	Qualification Report **GR-468**	Customer:	Subject: **OPM Telcordia GR-468 Qualification**
		Product: **Fiber Optic Power Monitors**	Date **20-Nov-2014**
		Responsible: **Luis Fernandes**	Department/Function: **Femtosecond Group / Senior Scientist**

1. **General:**
   This report details the test procedures and results obtained in the process of qualification of **Fiber Optic Power Monitors [1]** for C band applications **(OPM-11-1550-X)** under Telcordia GR-468-CORE [2] requirements. Procedures described in Telcordia GR-326-CORE [3], Telcordia GR-1221-CORE [4], and MIL-STD-883E [5] were also used were appropriate.
   The test results demonstrated that the OPM devices meet the criteria set forth in GR-468 [2] for the reliability of *Optoelectronic Devices Used in Telecommunications Equipment*. The devices meet or exceed the specifications [1] before and after all the stress condition tested in the study.

2. **Target specifications:**
   All OPM devices tested in this report passed the criteria specified in the test conditions [2] and in the specifications datasheet [1]. The specification targets and final results are shown in Table 6.

3. **Target specifications:**
   The goal of the tests presented in this report was to demonstrate that all the specifications described for the optical power monitors maintain the desired tolerances after subjected to the conditions defined in Telcordia GR-468 [2] or the conditions defined in the OPM datasheet [1] itself, whichever is more restrictive.
   The Operation storage temperature range is from -40 °C to 85 °C and the operation temperature range is from -5 °C to 75 °C. Specifications are provided at room temperature (23 °C) unless otherwise noted, however, the devices have been found to work up to 85 °C. The power monitors are optimized to work from 1530 nm to 1565 nm; however, the devices have also been shown to work from 1510 nm to 1610 nm. Specifications are provided at 1550 nm unless otherwise noted.

Table 1: OPM Specifications [1] targets.

Specifications	Targets
Wavelength dependent loss (WDL)	< 0.2 dB
Temperature dependent loss (TDL)	< 0.3 dB
Polarization dependent loss (PDL)	< 0.1 dB
Wavelength dependent response (WDR)	< 0.25 dB
Temperature dependent response (TDR)	< 0.2 dB
Polarization dependent response (PDR) SM version	< 0.2 dB
Directionality	> 20 dB
Responsivity Aging	< 0.5 dB
Polarization extinction ratio (ER) PM version	> 20 dB

4. **Definitions:**

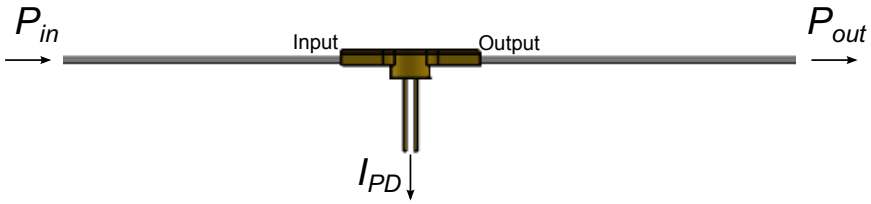


Figure 1: OPM scheme with labeled input power (P_{in}), output power (P_{out}), and output photodiode current (I_{PD}).

The quantities used to express the OPM specification in Table 1 are defined in Equations 1 to 8. Equation 1 defines the value of the responsivity, which is typically presented in mA/W units, and is the ratio between the current in the photodiode (I_{PD}) and the output power (P_{out}).

$$R = \frac{I_{PD}}{P_{out}} \quad (1)$$

The aging is defined in Equation 2 by the total variation of responsivity, as a decibel ratio, over the full test period.

$$Aging = 10log_{10}\frac{R_{initial}}{R_{final}} \quad (2)$$

Equations 3 to 8 define the polarization, temperature, and wavelength dependence of the quantities: insertion loss (equivalent to output power ratio) and responsivity. All are defined as the decibel ratio between the maximum and minimum values of the physical quantity over the range of a specific variable.

$$PDL = 10log_{10}\frac{P_{out}(\theta)_{max}}{P_{out}(\theta)_{min}} \quad (3) \qquad PDR = 10log_{10}\frac{R(\theta)_{max}}{R(\theta)_{min}} \quad (4)$$

$$TDL = 10log_{10}\frac{P_{out}(T)_{max}}{P_{out}(T)_{min}} \quad (5) \qquad TDR = 10log_{10}\frac{R(T)_{max}}{R(T)_{min}} \quad (6)$$

$$WDL = 10log_{10}\frac{P_{out}(\lambda)_{max}}{P_{out}(\lambda)_{min}} \quad (7) \qquad WDR = 10log_{10}\frac{R(\lambda)_{max}}{R(\lambda)_{min}} \quad (8)$$

The directionality is defined as the decibel ratio between the responsivity of the device (Equation 1) and the reversed responsivity, measured with light launched into the output side of the OPM. The polarization extinction ratio is measured with polarized light launched aligned with the slow axis of

a polarization maintaining (PM) fiber and is defined by the decibel ratio between the output power measured in the slow axis, and the output power measured in the fast axis of the same fiber.

