# 6 Technical Feasibility of NG-EPON

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### ~~6.5.1~~6.4.1 Single Mode Fiber Spectrum

The existing ODN designed for use with optical access networks is intended to carry multiple services, requiring allocation of specific wavelength bands (spectrum ranges) that need to coexist on the same fiber~~ strand~~. At the same time, the fiber medium itself has specific regions which are more favorable for telecommunication applications, while other regions remain largely unused due to their less favorable transmission characteristics. Figure 1~~Figure 32~~ presents attenuation and chromatic dispersion curves for the three most common single mode fiber type found in existing ODNs designed for optical access. Discussion on wavelength allocation plans for access systems can be found in 6.4.4.~~The existing spectrum allocation bands for 1G-EPON, 10G-EPON, OTDR, and RFoG systems are also presented for reference.~~

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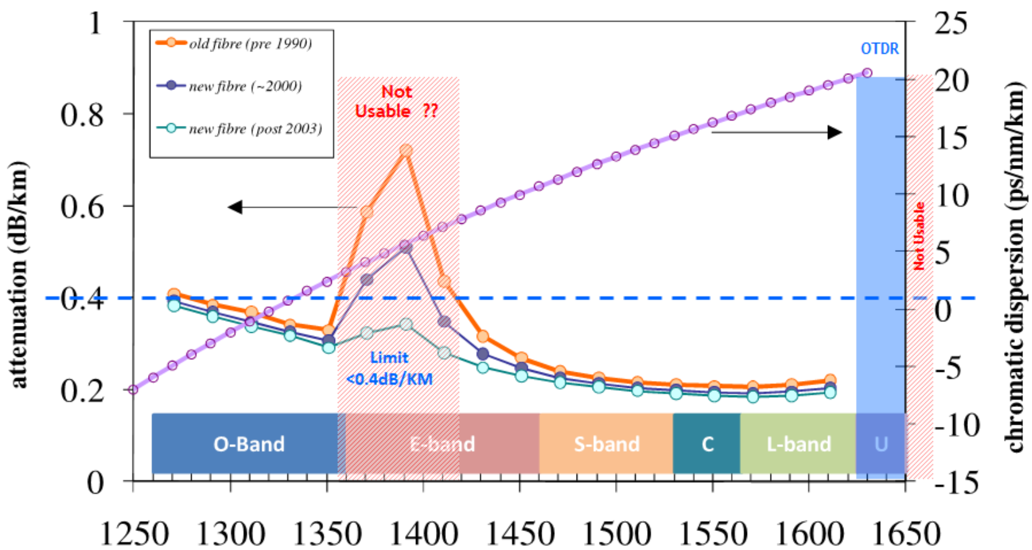


**Figure 1~~32~~: Attenuation and chromatic dispersion in different fiber types**

~~From~~ Figure 1~~Figure 32 it is clear that the spectrum availability for next generation optical access systems is very limited if all the existing services are to be supported on the same ODN. There are effectively just two free spectrum ranges usable for transmission: one range in the upper E band and one range in the upper L band.~~

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### ~~6.5.2~~6.4.2 Passive Splitter / Combiner for TDM-PON

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A power splitter distributes all incoming signals evenly among all output ports, requiring a wavelength filter at each ONU. Insertion loss, loss uniformity, return loss, and operating temperature range are just a few of the important features of ~~high- quality~~ Passive Splitter / Combiner (PSC) units. The specifications of the splitter can be found in Telcordia GR1209 (GR–1209–CORE for passive fiber optic components) or GR1221 (GR–1221–CORE for passive fiber optic component reliability). There are several manufacturing techniques for PSC, discussed briefly below. ~~Although the splitter is a relatively simple, low–cost, distribution structure, it requires optical filters with different center wavelengths to be located at ONUs. Additionally, a splitter adds higher channel loss when compared with a wavelength router, mainly due to its operating principle as well as manufacturing technology and inherent imperfections.~~

#### ~~6.5.2.1 Fused/Fused Biconical Taper (FBT) Couplers~~

A fused coupler is a structure formed by joining two independent optical fibers (see Figure 33). The claddings of the fibers are fused in a small region (length *z*). FBT devices work as a result of an energy transfer by coupling proximity between optical fiber cores.

