# 1. Super-PON PMD Proposal

## 1.1. Super-PON Overview

The name Super-PON indicates a set of physical layer specifications and management parameters for optical subscriber access networks supporting point-to-multipoint operations using wavelength division multiplexing over an increased-reach (up to at least 50 km) passive optical network (PON). The defining element of a Super-PON optical distribution network (ODN) is the presence of a passive wavelength router that determines the channels supported by the ODN.

Figure 1 shows an exemplary structure of a Super-PON.

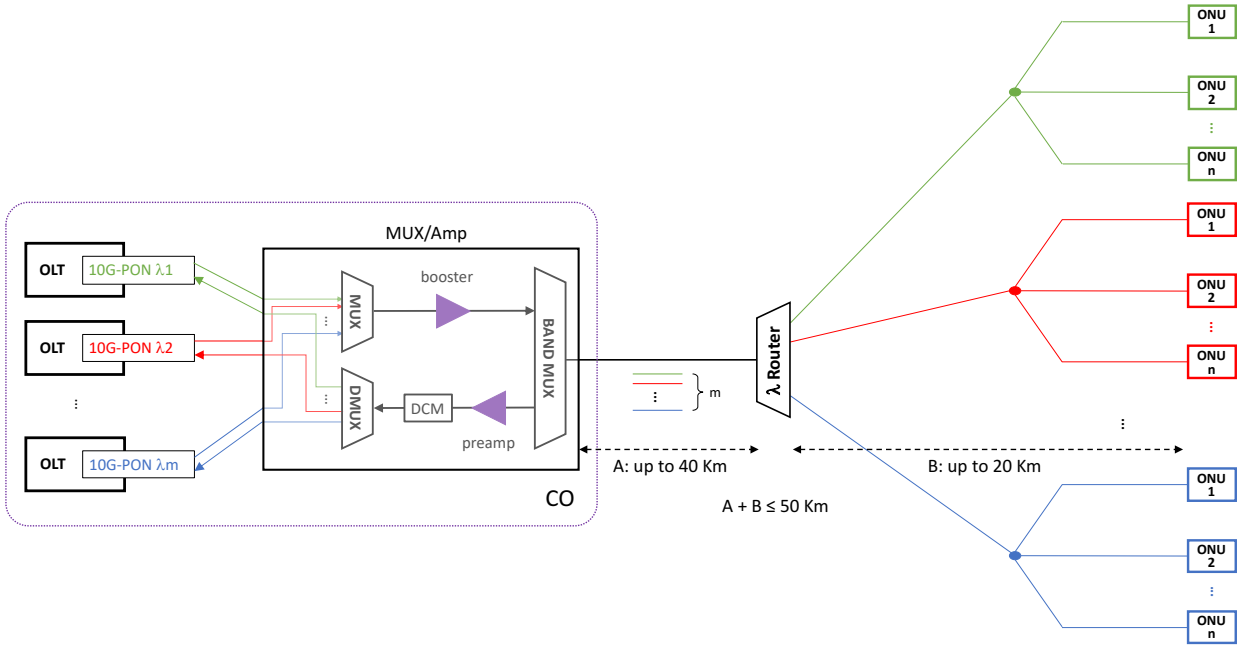


**Figure 1 - Example of Super-PON**

As shown in Figure 1, the OLT PMDs are full duplex, while the ONU PMDs are bidirectional. The wavelength pairs defining the Super-PON channel plan are shown in Table 2.

On the downstream direction, the downstream wavelengths belonging to the channels used by the m OLTs are multiplexed, amplified and finally multiplexed with the upstream wavelengths in order to get to the ODN fiber. In the ODN, these wavelengths are routed by the remote wavelength router over its physical ports. Each wavelength reaches a power splitter and then the ONUs served by the origin OLT. The point of attachment to the ODN determines the specific wavelength pair an ONU uses to operate.