5. Test conditions:

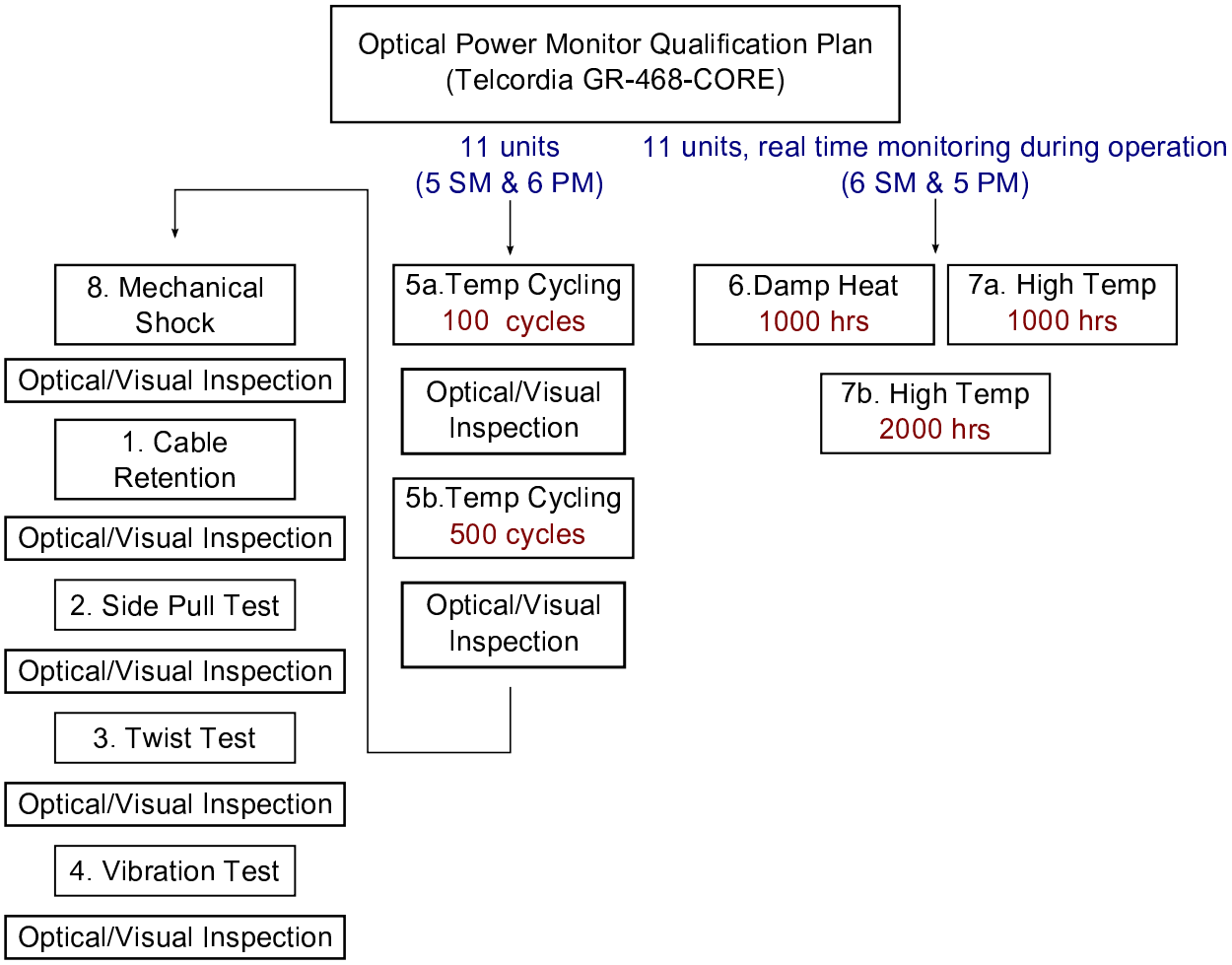


Figure 2: Qualification plan.

The qualification procedure was divided in two branches as described in Figure 2. A total of twenty two devices were used for this qualification, with a set of eleven devices used for powered operation tests, with real-time monitoring, while another set of eleven devices was used for unpowered thermal and mechanical stress tests. The test conditions shown in Figure 2 are defined in Table 2 with the reference to the appropriate support documentation where these tests are described in detail.

Table 2: Mechanical and environmental test condition. Tables 4-3, 4-4, and 4-5 in GR-465 [2].

Test	Condition	Reference
1. Cable Retention	0.5 kg, 1 minute	GR-468-CORE, 3.3.1.3.3 [2]
2. Side Pull	0.25 kg, 90 degree, 22 cm to 28 cm from device housing	GR-468-CORE, 3.3.1.3.2 [2]
3. Twist	0.5 kg, 10 cycles, 3 cm from device housing or strain relief	GR-468-CORE, 3.3.1.3.1 [2]
4. Vibration	20 G, 20 Hz to 2000 Hz to 20 Hz, 4 min/cycle, 4 cycles/axis	GR-468-CORE, 3.3.1.1.2 [2]
5a. Temp Cycling 100 cycles*	-40 ℃ to +85 ℃, 100 cycles	GR-468-CORE, 3.3.2.2 [2] and MIL-STD-883E, Method 1010.7 [5]
5b. Temp Cycling 500 cycles*	-40 ℃ to +85 ℃, 500 cycles	GR-468-CORE, 3.3.2.2 [2] and MIL-STD-883E, Method 1010.7 [5]
6. Damp Heat Operation	85 ℃ / 85% RH, 1000 hours	GR-468-CORE, 3.3.2.3 [2]
7a. High Temperature Operation	85 ℃ 1000 hours	GR-468-CORE, 3.3.3.1 [2]
7b. High Temperature Operation	85 ℃ 2000 hours	GR-468-CORE, 3.3.3.1 [2]
8. Mechanical Shock	Condition A (500 g, 1.0 ms), 5 times/direction	GR-468-CORE, 3.3.1.1 [2] and GR-1221-CORE, 6.2.1 [4]

*The conditions detailed in MIL-STD-883E, Method 1010.7 [5] were used, which are more restrictive and more aggressive than the conditions detailed in GR-468-CORE, 3.3.2.2 [2]. The monitor devices were kept at the extreme temperatures (-40 °C and 85 °C) for at least 10 minutes and the transition between each extreme was less than 1 minute.

6. Powered Environmental Test Results

Following the qualification plan described in Figure 2, eleven devices (6 single mode and 5 polarization maintaining power monitors) were subjected to 1000 hours of damp heat (85 °C / 85% RH) followed by 1000 hours of high temperature environment (85 °C), all while being powered with measurements taken at regular intervals. The results of this real time monitoring are shown on Figure 3 and Figure 4.