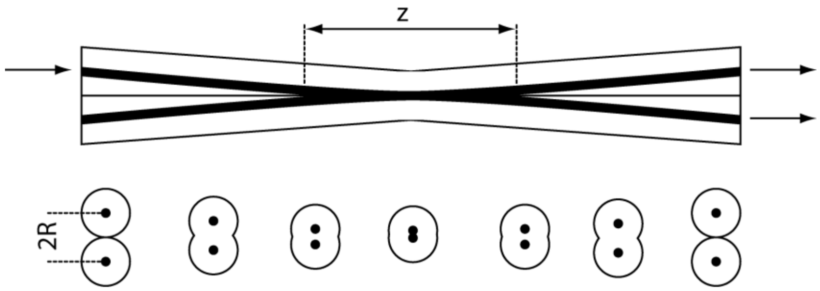


**Figure 33: Fused passive coupler/splitter**

To create a more complex structure than 1x2 or 2x2 configurations, 1x2 fused coupler components are concatenated by splicing each output arm of the first coupler to the input arm of the second ones, and so forth. This is done repeatedly to achieve the desired output power ratio and number of ports required, and a set of cascaded fused couplers and splices are usually housed and protected in a robust, environmentally hardened plastic packaging (see Figure 34.a with an example of an actual component, and Figure 34.b with internal structure of such a PSC module).

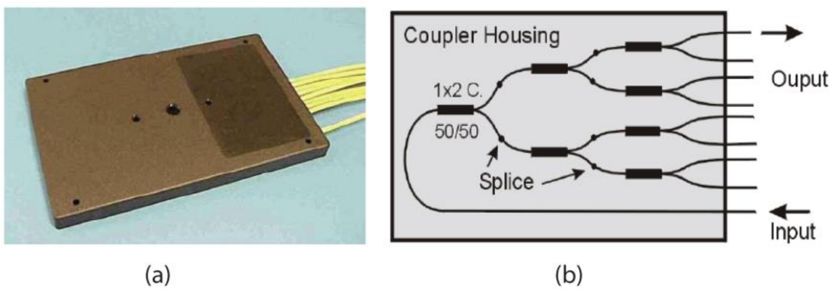


**Figure 34: (a) Standard PON multi–port PSC, and its (b) internal structure**

~~**6.5.2.2 Planar Lightwave Circuit (PLC)**~~

PSCs can be also manufactured using the planar lightwave circuit (PLC) technique, where power splitting / coupling function is ~~Glass optical fibers are routinely used today for high speed data transfer and, although they provide a convenient means for carrying optical information over long distances, they are inconvenient for complex high density photonic devices. In addition to being fragile, glass fiber devices are difficult to fabricate, especially when they have a high port count, and in most cases require manual processing, resulting in high cost. Integrated optics is becoming the approach of choice for advanced photonic components. Several material systems are being pursued as platforms for optical integration, and their properties are summarized in [ma4]. The most widely used integrated optics platform is silica on silicon. Whereas the choice of this platform in the early days of integrated optics was quite natural and justifiable, because of its kinship to silica fiber, the advantages of this technology outweigh the disadvantages, even after two decades of extensive global research.~~

~~Silica fiber has a propagation loss of 0.15 dB/km at 1550 nm wavelength, a remarkably low number that is achieved due to the fact that the fiber has no stress and no surface roughness. However, when silica is grown on a silicon wafer, typically at high temperature by chemical vapor deposition, a high level of stress is obtained in the wafer when it cools down to room temperature, due to the coefficient of thermal expansion mismatch between silica and silicon. This stress results in polarization dependent behavior, stress induced scattering, and high coupling loss when pig tailing to fiber blocks, due to warping in the substrate. The Reactive Ion Etching patterning of waveguides in silica creates rough edge walls, which in turn create scattering loss and further polarization dependence. Another limitation is that the highest contrast achieved to date in this technology is only 1.5% [ma5]. Additionally, the production yields with this technology have historically been low, especially for large interferometric devices such as AWGs, where numbers below 10% are common. Other platforms for integrated optics are being pursued, including silicon on insulator, silicon oxynitride, lithium niobate, indium phosphide, gallium arsenide, sol gels, and polymers. A very comprehensive analysis of the aforementioned PLC platforms is in [ma6].~~

~~The function of power splitting / combination in PLC is typically~~ achieved ~~by~~ within a Y–junction (see Figure 36.a). Such a Y-function is fabricated inside the bulk material~~, by using either~~ via photolithography techniques similar to the procedures used in the semiconductor industry or polymer processing techniques to imprint the Y–junction pattern into the base polymer material, which is then etched and treated accordingly, producing a custom design power splitter. ~~A Y junction is a three port device acting as a highly directional power splitter/combiner (see Figure 36.a) and it is manufactured by splitting a planar waveguide into two branches bifurcating at some angle θ.~~ When light is injected in the input end, its power is divided equally between its two branches, assuming that the Y–junction is perfectly symmetric around the axis of the input waveguide. In this sense, this device acts similarly to a standard fiber coupler, except that it has only three ports. Conceptually, it differs considerably from a fiber coupler since there is no coupling region in which modes of two different waveguides overlap.

