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Consideration on US/DS WDM filter for ONU

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Introduction

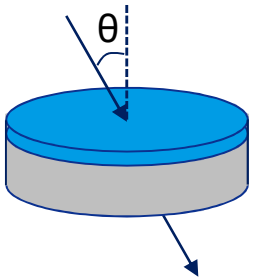
- Wavelength gap between downstream and upstream is one of the important parameter to decide wavelength plan.
- Several contributions are presented in the Task Force. “johnson_3ca_1a_1116” shows us a good direction for required US/DS gap from simple model bases. We need additional consideration to multi layer filter characteristics.
- We show some 45deg WDM filter characteristics as examples.

Filter wavelength shift against angle of incidence

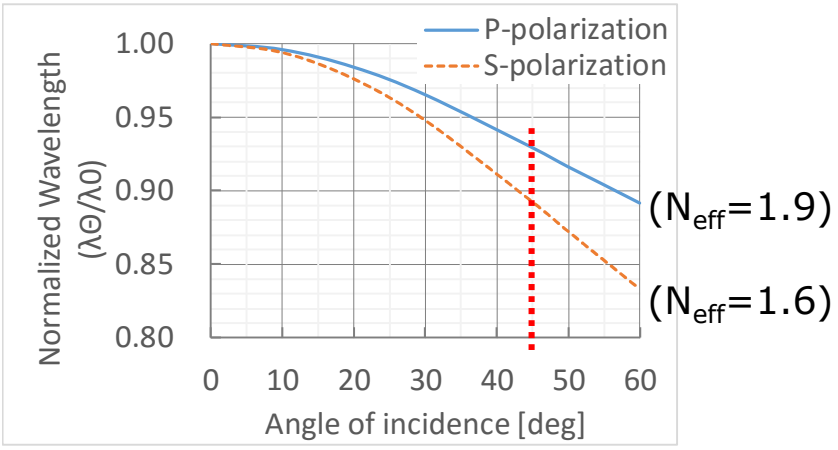
- The wavelength shift of an interference filter as a function of incident angle is given by following equation as described in "johnson_3ca_1a_1116".

$$\lambda(\theta) = \lambda(0)\sqrt{(1-\sin^2\theta/N^2_{eff})}$$

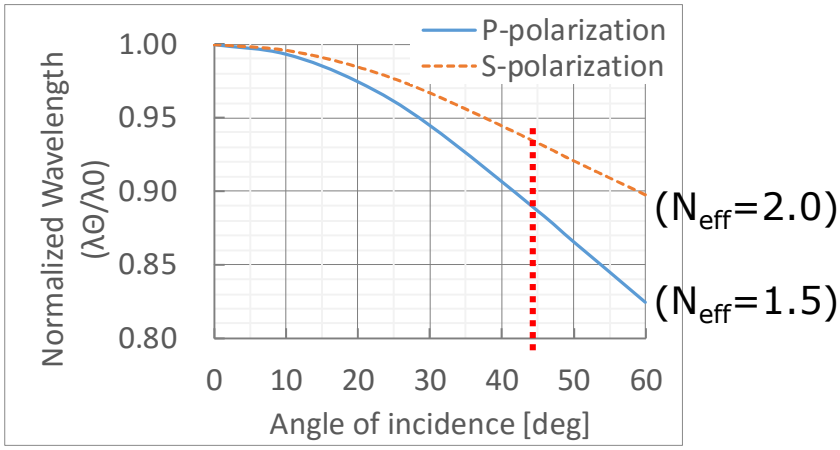
Neff: Effective reflective index



- The N_{eff} depends on filter design such as filter material, filter layer structure, filter spectrum shaping and polarization mode. Wavelength shift example is shown in below.