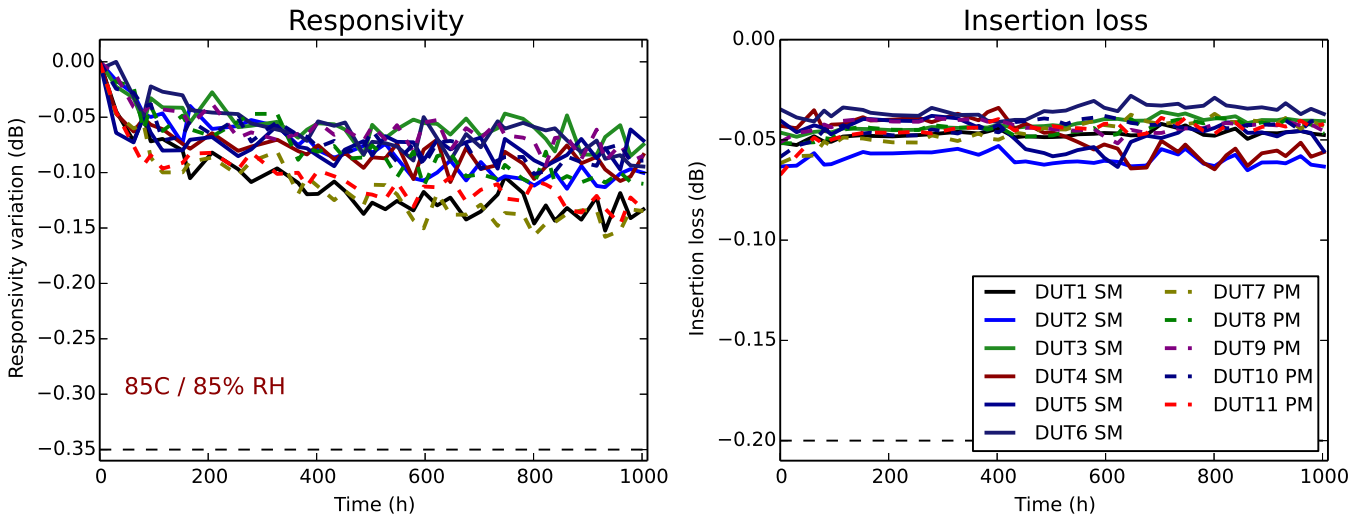
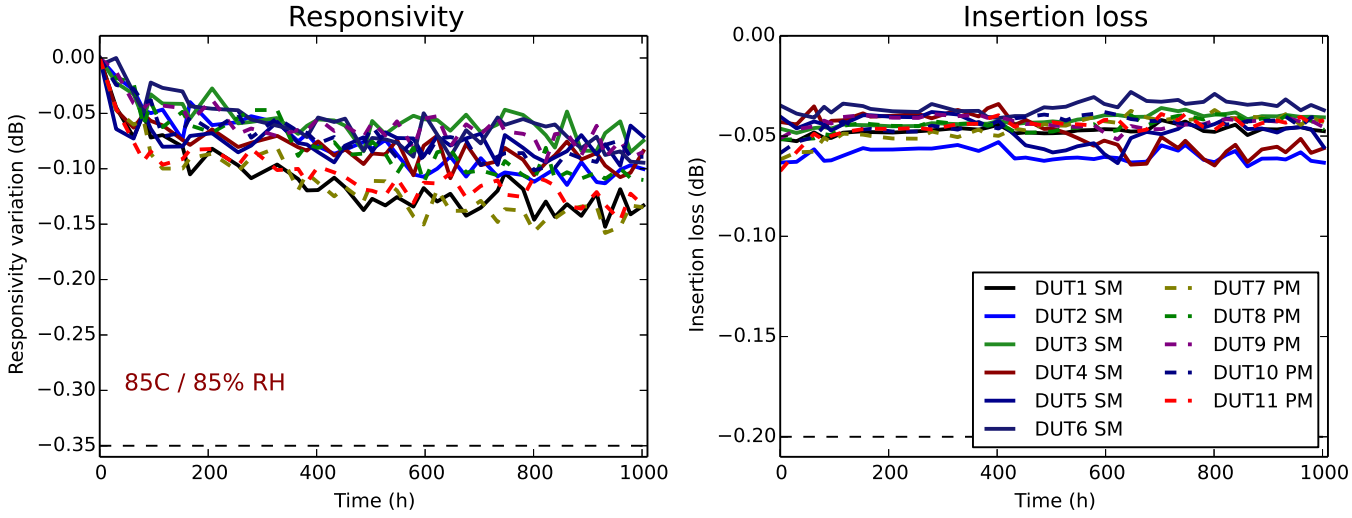