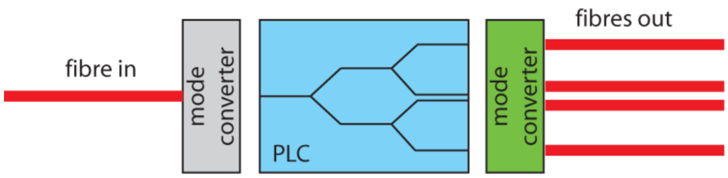


**Figure 35: Planar splitter sub–assembling parts**

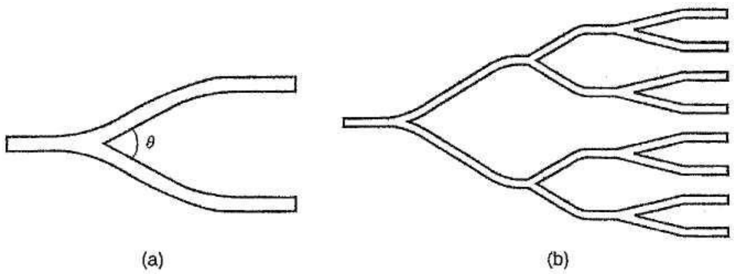


**Figure 36: (a) A Y-junction and (b) an 1:8 PSC made by combining several Y-junctions**

~~The operation of a Y-junction can be explained as follows: in the junction region, the waveguide is thicker and supports higher-order modes, but the very geometrical symmetry of the component prohibits the excitation of asymmetric modes. Assuming that the material thickness is changed gradually in an adiabatic manner, even higher-order symmetric modes are not excited, and the power is divided into two branches virtually without any excess loss. In practice, a sudden opening of the gap violates the adiabatic condition, resulting in certain insertion power loss associated with any Y-junction, and it is obvious that the power loss value depends on the $\theta$ angle (so called *branching angle*) and increases along with the increase in the $\theta$ angle value. In practice, the $\theta$ angle should be maintained below 1° to keep insertion power loss well below 1 dB. Power loss as small as 0.13 dB has been realized for waveguides with Δn = 0.3% [ma10].~~

Depending on the employed manufacturing scheme, PLC-based PSCs can achieve excess loss <0.2dB per single Y-junction, providing much lower total loss for PSCs with higher power count when compared with typical manufacturing techniques [ma8] [ma9].

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~~As shown in Figure 36b, multiple discrete Y-junctions can be combined to form a fully functional, multi-port power splitter/combiner. In general, the number of ports doubles after each bifurcation and is given by $2^N$ after $N$ Y-junction stages. Thus, a total of 10 Y-junction stages are necessary to produce a 1024-port power splitter/combiner.~~

~~6.5.2.2.1 Glass-based PLC power splitters/combiners~~

~~Standard Y-junction based power splitters/combiners are manufactured using one of the following technological processes:~~

- ~~ion exchange with glass substrate;~~
- ~~plasma-enhanced chemical vapour deposition;~~
- ~~flame hydrolysis deposition.~~

~~The differences between the three referenced processes lie in the "generation" or building-up of the waveguide in which the light propagates. The main objective of all these technologies is ultimately the same: to build a structure in which light can propagate without loss and that still behaves like an optical fiber. All the aforementioned processes produce a structure (doped glass) which has a higher refractive index than the~~

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~~surrounding material (also glass). The difference in the refractive index allows the waveguide to mimic the performance of a pure optical fiber, which is also made of glass with a core with higher refractive index. [ma11] provides details of the aforementioned manufacturing processes for glass-based PLC power splitters/combiners.~~

