10 Gb/s EPON Coexistence Options

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Initial assumptions

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Current 1 Gb/s EPONs (IEEE 802.3-2005):

- Video Overlay centered at 1550 nm
- 1 Gb/s downstream at 1490 nm
- 1 Gb/s upstream at 1310 nm

10 Gb/s EPONs (IEEE 802.3av):

- Video Overlay – remains backward compatible with 1 Gb/s system (centered at 1550 nm)
- 10 Gb/s upstream – potentially at 1310 nm, TDM shared with 1 Gb/s system
- 10 Gb/s downstream – currently unallocated (?)

Wavelength Planning [1]

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Main requirements:

- a must-be: full backward compatibility with 1Gb/s EPON system (IEEE 802.3-2005)
- support 1Gb/s and 10Gb/s ONUs in the same PON structure
- maintain optional analog video overlay compatible with 1Gb/s EPON systems
- take advantage of IC technology (if possible) to reduce the device cost / increase production yield

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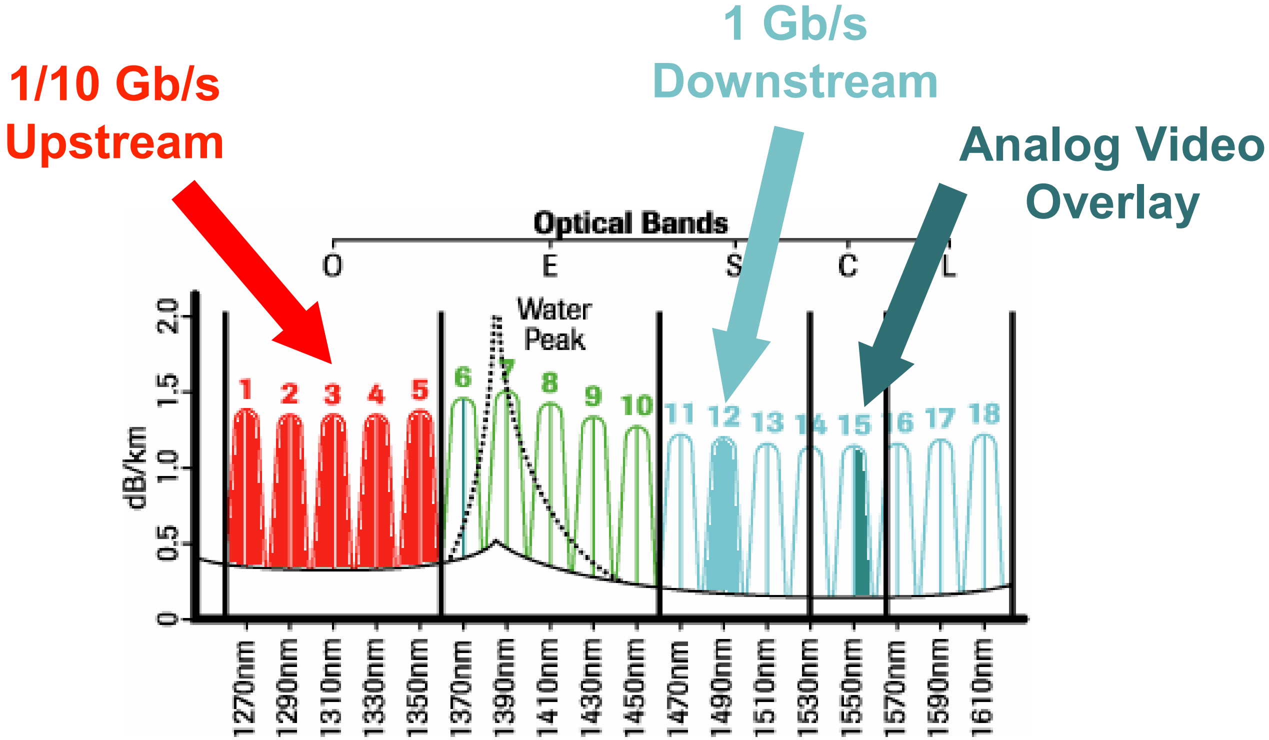
Current utilization of ITU-T CWDM grid:



Wavelength Planning [3]

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General remarks:

- O-band fully occupied (upstream channel)
- E-band 10 Gb/s LD "not commercially available"
- S-band and C-band already used (1 Gb/s downstream and video overlay) – application of expensive filters in the ONU triplexer/quadplexer
- L-band 10 Gb/s LD are still in the initial stages of development process (2-3 companies with commercial products)