Figure 3: Damp heat operation



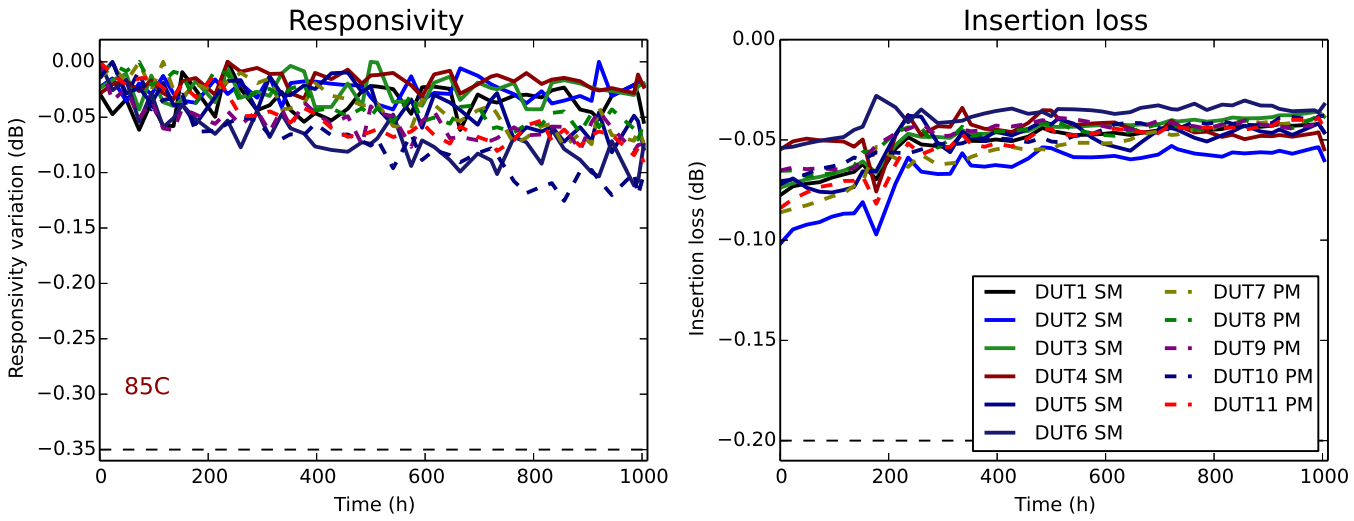


Figure 4: High temperature operation

The variation of responsivity and insertion loss as a function of temperature was measured at the end of the test operation test period and shown in Figure 5. The numeric values for each of the devices under test (DUT) are summarized in Table 3.

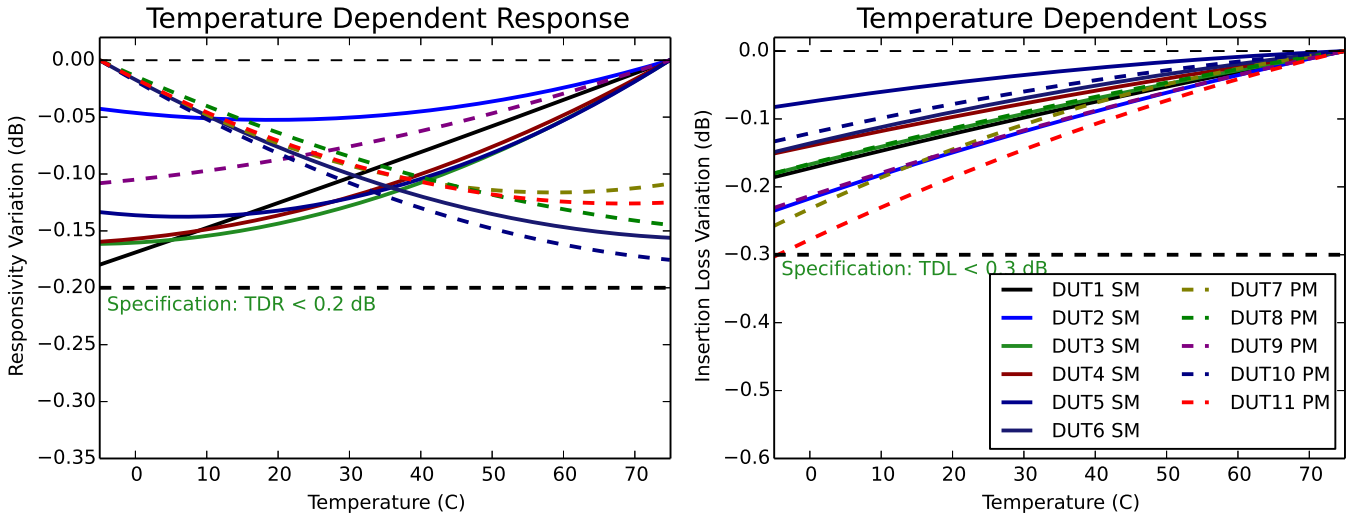


Figure 5: Responsivity and transmission as a function of temperature after the environmental test

Table 3: Temperature dependence (-5 °C to 75 °C) @ 1550 nm

Device	Final TDR (dB)	Final TDL (dB)
DTU1 SM	0.18	0.19
DTU2 SM	0.11	0.14
DTU3 SM	0.16	0.18
DTU4 SM	0.16	0.15
DTU5 SM	0.14	0.08
DTU6 SM	0.16	0.15
Worst	**0.18**	**0.19**
Target	**< 0.20**	**< 0.30**
DTU7 PM	0.12	0.23
DTU8 PM	0.14	0.18
DTU9 PM	0.11	0.23
DTU10 PM	0.19	0.16
DTU11 PM	0.13	0.30
Worst	**0.19**	**0.28**
Target	**< 0.20**	**< 0.30**

A summary of all the tests performed at the end of the test period is shown in Table 4. The specification tolerances [1] for the devices are shown after the accelerated aging provided by the damp heat and high temperature environments.