~~6.5.2.2.2 Polymer-based PLC power splitters/combiners~~

~~Polymer is the material of choice for integrated optics because, when synthesized and processed properly, it offers high performance (the loss in state-of-the-art polymers is slightly lower than the loss achieved in state-of-the-art silica, and the birefringence is smaller than that of silica by two orders of magnitude), tuneability (thermo-optic coefficient 30 to 40 times larger than in silica), environmental stability, high yields, and low cost, making it a material of choice for future generation PLC devices.~~

~~Generally low overall loss for polymer based devices makes polymers a perfect material for low-loss power splitters/combiners ideal for application in cost-effective PON networks with a limited power budget.~~

~~In 1997, the DuPont company demonstrated a Polyguide single mode Y-junction polycarbonate packaged 1×8 splitter characterized by the overall excess loss of 2.2 dB at 1300 nm (the inherent waveguide material loss was estimated at 1 dB, the Y-junction construction loss at 0.4 dB (3 stages), and the rest attributed to splices [ma7]). The power splitting operation thus imposed~~ $10 \times \log_{10} 8 + 2.2 = 11.23$ ~~dB of power loss. For comparison, a standard 8 port FBT PSC module is characterized by the total insertion loss of almost 11 dB.~~

~~[ma8] presents a trial manufacturing process for 0.97 dB/cm polymer based Y-junction with the total excess loss of 1.38 dB in the 640 nm transmission window. Various polymer materials were tested and minimum material loss was estimated at 0.19 dB/cm for bulk epoxy 301-2FL. A multiple port power splitter can be manufactured using the examined materials with the total excess loss of approximately~~ ~~$n \times \cdot 1.38$ dB (where $n$ is the number of splitting stages required to reach the target split factor), assuming that similar coupling loss is achievable as in the test devices.~~

~~A novel approach is presented in [ma9] in which the Y-junction power coupler/splitter is equipped with a micro-prism in the coupling area, to increase the mode separation efficiency and allow for reduced manufacturing precision requirements. Multi and single mode operation for the aforementioned coupler can be achieved with the 2-port device characterized by an excess loss below 1 dB, depending on the quality of the fiber-PLC splices.~~

### ~~6.5.3~~6.4.3 Wavelength Filters for WDM-PON

~~To allow for an unimpeded evolution from one generation of EPON to another, as well as for coexistence of multiple generations of EPON on the same ODN, ONUs need to be equipped with wavelength blocking filters (WBF) to receive optical signals only within the nominal receive window described by the respective standard and reject all optical transmissions outside that window. For example, 1G-EPON ONUs need to receive only downstream 1G-EPON wavelength range of 1480 nm – 1500 nm, and reject downstream 10G-EPON wavelength range of 1575 nm – 1580 nm, as well as any other signals (RFoG, CWDM, etc.).~~

~~There are no existing specifications of WBF for 1G-EPON and 10G-EPON devices in [802.3], though commercial 1G-EPON and 10G-EPON products typically employ WBF following [ITU-T G.984.5] and [ITU-T G.984.5Am1] specifications. These recommendations define both the wavelength blocking filters to be included within the ONU transceivers as well as the wavelength combiners / splitters, commonly referred to as WDM1 [ITU-T G.984.5] or~~

~~WDM1r [ITU-T G.984.5Am1], and used to combine / separate wavelengths at the CO. The same wavelength allocation plans for 1G-EPON and GPON, as well as 10G-EPON and XG-PON1 allows reuse the of the ONU WBF and OLT WDM1 designs for both types of optical access systems.~~

~~[Figure showing characteristics of WBD and WDM1 will be needed]~~

A WDM-PON system with multiple wavelength channels in downstream and upstream directions may either deliver all wavelengths to each ONU or perform wavelength filtering within the ODN and deliver only selected downstream wavelength channel(s) to each ONU. In the first approach, the TDM-PON ODN can be reused, though it requires each ONU to be capable of selecting appropriate downstream and upstream wavelength channels and filter out all other wavelength channels. In the latter approach, the ODN needs to employ some of sort of a WDM filter, placing specific wavelengths into selected output ports.

