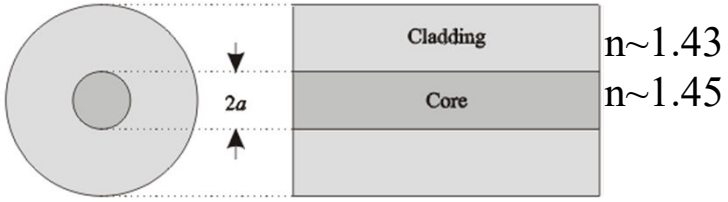
- Multiple cables per duct
- Up to 1000 fibers per cable
- Multi-core fibers?
- ~160 λ per fiber/core
- 10 Gbps or 100 Gbps per λ

Single and MultiMode Fiber

- Single-Mode Fiber (SMF) (8 to 10 μm mag)
- Multimode Fiber (MMF) (50 to 85 μm mag)
- SiO_2 (or plastic)
- 3 low attenuation bands (windows): 0.8, 1.3 , 1.55 μm



Refraction Index (RI):



Source:
Shivkumar Kalyanaraman

Absorption and Attenuation: Absorption Spectrum

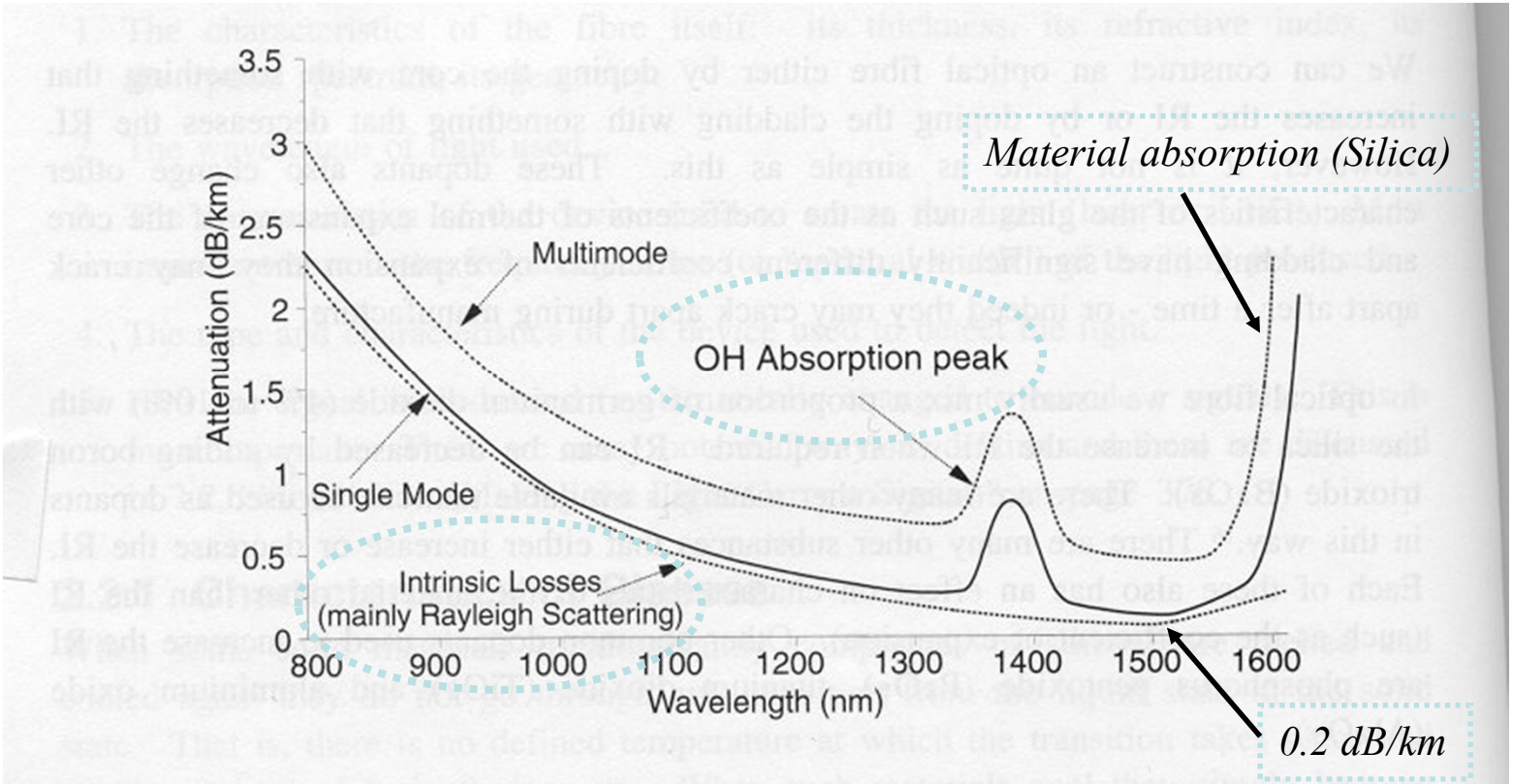


Figure 13. *Typical Fibre Infrared Absorption Spectrum. The lower curve shows the characteristics of a single-mode fibre made from a glass containing about 4% of germanium dioxide (GeO_2) dopant in the core. The upper curve is for modern graded index multimode fibre. Attenuation in multimode fibre is higher than in single-mode because higher levels of dopant are used. The peak at around 1400 nm is due to the effects of traces of water in the glass.*