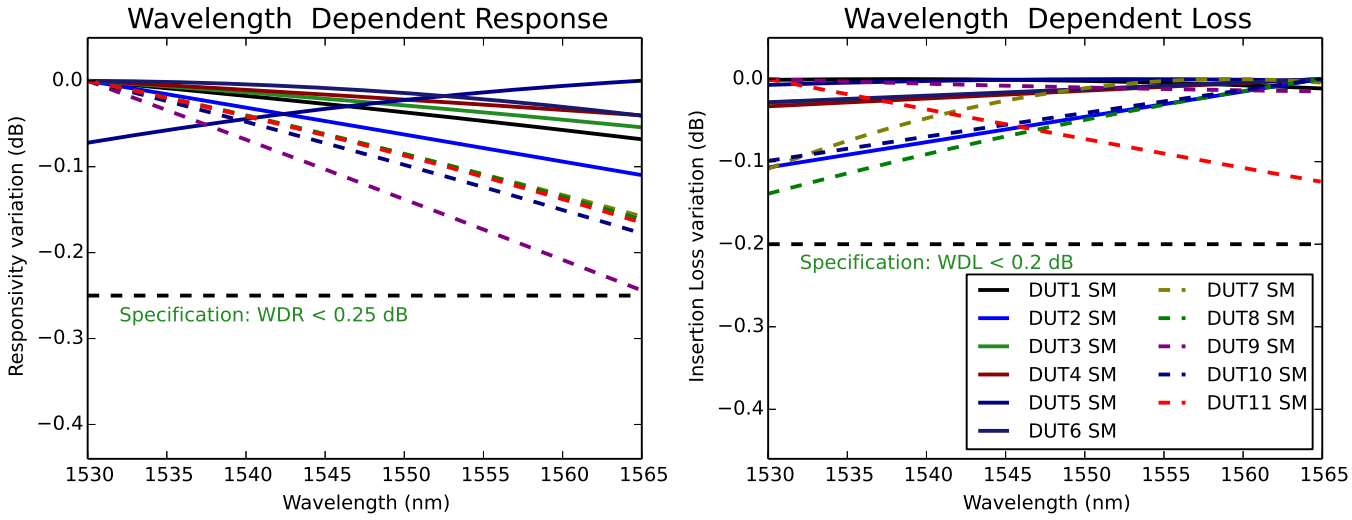


Figure 6: Wavelength dependence of responsivity and insertion loss.

Table 4: Summary of environmental test results @ RT and @ 1550 nm

Device	Aging (dB)	PDR (dB)	PDL (dB)	WDR (dB)	WDL (dB)	Directivity (dB)
DUT1 SM	0.21	0.17	0.02	0.06	0.01	23
DUT2 SM	0.08	0.19	0.02	0.11	0.11	27
DUT3 SM	0.33	0.18	0.03	0.05	0.03	21
DUT4 SM	0.28	0.20	0.03	0.04	0.03	27
DUT5 SM	0.33	0.11	0.04	0.07	0.01	25
DUT6 SM	0.19	0.20	0.02	0.04	0.03	23
Worst	**0.33**	**0.20**	**0.04**	**0.11**	**0.11**	**21**
Target	**< 0.50**	**< 0.20**	**< 0.10**	**< 0.25**	**< 0.20**	**> 20**

	Aging (dB)	ER (dB)	PDL (dB)	WDR (dB)	WDL (dB)	Directivity
DUT7 PM	0.01	26	0.03	0.16	0.11	24
DUT8 PM	0.09	30	0.01	0.16	0.14	20
DUT9 PM	0.02	23	0.01	0.24	0.01	20
DUT10 PM	0.06	26	0.02	0.18	0.10	21
DUT11 PM	0.05	25	0.01	0.16	0.12	24
Worst	**0.09**	**23**	**0.03**	**0.24**	**0.14**	**20**
Target	**< 0.50**	**> 20**	**< 0.10**	**< 0.25**	**< 0.20**	**> 20**

7. Mechanical and Thermal Stress Test results

Following the qualification plan described in Figure 2, eleven devices (five single mode and six polarization maintaining power monitors) were subjected to a set of seven unpowered stress tests. These tests are design to stimulate failure mechanisms related to displacement and weakening of the optical assembly due to various mechanical stresses as well and thermal gradients and fast temperature changes. The devices were measured originally after final assembly (Figure 7) and also after each of the tests as described in Figure 2. The results for each step are shown from Figure 8 to Figure 14.

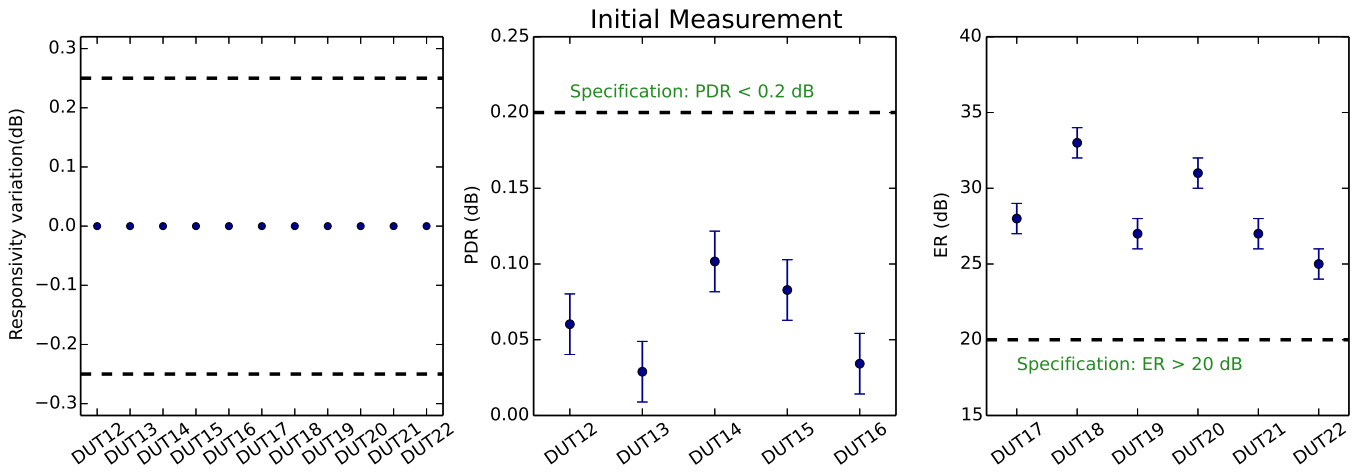


Figure 7: Initial Measurement of DUT12 to DUT22, performed after completed assembly.