WDM filters for the use in WDM-PON systems are typically implemented in the form of ~~A passive WDM router is commonly based on~~ an Arrayed Wave Guide (AWG), which was originally ~~used~~ developed for ~~in many~~ long–distance WDM systems as a channel multiplexer/demultiplexer and as an add–drop multiplexer (ADM)~~ once connected with additional, external components~~. An AWG routes each specific wavelength to a unique output port, separating multiple wavelengths at the same time. Its cyclic wavelength property enables the AWG to be used at the Remote Node (RN), both as multiplexer and demultiplexer at the same time, as depicted in Figure 37. Providing that the upstream channel wavelengths differ from the downstream wavelengths by an integer multiple of the free spectral range (FSR) of the AWG, the same AWG output port can be assigned for both upstream and downstream transmissions, as presented in Figure 37.a. A CWDM filter is used at the ONU for separating the two signals. There are several reasons for using the aforementioned CWDM filter:

- it prevents the downstream signal from entering the Laser Diode (LD) at the ONU;
- the insertion loss of the filter is far less (~ 0.5 dB) when compared to a 1×2 splitter (~ 3.5 dB);
- it prevents the potential upstream signal from entering the Photodetector (PD) at the ONU.)

However, provided that both the downstream and upstream channels use the very same wavelength channel (e.g. in a shared source scenario), two different output ports should be assigned to an ONU and a 2×N AWG should be used at the RN, as depicted in Figure 37.b.

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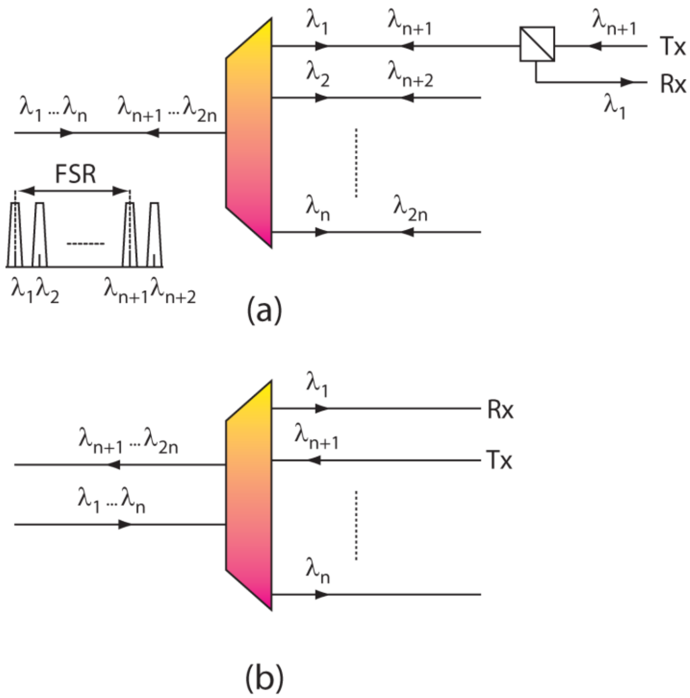


**Figure 37: RN with (a) bidirectional, or (b) unidirectional transceiver at the ONU**

The typical AWG insertion loss reaches 4 to 5 dB, regardless of the number of supported channels, which is significantly lower when compared with a standard ~~power splitter~~PSC~~, where the splitting loss is estimated as $10\times\log_{10}(N)$, where $N$ is the number of supported output channels, and should be increased by the excess loss of 0.5 to 1.5 dB, depending on the manufacturing precision, tolerances, etc~~. However, ~~in spite of such good properties in terms of insertion loss, the~~ a typical AWG's center wavelength shift of ~ 0.01 nm/°C makes it difficult to employ such components in ~~the RN~~ ODN without additional active temperature stabilization~~of a WDM PON, provided that no active temperature control measures can be used~~. This temperature dependency originates from the index change of the silica waveguide, leading to a change in the optical length of the circuit of the AWG. Recently, athermal packaging of AWGs has been reported, where AWG is ~~. Athemrmally packaged AWGs are made by having a~~ equipped with a temperature compensating material ~~that has~~ with a temperature coefficient different from that of AWG ~~silicon in part of the AWG~~ lightwave circuit [ma12] [ma13].

WDM filters ~~There is another common scheme for multiplexing/demultiplexing optical channels, called~~ can be also implemented using thin–film multicavity filters (TFMF) or multilayer interference filters. By positioning cascaded filters in the optical path, wavelengths can be demultiplexed, and vice versa. Each filter is designed to transmit a unique wavelength while reflecting others. This type of filter is better suited for CWDM channels, while the AWG is more adequate for implementing ~~the large channel counts compatible with~~ DWDM ~~applications~~channels.