Forrás: Shivkumar Kalyanaraman

Fiber: Transmission Windows

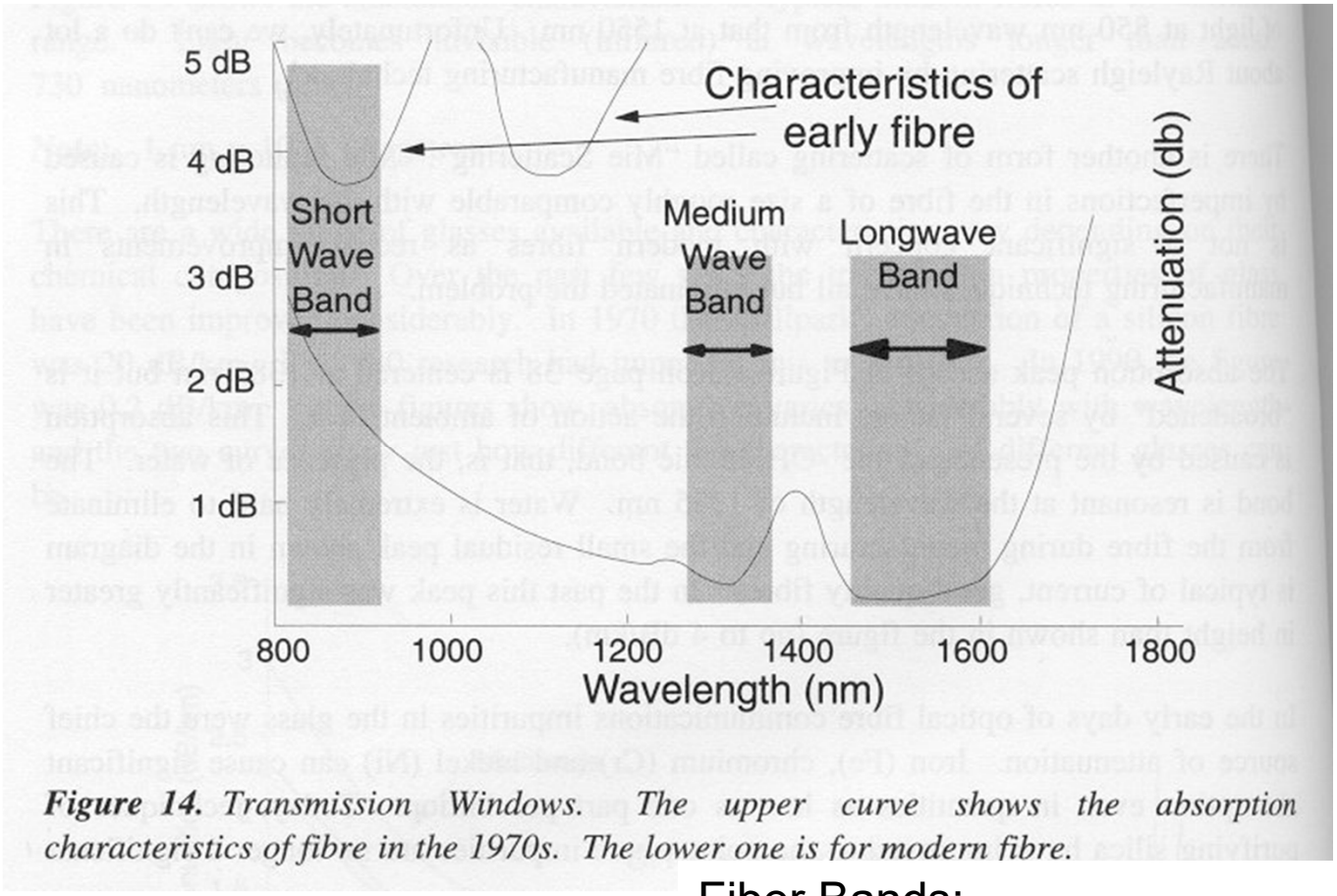


Figure 14. *Transmission Windows. The upper curve shows the absorption characteristics of fibre in the 1970s. The lower one is for modern fibre.*

Lucent's new AllWave Fiber (1998) eliminates absorption peaks due to watervapor in the 1400nm area!