ONU Triplexer options

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Wavelength filters [1]

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Required Wavelength Filter features:

- Low insertion / polarization loss
- Direct interfacing with SMF fiber
- Low temperature drift for stand-alone device
- High channel isolation (minimum crosstalk)
- High wavelength stability
- Easy customization of filter transfer function
- Simple production process with high yield
- Miniaturization, if possible, via CMOS process

Wavelength filters [2]

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Available wavelength filter solutions:

- Thin-Film Filters (TFF)
- Fiber Bragg Gratings (FBG)
- Diffraction Gratings (DG)
- Mach-Zehnder Filters (MZF)
- Planar Array Waveguides (PAW)

Wavelength filters [3]

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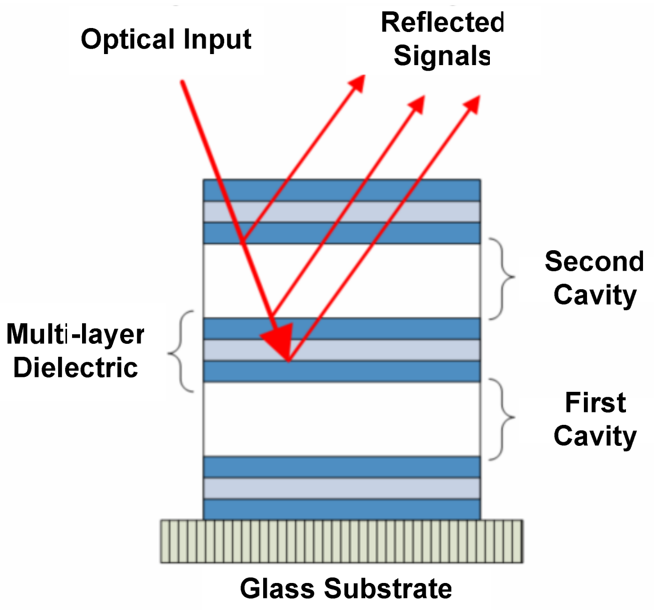
Thin-Film Filters (TFF):

- High chromatic dispersion
- Difficult narrow channel spacing
- Good temperature stability (stand-alone, no cooler)
- Flat-top passband
- Minimum polarization dependence
- Compact and inexpensive technology



Wavelength filters [4]

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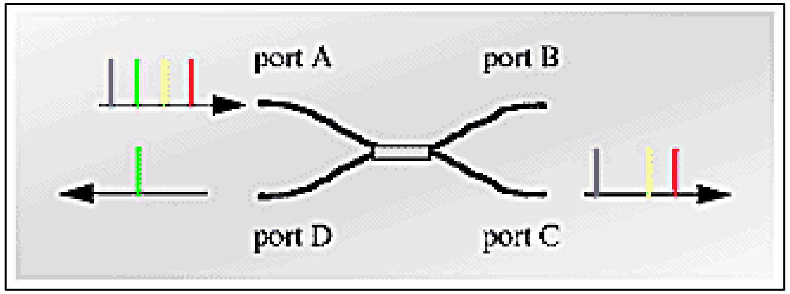
Fiber Bragg Grating (FBG):

- Temperature induced drift
- Refractive index instability
- Needs power splitters and circulators for mux/demux functions
- Easy coupling
- Low insertion loss
- Low transmission loss



Wavelength filters [5]

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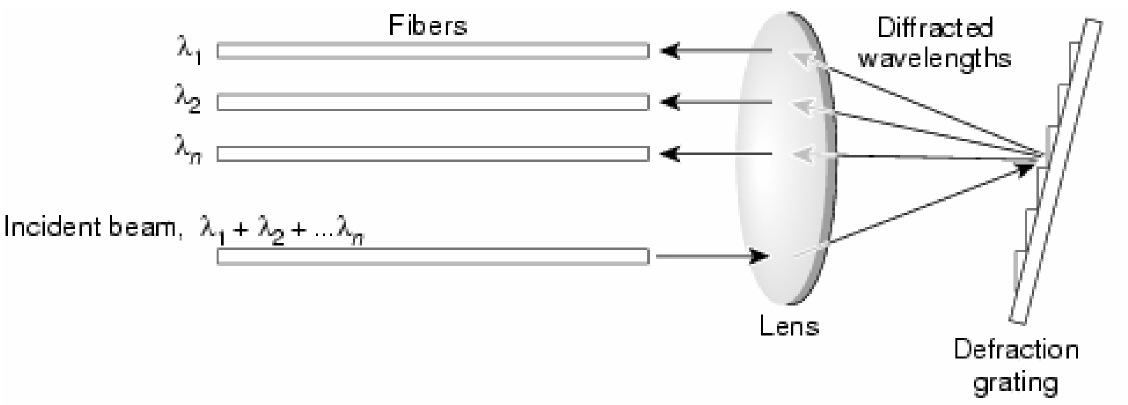
Diffraction Gratings (DG):