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Recently, a new type of wavelength router, called a *bulk grating*, has been suggested for use in a DWDM system [pr]. This bulk grating is based on a bulk–type diffraction grating and has lower insertion loss (less than 3 dB values are achievable) with narrower channel spacing and larger channel count when compared with the AWG. For instance, devices for 160 channels with 25 GHz channel spacing can be manufactured using the standard production techniques used currently for AWGs. The AWG has an apparent advantage for integration with other devices in thin structures, since it ~~is~~ may be implemented on a silica–based PLC, while the bulk grating has a potential for temperature insensitivity and narrow channel spacing, but does not allow for significant size reduction and its integration ~~is~~ remains problematic.

#### ~~6.5.4~~6.4.4 Existing Wavelength Allocation Plans for Optical Access Systems

Figure 38 presents a more detailed view of the existing spectrum allocation bands, covering not only optical access systems defined by IEEE 802.3 WG and SCTE systems, but also optical access technologies covered by ITU-T recommendations. The spectrum range above 1440 nm is already covered with either allocated transmission channels or guard bands for legacy systems. Any newly specified optical access standard needs to either operate within existing guard band regions, or displace one of the existing systems which would potentially break backward compatibility across three generations of equipment.

~~Also, of note is the fact that t~~The continued use of 1610 nm analog return channel for RFoG impedes deployment of next generation ITU-T systems, overlapping with the downstream channel of TWDM option.

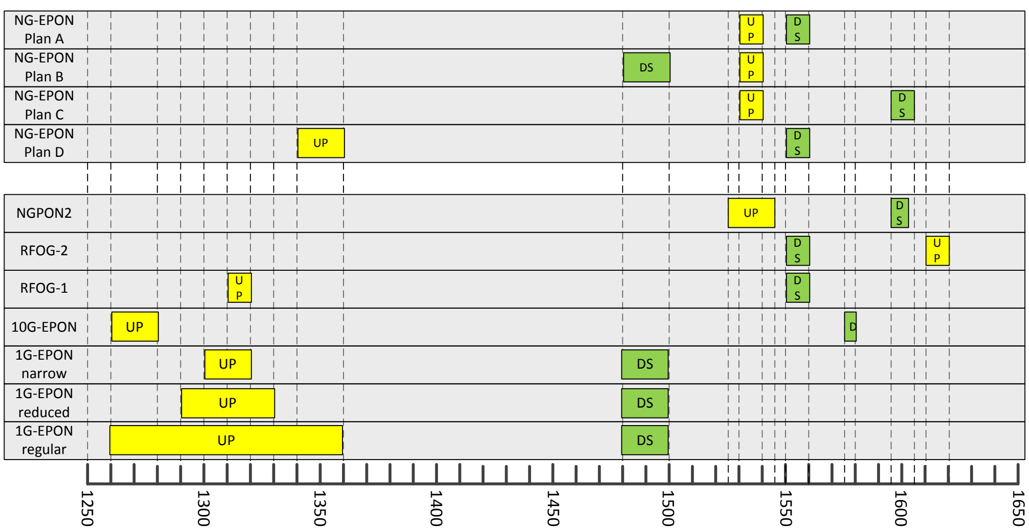


**Figure 38: Spectrum allocation bands for optical access defined in IEEE 802.3, SCTE, and ITU-T**

Example of wavelength allocation plans for several IEEE 802.3, SCTE, and ITU-T optical access systems are shown in Table 3. ~~Individual letter designations (A, B, through H) are explained in Table 3.~~ The 1260–1360 nm

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upstream band for 1G-EPON is defined in [802.3], though it is possible to purchase commercially available 1G-EPON transmitters conforming to reduced or narrow upstream bands, defined for GPON.

**Table 3: Wavelength allocation plans for selected IEEE 802.3, SCTE, and ITU-T optical access systems**

| System | Downstream [nm] | Upstream [nm] |
|---|---|---|
| **1G-EPON** | 1480-1500 | 1260-1360[1]<br>1290-1330[2]<br>1300-1320[3] |
| **10G-EPON** | 1575-1580 | 1260-1280 |
| **GPON** | 1480-1500 | 1260-1360 (regular)[1]<br>1290-1330 (reduced)[2]<br>1300-1320 (narrow)[3] |
| **NGPON2 (TWDM)** | 1596-1603 | 1524-1544 |
| **NGPON2 (P2P WDM)** | 1524-1625 | |
| **RFoG** | 1550 | 1310 / 1590 / 1610 |