On the upstream direction, an ONU transmits using the upstream wavelength belonging to the channel selected by the OLT to which it is connected. The upstream wavelengths are multiplexed by the wavelength router toward the Central Office (CO). In the CO, the upstream wavelengths are separated from the downstream ones, pre-amplified, processed by a dispersion compensation module (DCM), if needed, and finally demultiplexed for delivery to the appropriate OLT port.

Each OLT port operates over a specified channel determined by the operator in a CO, therefore it is assumed that OLT PMDs support a single channel. ONUs operate over the channel determined by their point of attachment to the ODN. On the receiving side, Super-PON ONUs use a broadband receiver. On the transmitting side, a variety of implementations is possible for ONUs, from ONUs supporting a single channel, to fully tunable ONUs able to support all channels, going through partially tunable ONUs able to support a contiguous subset of the defined channels.

## 1.2. PMD Specification Method

The Super-PON PMD sublayer is defined using the 'black link' approach at the test points shown in Figure 2.

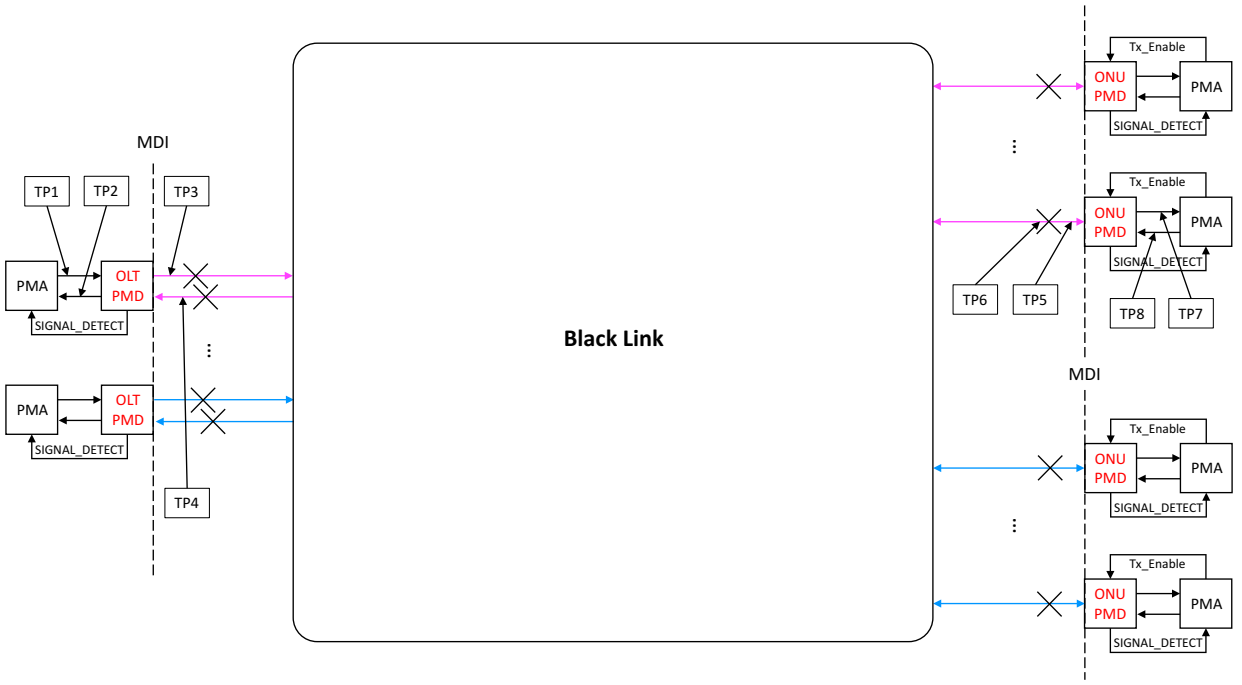


**Figure 2 - Super-PON PMD Test Points**

Test points TP1, TP3, TP5, and TP7 refer to the downstream channel, while test points TP8, TP6, TP4, and TP2 refer to the upstream channel. In the downstream channel, TP3 and TP5 are compliance points, while in the upstream channel TP6 and TP4 are compliance points. TP1, TP2, TP7, and TP8 are reference points for use by implementers.
An example of black link implementation is described in Annex 1.