- Large size (free-space)
- Insertion loss increase with size decrease
- Difficult coupling with the fiber
- Good temperature stability



Wavelength filters [6]

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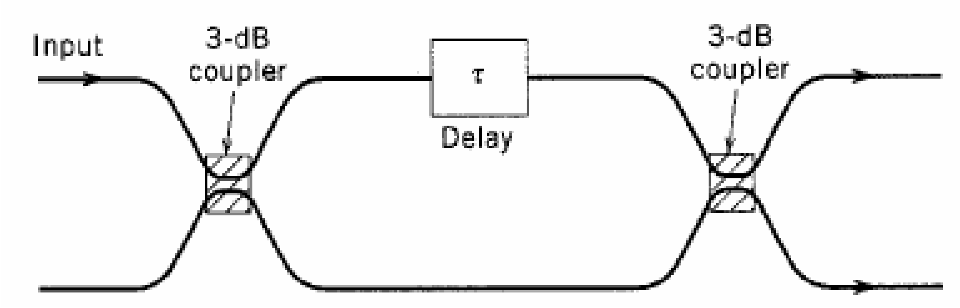
Mach-Zehnder Filters (MZF):

- Still quite expensive technology
- Insertion losses increase with the size reduction (miniaturization is questionable)
- Narrow channel spacing depend on the number of MZs
- Low polarization dependent losses



Wavelength filters [7]

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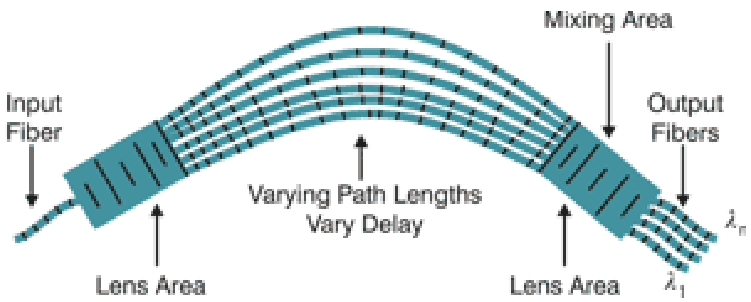
Planar Array Waveguides (PAW):

- High insertion loss
- Small free-spectral range
- Coupling losses depend on the device size
- Temperature stability (e.g. AAWG)
- Narrow channel spacing



ONU Triplexer architectures

Triplexer architecture [1]

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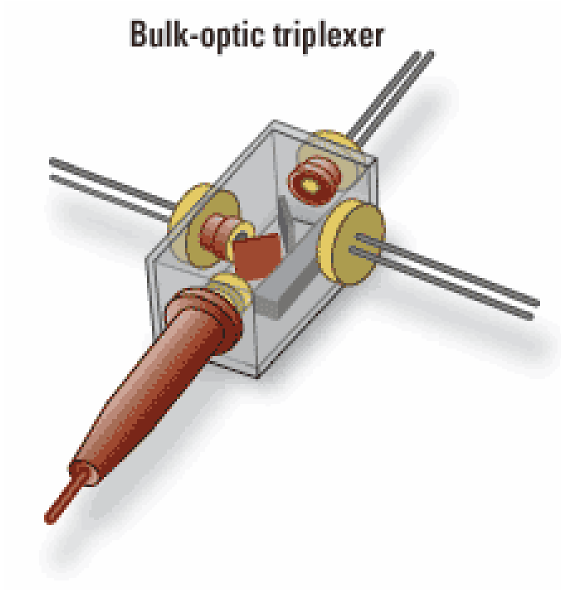
Architecture #1: TO-can with TFFs

- Electric leads are bent and soldered to PCB
- High cost in mass production due to manual assembly
- Automation possible but expensive
- Low insertion loss
- Small size for a complete transceiver (TOSA+ROSA)
- Large number of manufacturers



Triplexer architecture [1] (cont.)