Forrás: Shivkumar Kalyanaraman

Fiber Bands:

O-band: (Original) 1260-1360nm
E-band: (Extended) 1360-1460nm
S-band: (Short) 1460-1530nm
C-band: (Conventional): 1530-1565nm
L-band: (Long) 1565-1625nm
U-band: (Ultra-long): 1625-1675nm

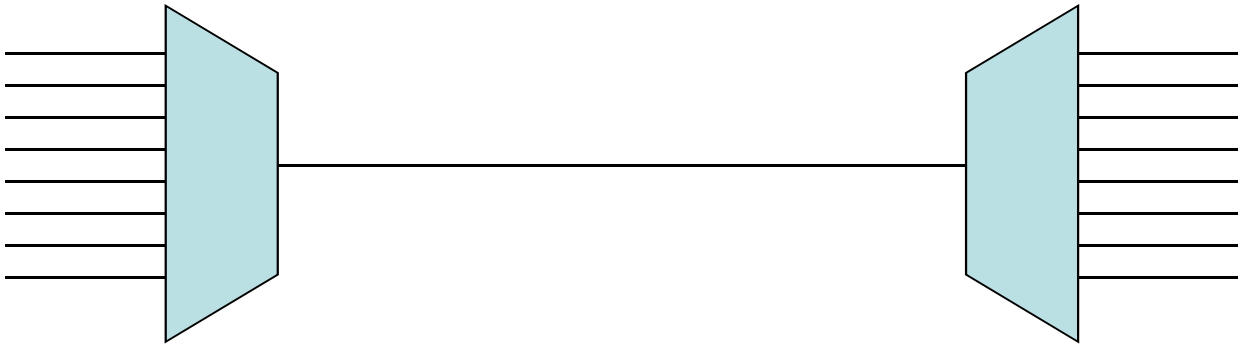
Wavelength MUX/DEMUX

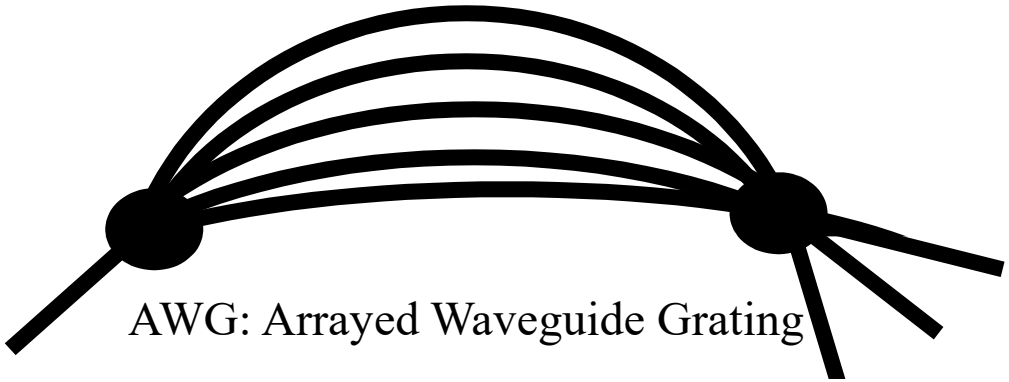
Point-to-point WDM link ...