## 1.3. PMD Naming

Super-PON PMD naming conforms to the following convention, with individual elements shown in Table 1:

$r_1/r_2$GBASE-SPg-dab

**Table 1 - Super-PON PMD Naming Convention**

| Parameter | Explanation | Allowed Values |
|---|---|---|
| $r_1$ | PMD downstream rate class (in Gb/s) | 10 |
| $r_2$* | PMD upstream rate class (in Gb/s) | 2.5, 10 |
| G | PMD operates at Gigabit rates | |
| BASE | PMD uses a baseband signal | |
| SP | PMD is of Super-PON P2MP type | |
| g | PMD FSR Set class$^{o}$ | 1, 2 |
| d | PMD direction class | D, U |
| a | PMD first transmit channel supported | 0 to F# |
| b+ | PMD last transmit channel supported | 0 to F# |

* If $r_1$ is equal to $r_2$ (i.e., the PMD is symmetric), $r_2$ is omitted.
+ If a is equal to b (i.e., the PMD supports a single channel), then b is omitted. It is assumed that type D PMDs support a single channel.
# See Table 2.
o This amendment defines the use of FSR Set 1. FSR Set 2 is reserved for a future amendment.

For example, using this convention:
- an FSR Set 1 10G symmetric OLT PMD supporting only transmit channel 3 is identified as 10GBASE-SP1-D3;
- an FSR Set 1 10G symmetric ONU PMD supporting transmit channels 2 to D is identified as 10GBASE-SP1-U2D;
- an FSR Set 1 10G/2.5G asymmetric ONU PMD supporting transmit channels 2 to 6 is identified as 10/2.5GBASE-SP1-U26;
- an FSR Set 1 10G/2.5G asymmetric ONU PMD supporting only transmit channel 4 is identified as 10/2.5GBASE-SP1-U4.

## 1.4. Channel Plan

The Super-PON channel plan is shown in Table 2.

**Table 2 - Super-PON Channel Plan**

| Channel | FSR Set 1 | | | | FSR Set 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | L-band 1 (downstream) | | C-band 1 (upstream) | | L-band 2 (downstream) | | C-band 2 (upstream) | |
| | Frequency+ (THz) | Wavelength* (nm) | Frequency+ (THz) | Wavelength* (nm) | Frequency+ (THz) | Wavelength* (nm) | Frequency+ (THz) | Wavelength* (nm) |
| 0 | 187.613 | 1597.93 | 192.000 | 1561.42 | 189.807 | 1579.46 | 194.193 | 1543.78 |
| 1 | 187.711 | 1597.10 | 192.100 | 1560.61 | 189.906 | 1578.64 | 194.294 | 1542.98 |
| 2 | 187.809 | 1596.27 | 192.200 | 1559.79 | 190.004 | 1577.82 | 194.396 | 1542.18 |
| 3 | 187.906 | 1595.44 | 192.300 | 1558.98 | 190.103 | 1577.00 | 194.497 | 1541.38 |
| 4 | 188.004 | 1594.61 | 192.400 | 1558.17 | 190.202 | 1576.18 | 194.598 | 1540.57 |
| 5 | 188.102 | 1593.78 | 192.500 | 1557.36 | 190.301 | 1575.36 | 194.699 | 1539.77 |
| 6 | 188.200 | 1592.95 | 192.600 | 1556.56 | 190.400 | 1574.54 | 194.800 | 1538.97 |
| 7 | 188.297 | 1592.12 | 192.700 | 1555.75 | 190.499 | 1573.73 | 194.901 | 1538.18 |
| 8 | 188.395 | 1591.30 | 192.800 | 1554.94 | 190.597 | 1572.91 | 195.003 | 1537.38 |
| 9 | 188.493 | 1590.47 | 192.900 | 1554.13 | 190.696 | 1572.09 | 195.104 | 1536.58 |
| A | 188.590 | 1589.65 | 193.000 | 1553.33 | 190.795 | 1571.28 | 195.205 | 1535.78 |
| B | 188.688 | 1588.83 | 193.100 | 1552.52 | 190.894 | 1570.47 | 195.306 | 1534.99 |
| C | 188.786 | 1588.00 | 193.200 | 1551.72 | 190.993 | 1569.65 | 195.407 | 1534.19 |
| D | 188.883 | 1587.18 | 193.300 | 1550.92 | 191.092 | 1568.84 | 195.508 | 1533.40 |
| E | 188.981 | 1586.36 | 193.400 | 1550.12 | 191.191 | 1568.03 | 195.609 | 1532.61 |
| F | 189.079 | 1585.54 | 193.500 | 1549.32 | 191.289 | 1567.22 | 195.711 | 1531.82 |