Short Wavelength Pass Filter

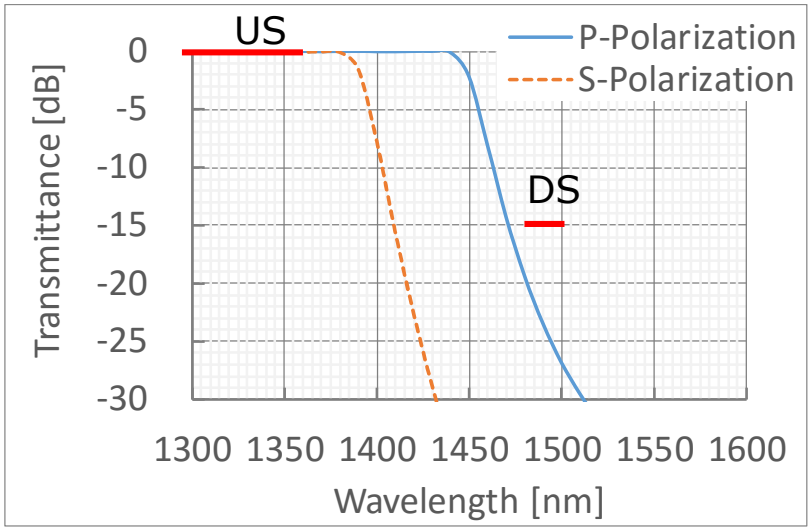


Long Wavelength Pass Filter

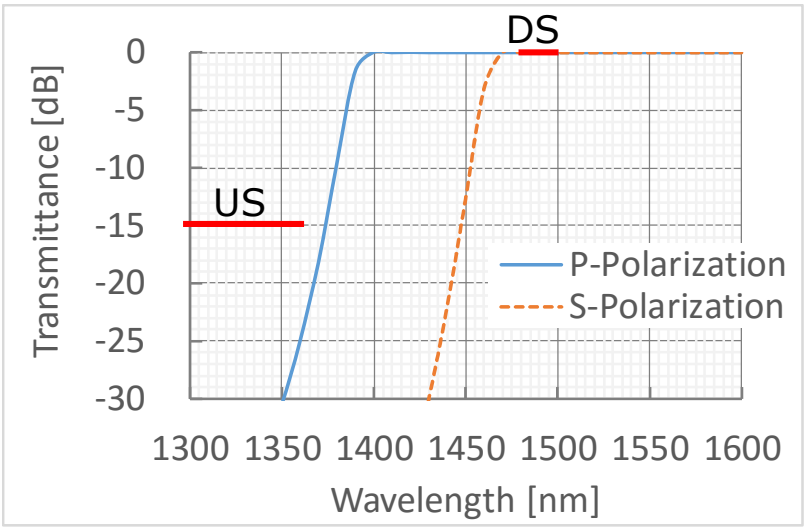
US/DS Filter characteristics used in GE-PON Bi-D

- Familiar GE-PON Bi-D US/DS Filter wavelength characteristic examples are shown here.

US/DS filter for GE-PON ONU (Short Wavelength Pass Filter)



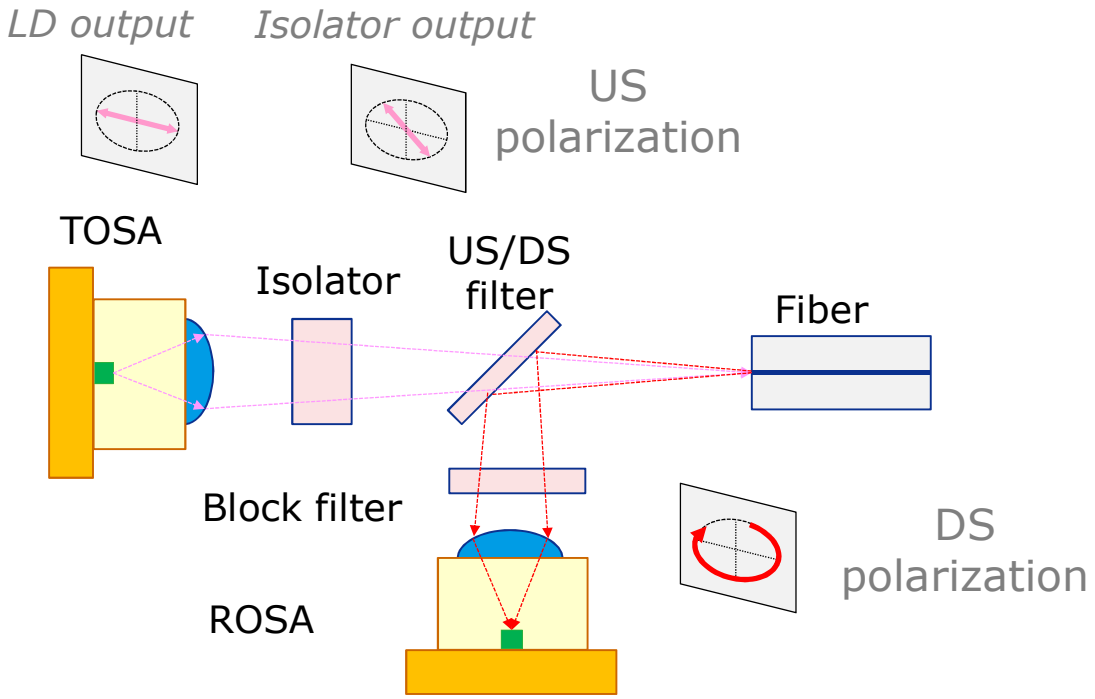
US/DS filter for GE-PON OLT (Long Wavelength Pass Filter)