[1] Typical for Fabry Perot lasers
[2] Typical for DFB lasers without temperature control
[3] Typical for DFB lasers with temperature control

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### ~~6.5.5~~6.4.5 Wavelength Allocation Plans for NG-EPON

1G-EPON, as first specified in [802.3ah, now part of 802.3], opted for a very cost-effective use of upstream wavelength and least challenging (as far as dispersion) portion of the fiber spectrum, allowing the use of the whole 100 nm region around 1310 nm. While initial generations of optical 1G-EPON transceivers based on FP laser diodes indeed took advantage of this whole spectrum, the development of cost-effective, temperature uncontrolled DFB designs allowed a quick reduction of the occupied upstream band to 40 nm. Today the progress of DFB technology allows for development of 20 nm upstream transceivers for EPON, with a limited or even absent temperature control loop.

10G-EPON [802.3] started off with a much more efficient use of fiber spectrum in both downstream and upstream directions, requiring only 5 nm spectrum in the downstream (1575 nm – 1580 nm) and 20 nm in the upstream (1260 nm – 1280 nm). Due to partial overlap with 1G-EPON upstream channel, a dual-rate burst-mode operation was defined in [802.3], allowing for seamless coexistence of legacy 1G-EPON with 100 nm wide upstream and newer 10G-EPON devices.

Given a very constrained availability of free spectrum in deployed SMF (see section 6.4.1 for more details), and the number of simultaneously coexisting transport technologies (1G-EPON, 10G-EPON, RFoG with or without return channel, TDR, and others) the decision on the placement and number of wavelength channels (if multiple-wavelength design is adopted) is non-trivial. Examples of wavelength allocation plans are included in the following sections and shown in Figure 38.

#### ~~6.5.5.1~~6.4.5.1 Plan A: Coexistence with 1G-EPON and 10G-EPON

Figure 38 presents the wavelength plan for NG-EPON (Plan A) guaranteeing coexistence for 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 10 nm wide and placed between 1550 nm and 1560 nm, while the upstream NG-EPON wavelength band is also 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the spectrum band currently reserved for the downstream RF overlay is reused for NG-EPON.

Both downstream and upstream NG-EPON wavelength bands can carry up to 10 separate channels if 100 GHz channel spacing is used.

Optical components for C-band are technically mature and are expected to be cost-efficient at this time, though they are typically designed for transport systems and support very limited power budgets. The dispersion in C-band is much higher when compared with O-band, and thus typically EML transmitters are used. There have been announcements of DML transmitters developed for O-band as well [TBD, reference missing]. However, there are no broadly available C-band components supporting power budgets in excess of 29 dB, capable of operating over the most common ODN designs deployed today.

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#### ~~6.5.5.2~~6.4.5.2 Plan B: Coexistence with RF overlay and 10G-EPON

Figure 38 presents the wavelength plan for NG-EPON (Plan B) guaranteeing coexistence for RF overlay, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 20 nm wide and placed between 1480 nm and 1500 nm, while the upstream NG-EPON wavelength band is 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the spectrum band currently reserved for the downstream 1G-EPON is occupied by the downstream NG-EPON, while the upstream NG-EPON band is placed between downstream 1G-EPON band and RF overlay, effectively changing requirements for existing wavelength filters on 1G-EPON devices with RF overlay.

The upstream NG-EPON wavelength band can carry up to 10 separate channels if 100 GHz channel spacing is used, just like in Plan A. The downstream NG-EPON wavelength band can carry up to 20 separate channels, if 100 GHz channel spacing is used. Alternatively, lower cost 200 GHz grid can be used if only 10 channels are needed.

Observations about maturity of C-band components in section 6.4.5.1 are also applicable to NG-EPON upstream band in this plan. The S-band optical PON-specific components are much more mature, given the long-term deployment of 1G-EPON operating in the same wavelength band in downstream. The transition from 1G to 10G lasers should be relatively straightforward, given the maturity of laser drivers for 10G-EPON transceivers.

#### ~~6.5.5.3~~6.4.5.3 Plan C: Coexistence with RF overlay, 1G-EPON, and 10G-EPON

Figure 38 presents the wavelength plan for NG-EPON (Plan C) guaranteeing coexistence for downstream RF overlay, 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 10 nm wide and placed between 1595 nm and 1605 nm, while the upstream NG-EPON wavelength band is also 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the NG-EPON wavelength bands are located in areas currently not used by 1G-EPON, 10G-EPON, or downstream RF overlay.