+ Normative
* Informative

## 1.5. Supported Combinations of OLT and ONU PMDs

Recommended pairings of OLT PMDs with ONU PMDs are shown in Table 3.

**Table 3 - OLT and ONU Pairings**

| | | ONU PMDs | |
|---|---|---|---|
| | | 10GBASE-SP1-Uyz | 10/2.5GBASE-SP1-Uyz |
| OLT PMDs | 10GBASE-SP1-Dx | 10G/10G* | N/A |
| | 10/2.5GBASE-SP1-Dx | N/A | 10G/2.5G* |

* For the pairing to work, channel x belongs to the channel interval {y, z}.

## 1.6. PMD to MDI Optical Specifications for OLT PMDs

**Table 4 - OLT Transmit Characteristics**

| Parameter | 10GBASE-SP1-Dx<br>10/2.5GBASE-SP1-Dx | Unit |
|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | GBd |
| Central channel frequencies | see Table 2 L-band 1 | THz |
| Maximum spectral excursion | ± 12.5 | GHz |
| Side-mode suppression ratio (SMSR) (min) | 35 | dB |
| Average launch power (max) | 2 | dBm |
| Average launch power (min) | -3 | dBm |
| Average launch power of OFF transmitter (max) | -39 | dBm |
| Extinction ratio (min) | 8.2 | dB |
| $RIN_{15}OMA$ (max) | -120 | dB/Hz |
| Transmitter and dispersion penalty (TDP)<br>@ 0 to 1000 ps/nm residual CD | 0* | dB |
| Optical return loss tolerance (max) | 15 | dB |
| Transmitter reflectance (max) | -10 | dB |
| Transmitter eye mask definition<br>{X1, X2, X3, Y1, Y2, Y3} | {0.25, 0.4, 0.45, 0.25, 0.28, 0.4} | UI |
| * A negative chirp transmitter is assumed, which results in a negative dispersion penalty in the positive dispersion region. | | |

NOTE: With the exception of speeds and frequencies, the values in Table 4 are work in progress.

**Table 5 - OLT Receive Characteristics**

| Parameter | 10GBASE-SP1-Dx | 10/2.5GBASE-SP1-Dx | Unit |
|---|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | 2.578125 ± 100 ppm | GBd |
| Channel frequency range | 191.990 to 193.510 | | THz |
| Bit error ratio (max) | $10^{-3}$ | | |
| Average receive power (max) | -6 | -6 | dBm |
| Damage Threshold | -5 | -5 | dBm |
| Receiver sensitivity (max) | -28 | -30 | dBm |
| Receiver reflectance (max) | -12 | -12 | dB |
| Signal detect threshold (min) | -45 | -45 | dBm |
| Stressed receiver sensitivity (max) | -27 | -29.5 | dBm |
| Minimum received OSNR | | | |

NOTE: With the exception of speeds and frequencies, the values in Table 5 are work in progress.