DWDM (Denser – Wider – Denser)

CWDM (Coarse)

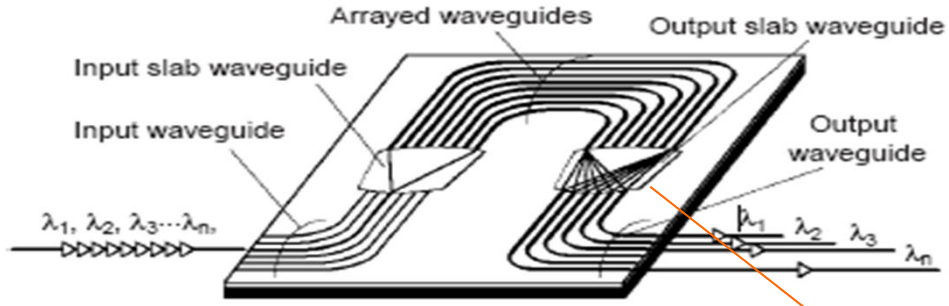
(WDM: Wavelength Division Multiplexing)





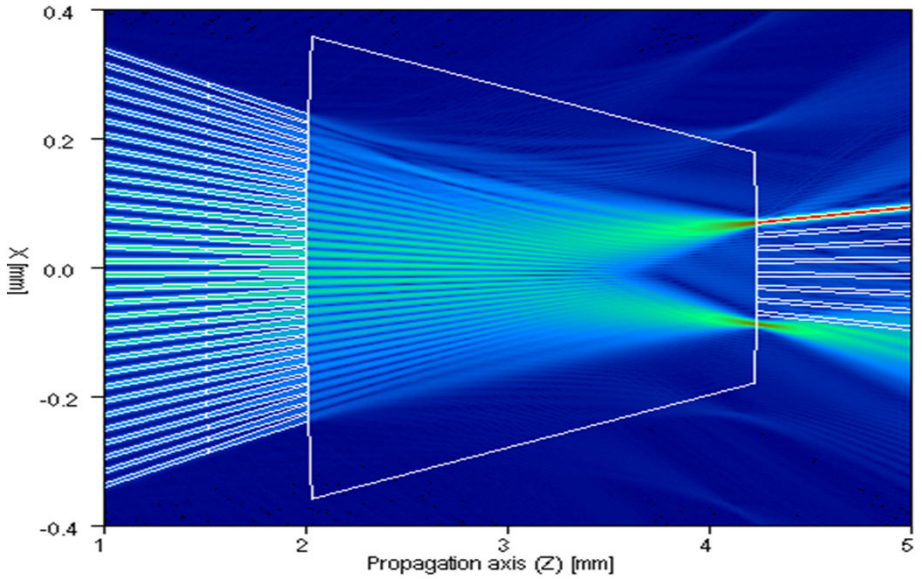
AWG: Arrayed Waveguide Grating

Arrayed waveguide grating



- **AWG**

- Great scalability
- Low losses
- Non reconfigurable
  - It requires wavelength conversion

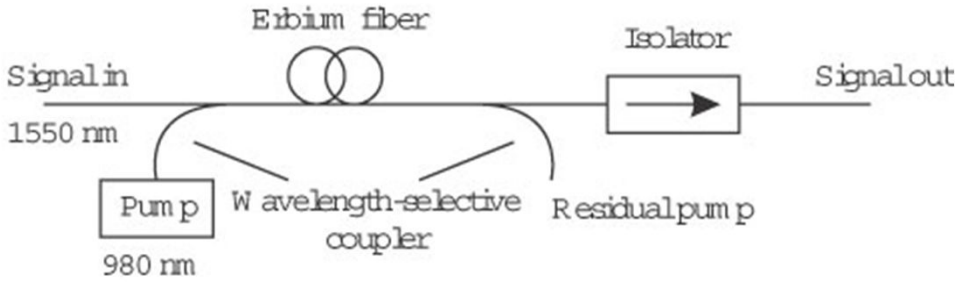


Source: Robotiker, Andrea Bianco Redondo Networks 2008, Budapest

C2V animation

All-Optical 3R?