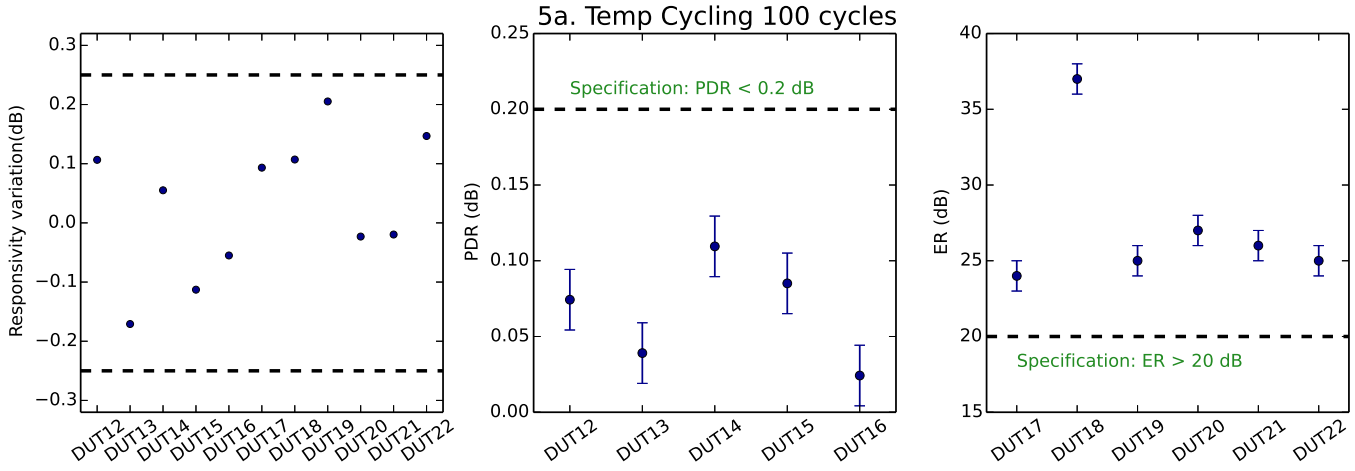


Figure 8: Measurement after 100 temperature cycles (Condition 5a).

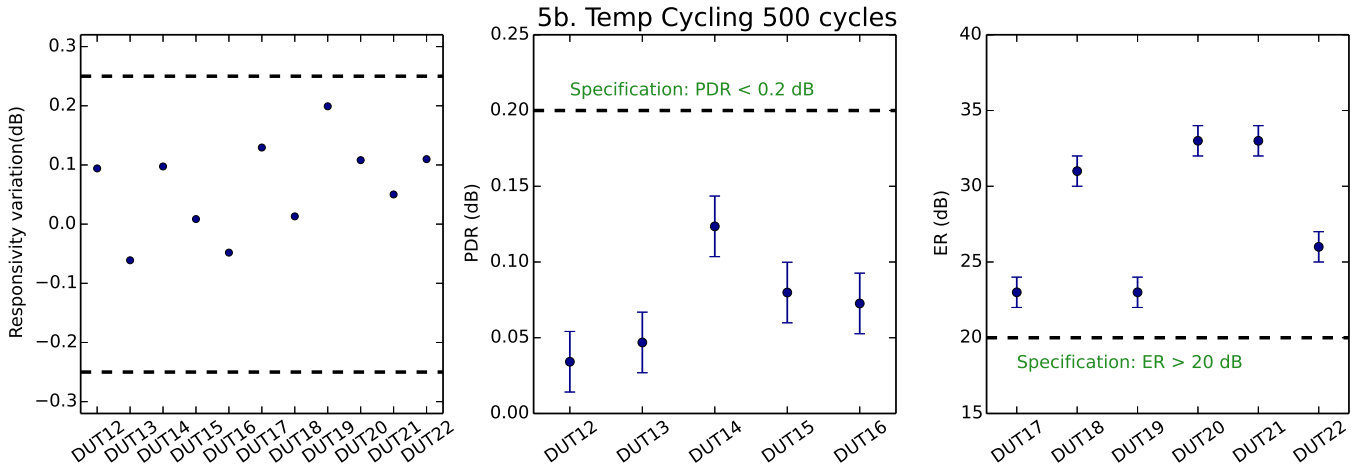


Figure 9: Measurement after 500 temperature cycles (Condition 5b).

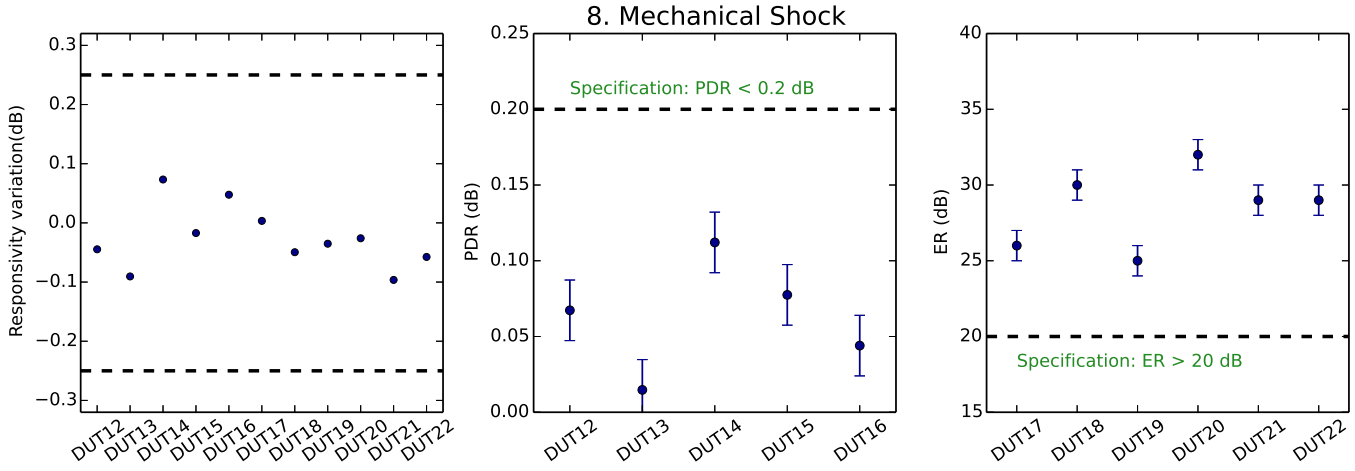


Figure 10: Measurement after Mechanical Shock test (Condition 8).