## 1.7. PMD to MDI Optical Specifications for ONU PMDs

**Table 6 - ONU Transmit Characteristics**

| Parameter | 10GBASE-SP1-Ux+ | 10/2.5GBASE-SP1-Ux+ | Unit |
|---|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | 2.578125 ± 100 ppm | GBd |
| Central channel frequencies | see Table 2 C-band 1 | | THz |
| Maximum spectral excursion | ± 10 | | GHz |
| Side-mode suppression ratio (SMSR) (min)* | 38 | 38 | dB |
| Average launch power (max) | see Figure 3 | see Figure 4 | dBm |
| Average launch power (min) | see Figure 3 | see Figure 4 | dBm |
| Launch power – extinction ratio | | | |
| Transmitter and dispersion penalty (TDP)<br>@ -450 ps/nm residual CD<br>@ +450 ps/nm residual CD<br>@ +900 ps/nm residual CD | <br>1<br>1<br>N/A | <br>0.5<br>0.5<br>0.5 | dB |
| Average launch power of OFF transmitter (max) | -45 | -45 | dBm |
| Extinction ratio (min) | see Figure 3 | see Figure 4 | dB |
| $RIN_{15}OMA$ (max) | -128 | -128 | dB/Hz |
| Optical return loss tolerance (max) | 15 | 15 | dB |
| Transmitter reflectance (max) | -10 | -10 | dB |
| Transmitter eye mask definition<br>{X1, X2, X3, Y1, Y2, Y3} | {0.25, 0.4, 0.45, 0.25, 0.28, 0.4} | | UI |
| Turn-on time (max) | 128 | | ns |
| Turn-off time (max) | 128 | | ns |

* It is assumed the SMSR is measured with only the DC laser bias (no data modulation).
+ The specification is on a per-channel basis, an ONU PMD may support multiple channels.

NOTE: With the exception of speeds and frequencies, the values in Table 6 are work in progress.