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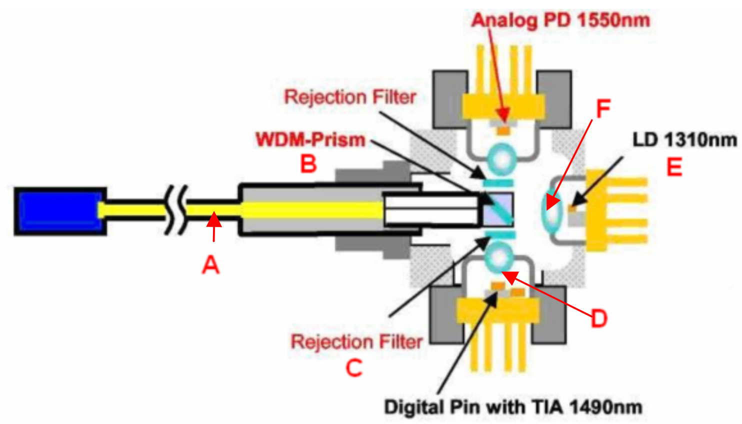
Downstream (OLT → ONU):

- Signal beam from fiber (A) is split in the WDM-Prism (B), reflected by the TFF (C) and then collimated (D) by the lens to the PD



Upstream (ONU → OLT):

- Signal transmitted by the LD (E) is collimated by the lens (F) and passes through WDM-Prism (B) to the fiber (A)

Properties:

- Discrete assembly components (TFFs, LD, PD, lenses) are placed in the bulk of the TO-can
- Typical channel isolation of 30 dB

Triplexer architecture [2]

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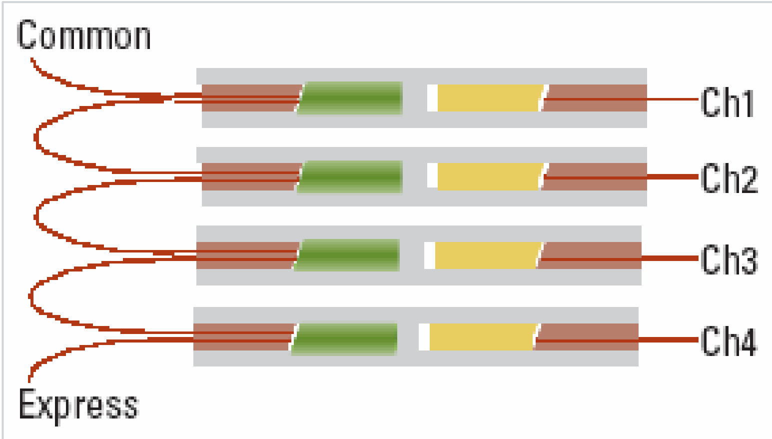
Architecture #2: Three-port TFF cascade



- Bulk packaging → large size
- Higher temperature dependent loss
- Low insertion loss for [2..4] channels

Triplexer architecture [2] (cont.)

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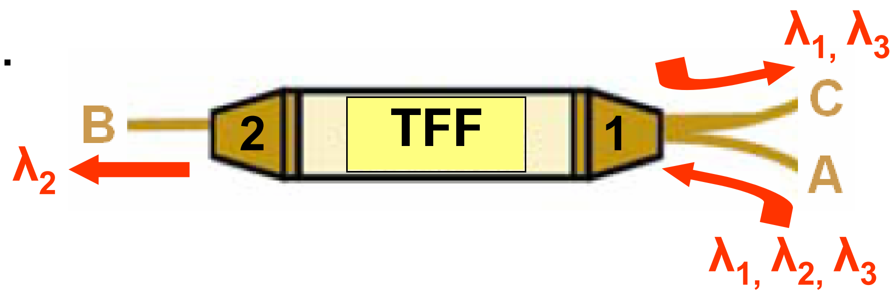
Operation

- The signal beam from the fiber (A) is filtered by the TFF and then collimated by the output lens (2) to the output port (B). The entrance lens (1) is used to collimate the reflected signal to the other output port (C).