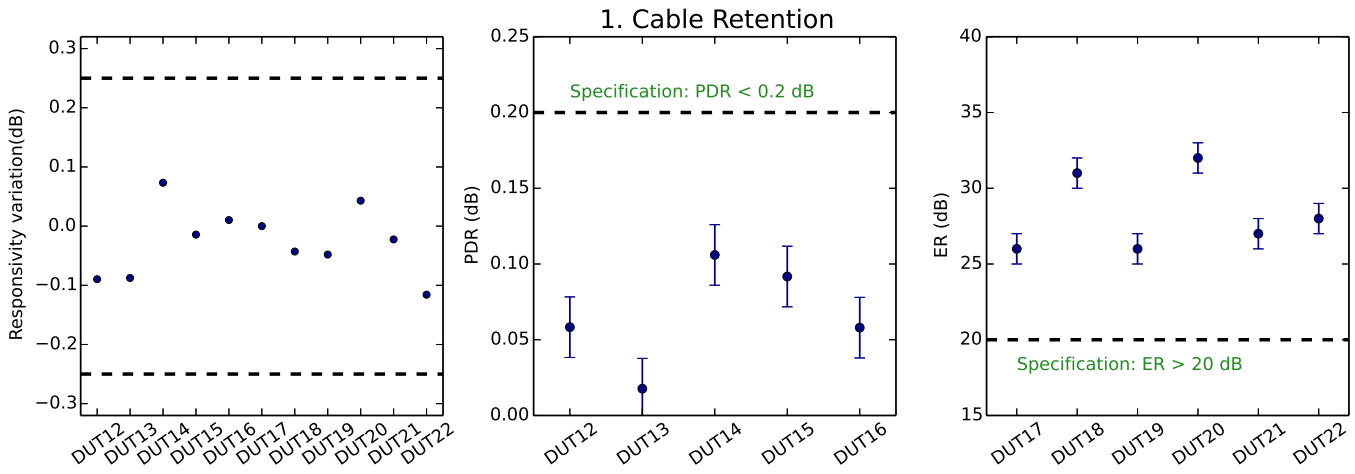


Figure 11: Measurement after Cable Retention test (Condition 1).

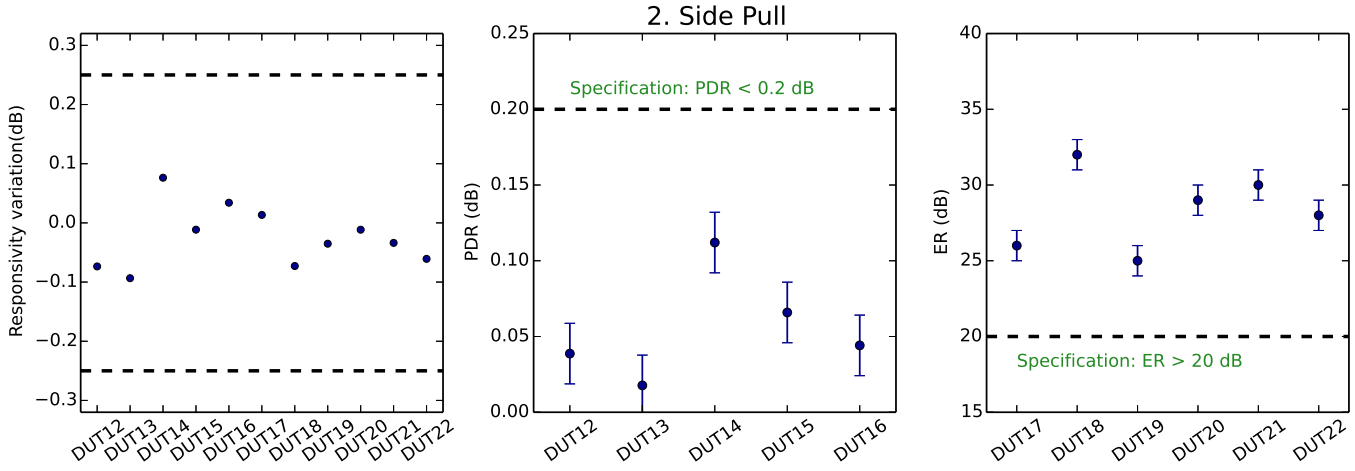


Figure 12: Measurement after Side Pull test (Condition 2).

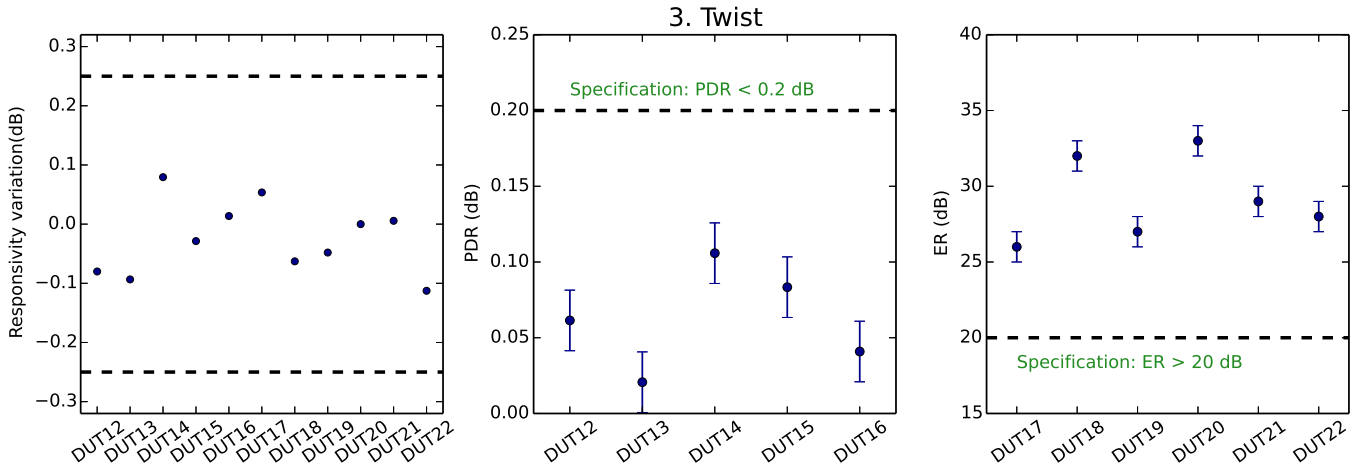


Figure 13: Measurement after Twist test (Condition 3).