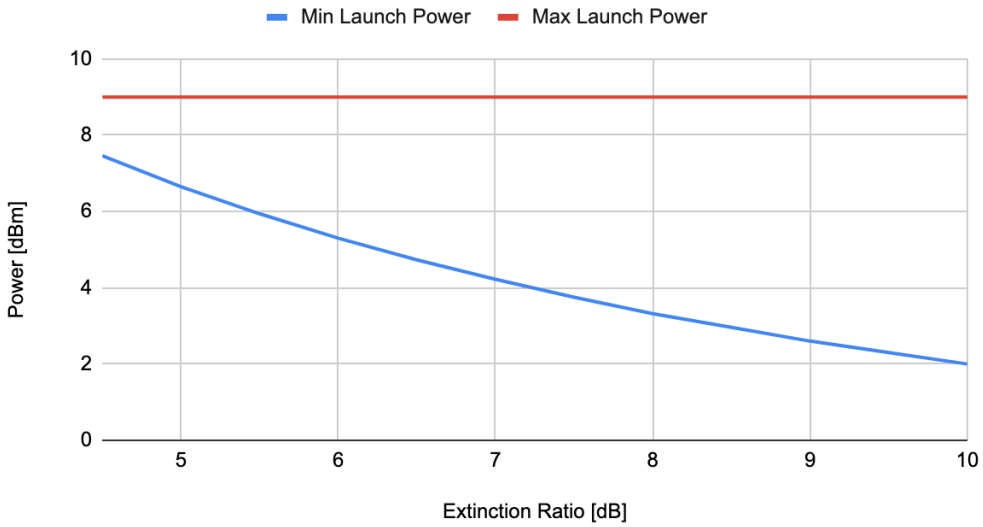


**Figure 3 - Acceptable ONU Launch Power at 10Gb/s**

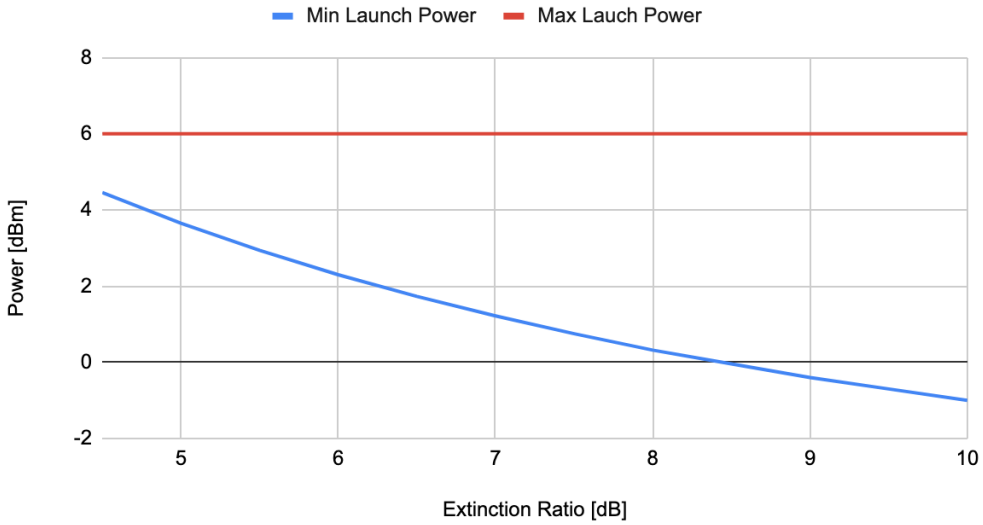


**Figure 4 - Acceptable ONU Launch Power at 2.5Gb/s**

NOTE: Both Figure 3 and Figure 4 need to be replaced by formulas.

**Table 7 - ONU Receive Characteristics**

| Parameter | 10GBASE-SP1-Ux+<br>10/2.5GBASE-SP1-Ux+ | Unit |
|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | GBd |
| Channel frequency range | 187.600 to 189.092 | THz |
| Bit error ratio (max) | $10^{-3}$ | |
| Average receive power (max) | -8 | dBm |
| Damage Threshold | -2 | dBm |
| Receiver sensitivity (max) | -29 | dBm |
| Receiver reflectance (max) | -12 | dB |
| Signal detect threshold (min) | -44 | dBm |
| Stressed receiver sensitivity (max) | -29 | dBm |
| + The specification is on a per-channel basis, an ONU PMD may support multiple channels. | | |

NOTE: With the exception of speeds and frequencies, the values in Table 7 are work in progress.

## 1.8. Black Link Specification

**Table 8 - Optical Path OLT to ONU, 10Gb/s**

| Parameter | OLT to ONU, 10Gb/s | Unit |
|---|---|---|
| Maximum ripple | | dB |
| Maximum (residual) chromatic dispersion | | ps/nm |
| Minimum (residual) chromatic dispersion | | ps/nm |
| Minimum optical return loss | | dB |
| Maximum discrete reflectance | | dB |
| Maximum differential group delay | | ps |
| Maximum inter-channel crosstalk | | dB |
| Maximum interferometric crosstalk | | dB |
| Maximum optical path OSNR penalty | | dB |
| Maximum link loss | | |

**Table 9 - Optical Path ONU to OLT, 10Gb/s**

| Parameter | ONU to OLT, 10Gb/s | Unit |
|---|---|---|
| Maximum ripple | | dB |
| Maximum (residual) chromatic dispersion | | ps/nm |
| Minimum (residual) chromatic dispersion | | ps/nm |
| Minimum optical return loss | | dB |
| Maximum discrete reflectance | | dB |
| Maximum differential group delay | | ps |
| Maximum inter-channel crosstalk | | dB |
| Maximum interferometric crosstalk | | dB |
| Maximum optical path OSNR penalty | | dB |
| Maximum link loss | | |