Parameters

- Typical insertion losses (< 1 dB)
- Typical channel isolation of 25 dB

Triplexer architecture [3]

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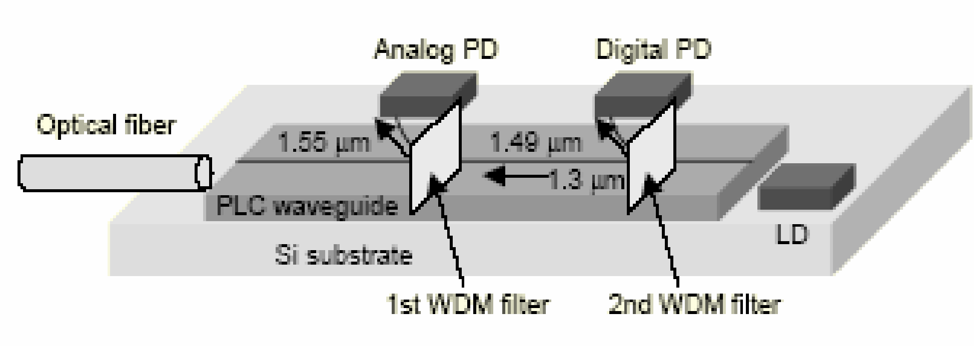
Architecture #3: Planar lightwave circuit (PLC) waveguide with external TFF



- TFF and lenses need manual assembly
- Low assembly yield due to complicated structure made from discrete components
- High device cost (low yield, complicated manufacturing process)
- Compact transceiver device

Triplexer architecture [4]

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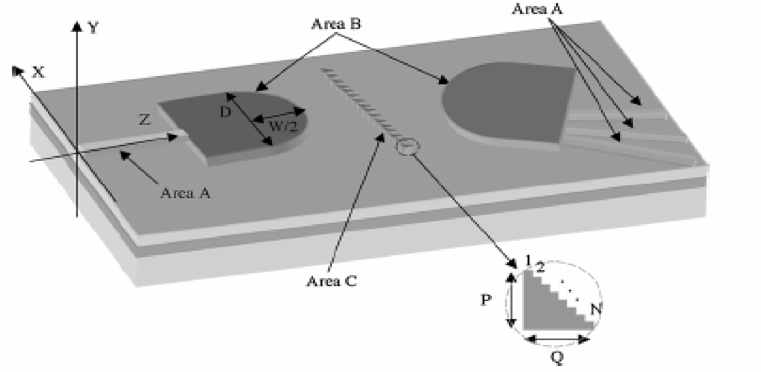
Architecture #4: Planar lightwave circuit (PLC) waveguide with embedded DG filtering

- Simple assembly process for mass production
- High transceiver integration

  (electronics + optics on the same dye)
- Low manufacturing cost (CMOS)
- Very few manufacturers



Triplexer architecture [3]

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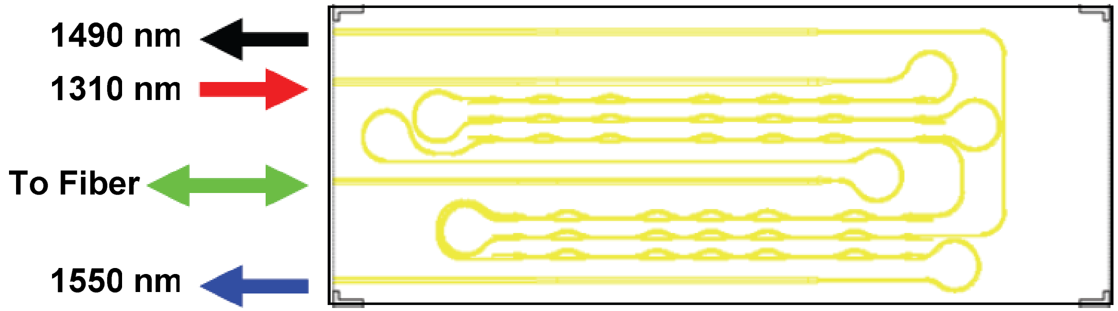
Architecture #5: Planar lightwave circuit (PLC) waveguide with cascaded MZs



- Very compact device for high integration
- High channel isolation with easily customizable filter pass-band shape
- Requires mode transformer for fiber coupling
- High insertion loss and high device cost

Conclusions

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There are several possible ONU triplexer architectures:

- TFF based, bulk TO-can triplexers are most popular and have a well established manufacturers' base
- Multiport TFF cascade n-plexers are typically used in CATV networks for selective drop operations at the distribution nodes - bulky, hard to miniaturize
- Other triplexer architectures are uncommon and still rather exotic

Several WDM filter structures are possible

- TFF option has probably the lowest cost and most stable parameters