- 3R: Re-Amplification, Re-Shaping, Re-Timing
  - all optically?
- SOA: Semiconductor Optical Amplifier
- EDFA: Erbium Dopped Fiber Amplifier (Er^{3+} or smilar elements)
- Ramman Amplifier



OTN: G.872 + G. 709 + etc.

- Optical Transport Network - Digtal Wrapper
- Defines:
  - Simultaneous wavelength **AND** Time Division Multiplexing
    - „Overlay” – „Peer” – „Augmented” Models
  - Optical layer parameters
  - Frameing structures and byte definitions
  - Intra- and Inter-Domain Interfaces: IaDI, IrDI
  - FEC (Forward Error Correction)
  - Applications

OTN vs OTNT: strict and loose (general) sense

Strict: Optical Transport Network (OTN)

„...Optical Network Elements connected by optical fibre links, able to provide functionality of transport, multiplexing, routing, management, supervision and survivability of optical channels carrying client signals...”

„... provision of transport for any digital signal independent of client-specific aspects...”

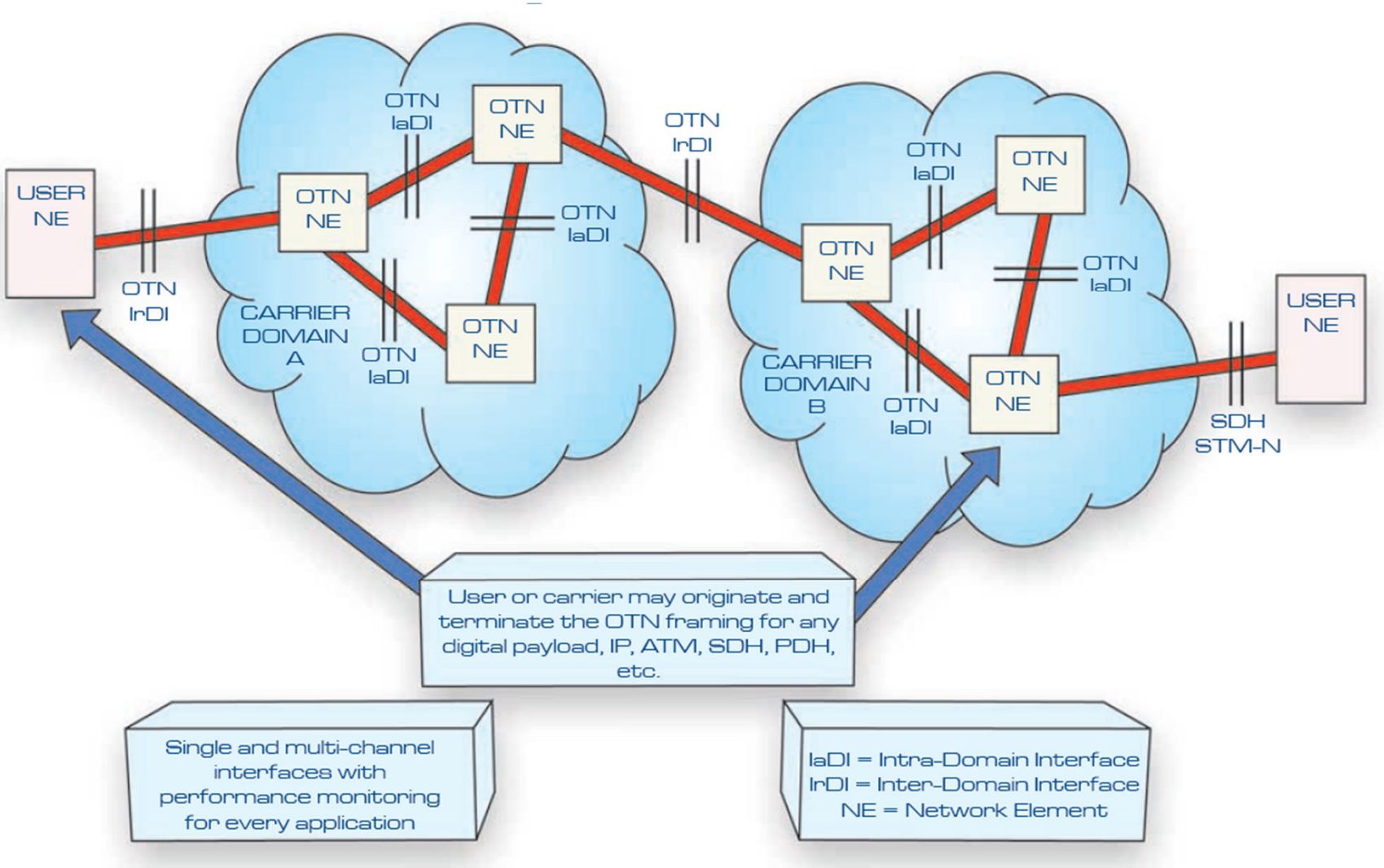
- **ITU-T G.709** (01/03) Interfaces for the **OTN**
- **ITU-T G.798** (5/02) Characteristics of **OTN** Hierarchy Equipment Functional Blocks
- **ITU-T G.872** (10/01) Architecture for the **OTN**
- **ITU-T G.8251** (10/01) The Control of Jitter and Wander within the **OTN**