**Table 10 - Optical Path ONU to OLT, 2.5Gb/s**

| Parameter | ONU to OLT, 2.5Gb/s | Unit |
|---|---|---|
| Maximum ripple | | dB |
| Maximum (residual) chromatic dispersion | | ps/nm |
| Minimum (residual) chromatic dispersion | | ps/nm |
| Minimum optical return loss | | dB |
| Maximum discrete reflectance | | dB |
| Maximum differential group delay | | ps |
| Maximum inter-channel crosstalk | | dB |
| Maximum interferometric crosstalk | | dB |
| Maximum optical path OSNR penalty | | dB |
| Maximum link loss | | |

# Annex 1 (Informative)

Figure 5 shows an example of Super-PON black link implementation, able to satisfy the Super-PON objectives.

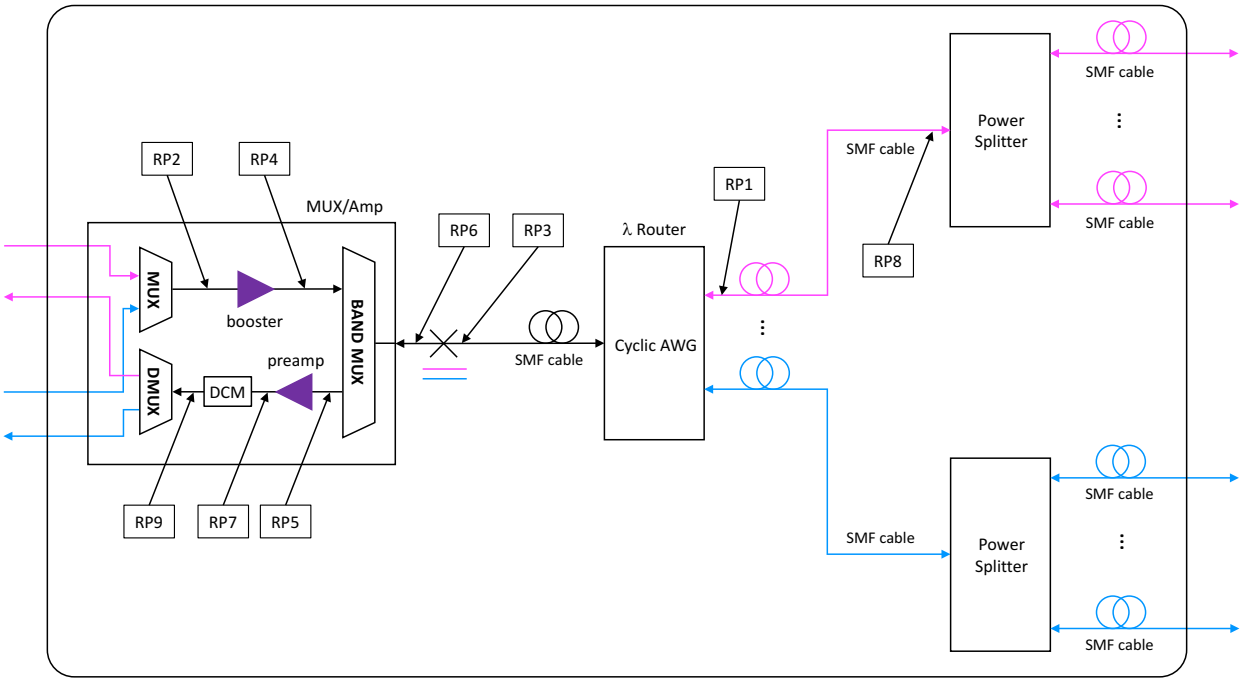


**Figure 5 - Example of Black Link Implementation**

Reference points RP4, RP4, RP6, and RP8 refer to the downstream channel, while reference points RP1, RP3, RP5, RP7, and RP9 refer to the upstream channel.