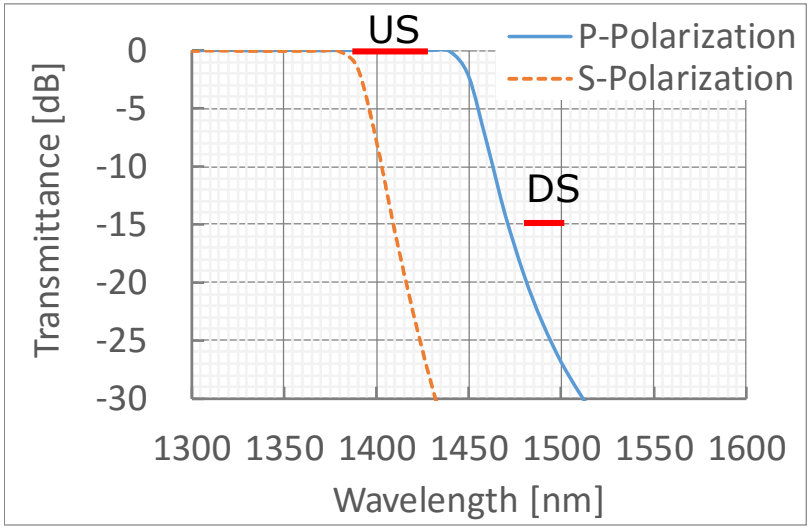


How do we narrow down the US/DS Gap using this filter?

Bi-D for narrow wavelength gap

- Choose one polarization for Transmitter
  - ✓ The technique is well known and used in 1270±10 /1330±10 CPRI Bi-D transceiver.
- Requirement for 45deg US/DS filter for ONU
  - ✓ Tx: Need to transfer P polarization because LD output is linearly polarized.
    More practical design, we can use 45degree rotated linear polarized light.
    (Filter characteristics will be somewhere between S-polarization and P-polarization)
  - ✓ Rx: Need to reflect S-polarization and P-polarization