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Both downstream and upstream NG-EPON wavelength bands can carry up to 10 separate channels if 100 GHz channel spacing is used.

Observations about maturity of C-band components in section 6.4.5.1 are also applicable to NG-EPON upstream band in this plan. The placement of the downstream NG-EPON wavelength channel in L-band requires redesign of the existing 10G-EPON transceivers to place their operating wavelength above 1595 nm. .

#### 6.4.5.4 Plan D: Coexistence with 1G-EPON and 10G-EPON, reuse of downstream RF overlay band [~~xref~~bhn2]

~~6.5.5.4~~ *Insert new reference [bhn2]: Marek Hajduczenia, Michel Allard , "Wavelength allocation plan for NG-EPON", bhn_and_cogeco_ngepon_1_0914_R03.pdf, September 2014, Kanata, Ontario*

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Figure 38 presents the wavelength plan for NG-EPON (Plan D) guaranteeing coexistence for 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength is 10 nm wide and placed between 1550 nm and 1560 nm, effectively reusing the downstream RF overlay band. The upstream NG-EPON wavelength band is 20 nm wide and placed between 1340 nm and 1360 nm, overlapping with the IEEE 802.3-defined 1G-EPON upstream wavelength band.

Coexistence with 1G-EPON and 10G-EPON in the downstream direction is achieved via WDM, where 1G-EPON, 10G-EPON, and NG-EPON wavelength bands are non-overlapping, and separated sufficiently to implement low-cost wavelength filters. Furthermore, given the reuse of the RF overlay downstream band, 1G-EPON and 10G-EPON ONUs are already equipped with the appropriate wavelength rejection filters to make sure that downstream NG-EPON transmissions do not affect their receivers.

The coexistence with 10G-EPON in the upstream direction is achieved via WDM, where 10G-EPON and NG-EPON wavelength bands are non-overlapping, and separated sufficiently to implement low-cost wavelength filters. Coexistence with 1G-EPON in the upstream direction is achieved via WDM or TDM schemes. The TDM coexistence mode extends to the concept of TDM coexistence defined for 1G-EPON and 10G-EPON to a triple-rate burst mode operation mode. This mode of operation is only required when the operator uses 1G-EPON ONUs with broad spectrum (100 nm) transmitters. The WDM coexistence mode is supported when the operator uses 1G-EPON ONUs with reduced-band or narrow-band transmitters, and 1G-EPON and NG-EPON transmissions can be WDM-filtered.

The downstream NG-EPON wavelength band can carry up to 10 separate channels if 100 GHz channel spacing is used. The upstream NG-EPON wavelength band can carry up to 10 separate channels if a more relaxed 200 GHz channel spacing is used.

The optical components for the downstream channel are available today, requiring minimum changes to the manufacturing process to support the required power budgets. The optical components for the upstream channel can build on upstream components for 10/10G-EPON, requiring minimum changes to shift the transmission wavelength from 1260 – 1280 nm band to 1340 – 1360 nm band.

#### ~~6.5.5.5~~6.4.5.5 Comparison of Different Wavelength Allocation Plans

Table 4 presents a comparison of different wavelength allocation plans for NG-EPON, summarizing the key characteristics of specific plans presented in the previous sections.

**Table 4: Comparison of Different Wavelength Allocation Plans for NG-EPON**

<table>
<tr><th>Wavelength Plan</th><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>Downstream band [nm]</td><td>1550–1560</td><td>1480–1500</td><td>1595–1605</td><td>1550–1560</td></tr>
<tr><td>Upstream band [nm]</td><td>1530–1540</td><td>1530–1540</td><td>1530–1540</td><td>1340–1360</td></tr>
<tr><td>Number of channels<br>[in 100 GHz grid]</td><td>10 / 10</td><td>20 / 10</td><td>10 / 10</td><td>10 / 20</td></tr>
<tr><td>Maturity of optics<br>Downstream / Upstream</td><td>Moderate / Moderate</td><td>High / Moderate</td><td>High / Moderate</td><td>High / High</td></tr>
<tr><td>Coexistence with 1G-EPON</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coexistence with 10G-EPON</td><td colspan="3">Yes</td><td>Yes</td></tr>
<tr><td>Coexistence with RF overlay</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>Coexistence with OTDR</td><td colspan="3">Yes</td><td>Yes</td></tr>
</table>

**~~6.6~~6.5**