General: Optical Transport Networks & Technologies (OTNT)

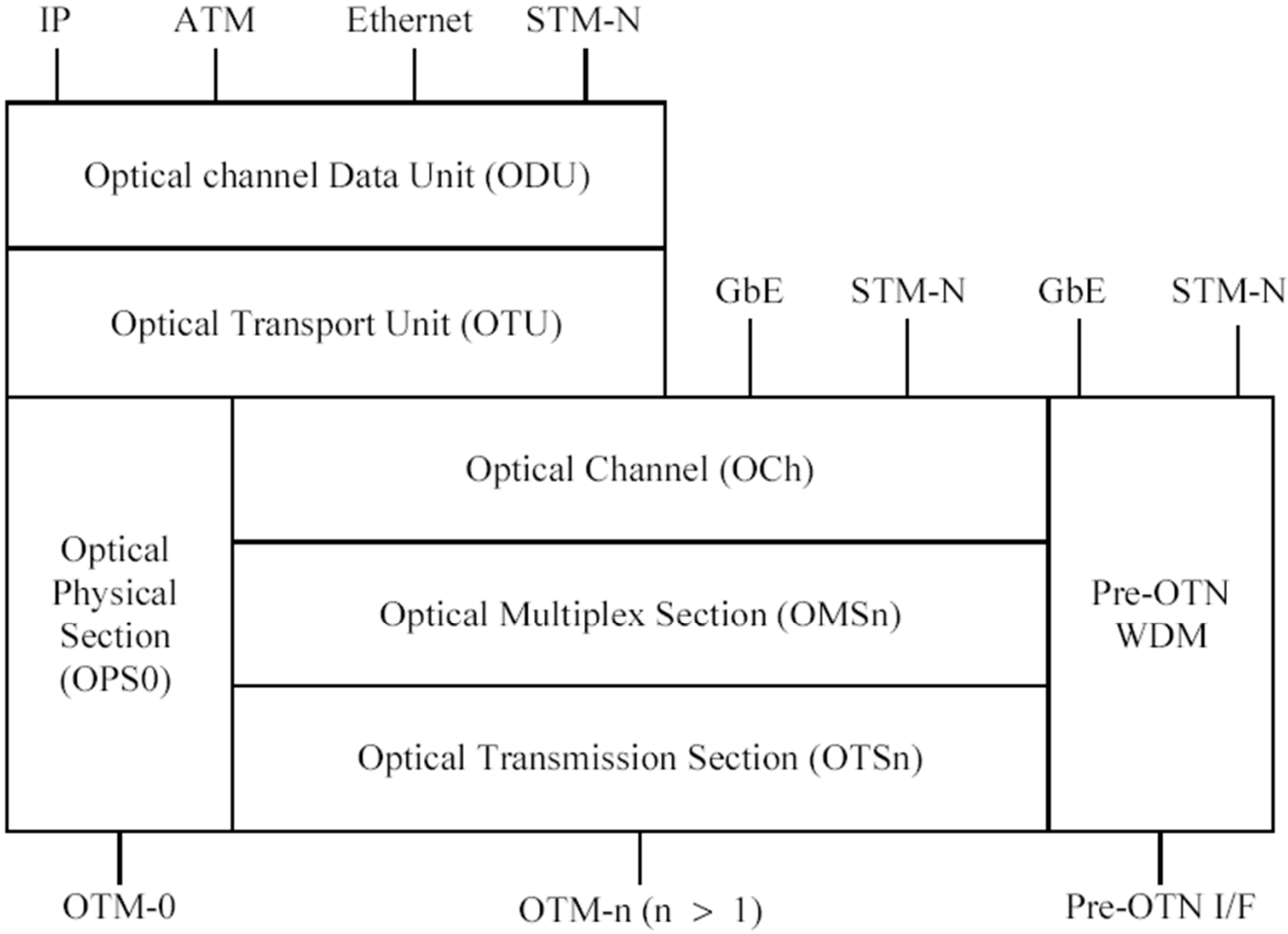
- All network functionality and related technologies that are based on optical transport
- E.g., SDH also falls into this category