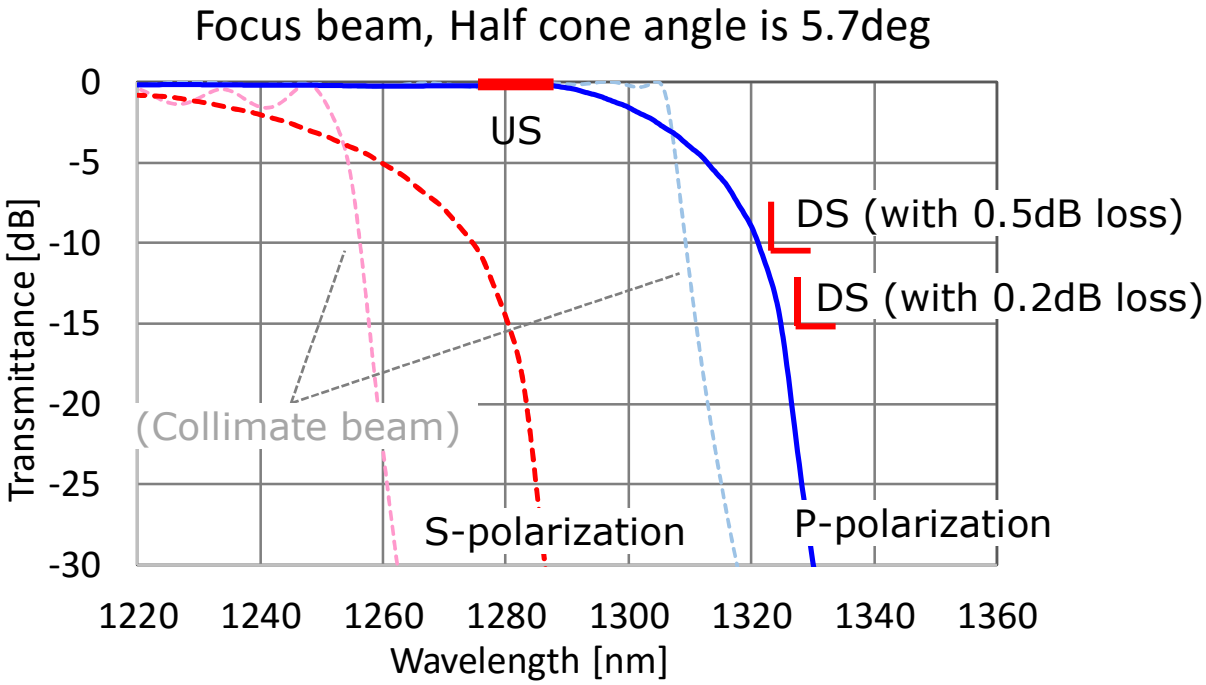




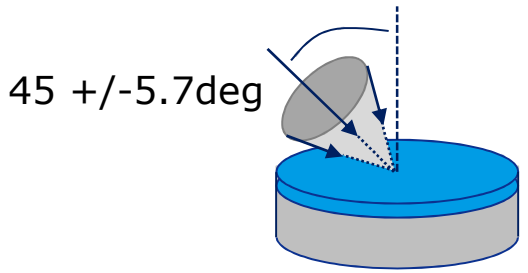
US/DS Filter characteristic example in O-band

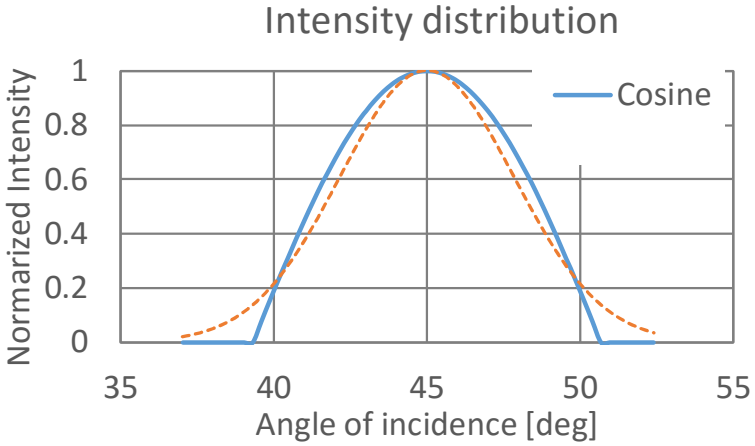
- Short wavelength pass filter responses example in O-band is shown bottom figure, in the case of focus beam with 5.7deg half-cone.
  - ✓ 35nm gap with 0.5dB excess loss
  - ✓ 40nm gap with 0.2dB excess loss

WDM filter for ONU
(Short Wavelength Pass Filter)



Simulation conditions





(Note) This filter wavelength is not tuned to current wavelength plans, for introducing filter characteristics purpose only.

O-band US/DS filter characteristics summary For focus beam coupling Bi-D

- Transmittance and Rx excess loss of US/DS filters in O-band is summarized below. This table is based on 3 filter vender's simulation result and not including margin.