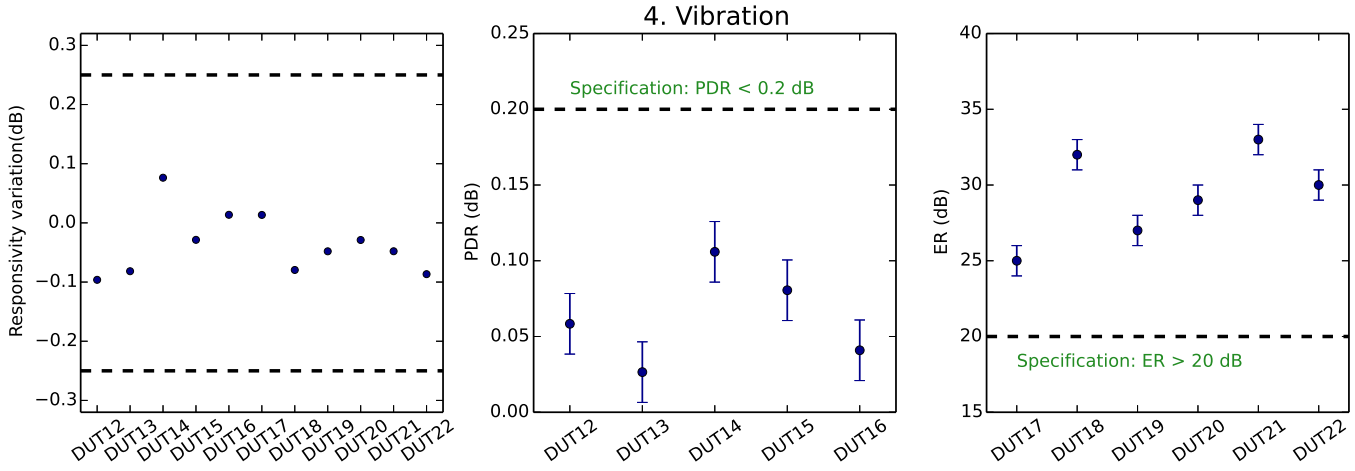


Figure 14: Measurement after Vibration test (Condition 4).

The eleven devices were found to be stable after each stress test. The final detailed measurements and its compliance with the original specifications [1] are summarized in Table 5.

Table 5: Summary of stress test results @ RT and @ 1550 nm

Device	Final Variation (dB)	PDR (dB)	PDL (dB)	WDR (dB)	Directivity (dB)
DTU12 SM	0.10	0.06	0.03	0.05	22
DTU13 SM	0.08	0.03	0.04	0.04	22
DTU14 SM	0.08	0.10	0.02	0.05	23
DTU15 SM	0.03	0.08	0.02	0.03	27
DTU16 SM	0.01	0.04	0.03	0.08	21
Worst	**0.10**	**0.10**	**0.04**	**0.08**	**21**
Target	**< 0.25**	**< 0.20**	**< 0.10**	**< 0.25**	**> 20**

	Final Variation (dB)	ER (dB)	PDL (dB)	WDR (dB)	Directivity (dB)
DTU17 PM	0.01	25	0.01	0.19	22
DTU18 PM	0.08	32	0.01	0.19	20
DTU19 PM	0.05	27	0.02	0.16	20
DTU20 PM	0.03	29	0.01	0.15	22
DTU21 PM	0.05	33	0.01	0.20	21
DTU22 PM	0.09	30	0.02	0.19	24
Worst	**0.09**	**25**	**0.02**	**0.20**	**20**
Target	**< 0.25**	**> 20**	**< 0.10**	**< 0.25**	**> 20**

8. Conclusions

All OPM devices tested in this report passed the criteria specified in the qualification conditions [2] and in the specifications datasheet [1]. Moreover the specifications were found to be reliable after the mechanical and environmental tests described above. The specification targets and final results, together with the applicable ranges, are shown in Table 6.

Table 6: OPM Specifications [1] results

Specifications	Targets	Results	Conditions
Wavelength dependent loss (WDL)	< 0.2 dB	< 0.14 dB	From 1530 nm to 1565 nm @ RT
Temperature dependent loss (TDL)	< 0.3 dB	< 0.2 SM < 0.3 PM	From -5 °C to 75 °C @ 1550 nm
Polarization dependent loss (PDL)	< 0.1 dB	< 0.04 dB	From -5 °C to 75 °C and from 1530 nm to 1565 nm
Wavelength dependent response (WDR)	< 0.25 dB	< 0.24 dB	From 1530 nm to 1565 nm @ RT
Temperature dependent response (TDR)	< 0.2 dB	< 0.19 dB	From -5 °C to 75 °C @ 1550 nm
Polarization dependent response (PDR) SM version	< 0.2 dB	< 0.2 dB	From 1530 nm to 1565 nm @ RT
Directionality	> 20 dB	> 20 dB	From 1530 nm to 1565 nm @ RT
Responsivity Aging	< 0.5 dB	< 0.35 dB	After test 7a and test 7b.
Polarization extinction ratio (ER) PM version	> 20 dB	>23 dB	From 1530 nm to 1565 nm @ RT

[1] DTS0042, Fiber Optic Power Monitors Datasheet, 2014

[2] Telcordia GR-468-CORE, Issue 2, September 2004

[3] Telcordia GR-326-CORE, Issue 3, September 1999

[4] Telcordia GR-1221-CORE, Issue 3, September 2010

[5] MIL-STD-883E, Method 1010.7