Global Optical Transport Network

http://www.itu.int/dms_pub/itu-t/oth/0B/04/T0B040000150001PDFE.pdf



OTN and WDM

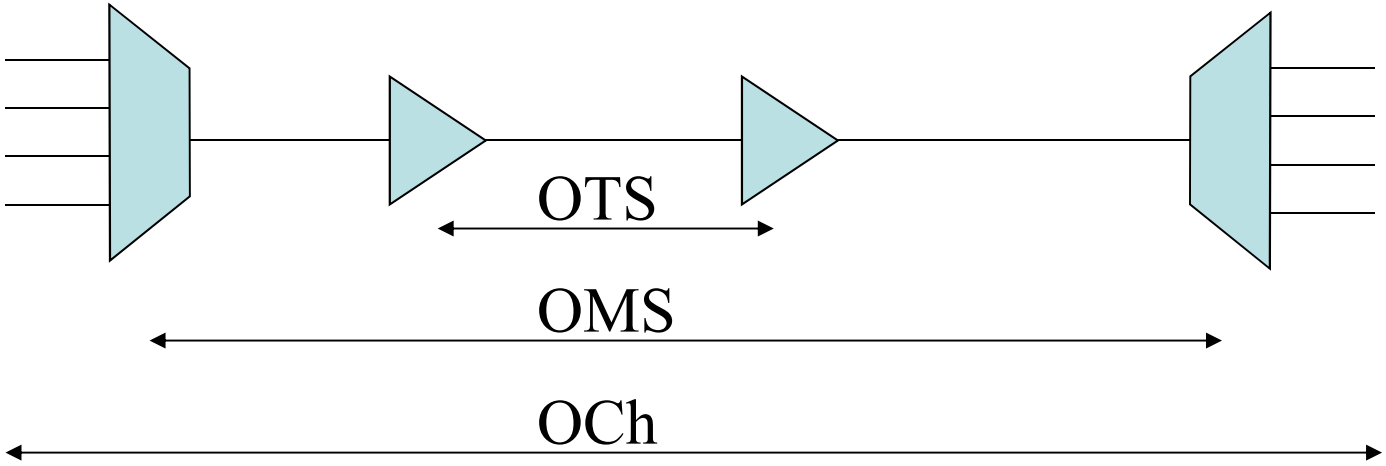


Source: ITU-T G.872: Relationship between OTN and WDM

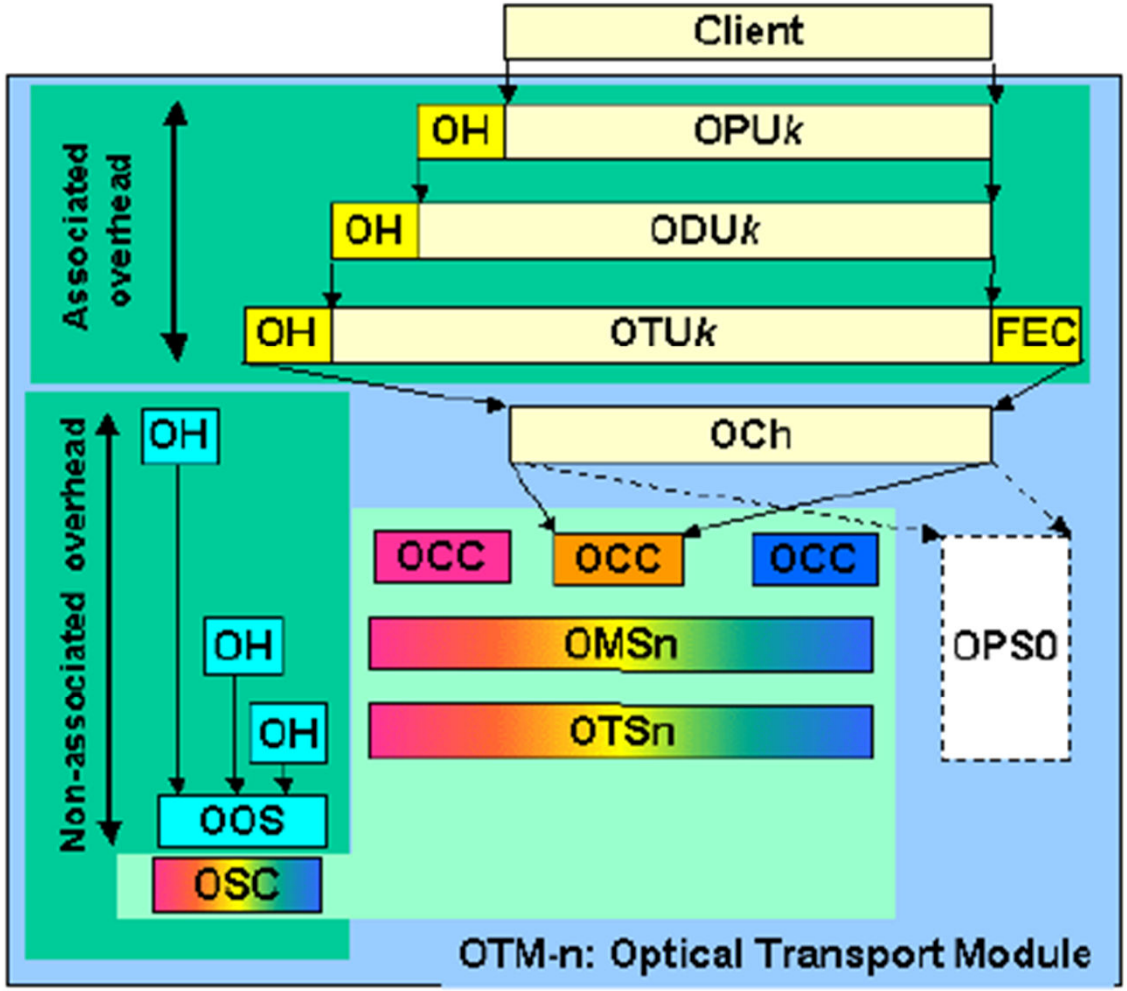
G.709 OTN

Optical Transport Network:

- OTS: Optical Transmission Section
- OMS: Optical Multiplex Section
- Och: Optical (Lambda) Channel



ITU-T G.709 framing structure



OPU: OCh Payload Unit

ODU: OCh Data Unit

OTU: OCh Transport Unit

Optical Channel

Optical Channel Carrier

Optical Multiplex Section

Optical Transmission Section

OTM Overhead Signal

Optical Supervisory Channel

Optical Physical Section

Source: Alcatel