	US/DS Gap		
	40nm	50nm	60nm
Transmittance [dB]	<-10	<-16	<-26
Rx excess loss [dB]	<0.5	<0.1	0.0

Maximum value from 3 venders are used

Conditions for the estimation
- ✓ *Assume 45deg rotated Polarization for Tx*
- ✓ *Assume 45deg focus beam with 5.7deg half cone angle*
- ✓ *Intensity distribution is Gaussian for Tx and Rx*
- ✓ *Assume 0.2dB Tx excess insertion loss*

- Taking 5nm guard band into account for filter manufacturing and filter assembly tolerance, based on "johnson_3ca_1a_1116" , we show following values as a guide line.
  - ✓ >45nm US/DS gap with <0.5dB excess filter loss for focus beam coupling ONU
  - ✓ >50nm US/DS gap with <0.2dB excess filter loss for focus beam coupling ONU

Trade off between TDP and filter loss

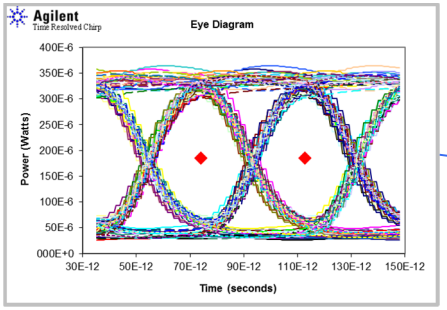
- Filter excess loss for focus beam coupling Bi-D, <u>with margin</u>

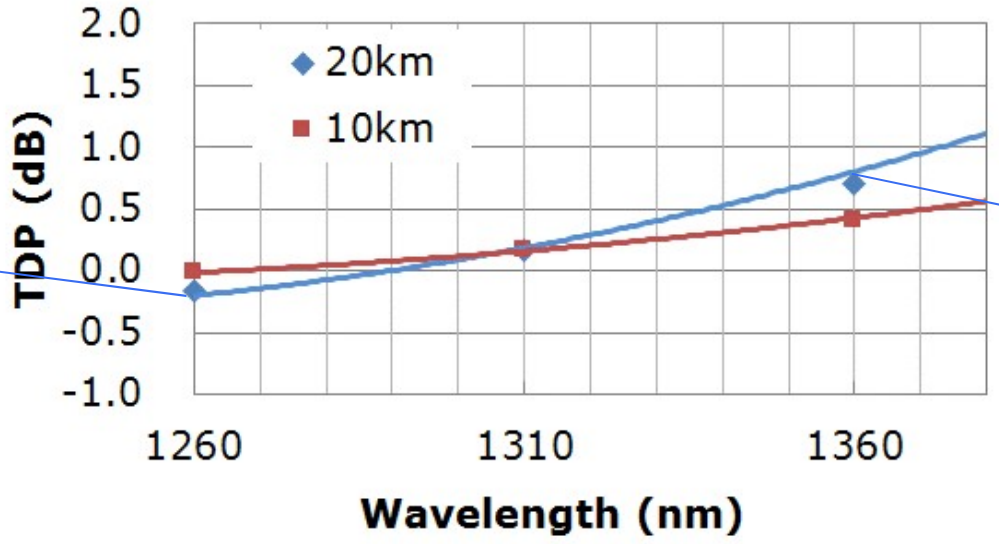
Assume US0 on 1290nm

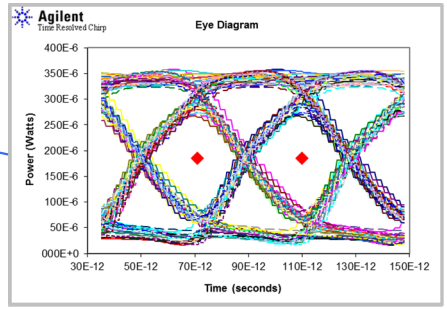
	Item	45ns Gap (1335nm)	50nm Gap (1340nm)	60nm Gap (1350nm)	70nm Gap (1360nm)
DS	Filter excess loss to Rx [dB]	<0.5	<0.2	0	0
	Dispersion penalty increase [dB]	0 (reference)	0.1	0.2	0.3
US	Filter excess loss to Tx [dB]	<0.2	<0.1	0	0

- Trade off between EML Tx TDP ("umeda_3ca_1_0316") should be considered

Simulated TDP of EML transmitter (at SMF D_0=1310nm)







Summary

- Filter characteristics based on actual filter design are shown
- We estimate required US/DS Gap based on above.
- For focus beam ONU Bi-D
  - ✓ 40nm gap is feasible, >45nm would be preferred
  - ✓ 60nm gap offer enough margin, but need to consider other trade off such as TDP.

Thank you