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TECHNICAL REPORT

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Fibre optic interconnecting devices and passive components – Part 02: Report of round robin test results on SC plug style fixed attenuators

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Fibre optic interconnecting devices and passive components – Part 02: Report of round robin test results on SC plug style fixed attenuators

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

Part 02: Report of round robin test results on SC plug style fixed attenuators

FOREWORD

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IEC 62627-02, which is a technical report, has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86B/2941/DTR	86B/2993/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62627 series, published under the general title *Fibre optic interconnecting devices and passive components,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

Part 02: Report of round robin test results on SC plug style fixed attenuators

1 Scope

This part of IEC 62627 reports the measurement results of two round robin test programs each carried out on SC/PC and SC/APC plug style fixed attenuators. The work was initiated at Cenelec TC 86BXA in June 2003 in order to get a clear understanding on the accuracy and repeatability of the spectral attenuation loss measurements on fixed attenuators.

Out of these results recommendations are made for attenuation tolerance values that can be used in the performance standards.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61300-3-2, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-2: Examinations and measurements – Polarization dependent loss in a single-mode fibre optic device*

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*

IEC 61300-3-7, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-7: Examinations and measurements – Wavelength dependence of attenuation and return loss of single mode components*

IEC 61754-4, *Fibre optic connector interfaces – Part 4: Type SC connector family*

IEC 61755-1, *Fibre optic connector optical interfaces – Part 1: Optical interfaces for single mode non-dispersion shifted fibres – General and guidance*

3 Background

While preparing a product specification for SC plug style fixed attenuators, members of the Cenelec TC86BXA reported unexpected large and wavelength dependent variations in the attenuation. Also poor performance was seen in the mating durability test.

At the same time, several customer complaints were reported from operators that used plug style attenuators on active transceivers.

In order to understand these issues a round robin test was organised among various test laboratories.

4 Conclusions

4.1 Attenuation measurements with reference connectors

The attenuation measurement results of the SC plug style fixed attenuators with reference connectors reported in Clause 5 show larger than expected variations for spectral attenuation, especially in the 1 310 nm window. When taking the performance criteria used to purchase these fixed attenuators being:

– attenuators with nominal attenuation value ≤ 5 dB: tolerance level of 0,5 dB.

– attenuators with nominal attenuation value > 5 dB: tolerance level of 10 % on nominal value.

Only 9 of the 18 SC/PC attenuators would pass all the 7 participating laboratories and only 12 of the 18 SC/APC attenuators would pass 5 test laboratories.

Physical phenomena like modal noise interference largely influence the repeatability of results, even when the measurements are performed with reference connectors and reference adapters.

Wideband source measurements with LED source and power meter proved high uniformity of results obscuring the unwanted effects of modal noise. All the attenuators passed the tight criteria of measurements against reference plugs when the attenuation measurements were made according to IEC 61300-3-4 with LED light source at 1 310 nm and 1 550 nm.

Following realistic performance criteria for the wavelength dependent attenuation measured with reference connectors are therefore suggested:

– attenuators with nominal attenuation value ≤ 5 dB: tolerance level of 0,75 dB.

– attenuators with nominal attenuation value > 5 dB: tolerance level of 15 % on nominal attenuation value.

4.2 Attenuation measurements with grade B connectors

In random mating conditions using connectors with attenuation grade B (as defined in IEC 61755-1), the variations in wavelength dependent attenuation becomes much larger, especially in the 1 310 nm region. Spectral loss values up to 19 dB are reported for a 15 dB attenuator. When taking the performance requirements used to purchase these fixed attenuators, the pass/fail results for random mated measurements would allow only 6 of the 18 attenuators to pass the 5 participating test laboratories.

4.3 Polarisation dependent loss

PDL measurement results also show a larger variation of values for measurements in the 1310 nm window.

4.4 Mechanical interface

The non reproducibility of the spectral attenuation measurements indicated possible mechanical interface issues. Thorough analysis of mechanical behaviour of “plug-attenuator-adapter-plug” and “transceiver-attenuator-plug” configurations was done. The relevant dimensions H_m and H_f of parameter H in the type SC connector mechanical interface standard IEC 61754-4 were checked in worst case situations. Main conclusion is that there is no room for additional tolerances in the existing interface standard for the SC connector and adapter. SC plug style attenuators should be made with fixed values for parameters H_f and H_m without any tolerance range.

The functional performance of the SC plug style attenuators can not be assured at this time. With the dimensions and tolerances in the current IEC 61754-4 mechanical interface

documents for the SC connector and adapter, it is **not possible** to make a plug style attenuator which guarantees intermateability in all applications.

Additionally, active transceivers with fixed ferrule **should never be** connected with a plug style attenuator made according to the relevant IEC 61754-4 mechanical interface.

5 Test results

5.1 Round robin test results of SC/PC plug style attenuator

5.1.1 SC/PC plug style attenuator test samples

In total 18 SC/PC plug style fixed attenuators were collected for this round robin test:

– attenuators with nominal attenuation of 15 dB (labelled 1, 2, 3, 4, 5 and 6)
– attenuators with nominal attenuation of 5 dB (labelled 7, 8, 9, 10, 11 and 12)
– 6 attenuators with nominal attenuation of 1 dB (labelled 13, 14, 15, 16, 17 and 18)

The attenuators were obtained from various suppliers. The operating principle of all devices is based on the use of attenuating fibre.

The performance grade of these attenuators was defined as:

Operating wavelength range:	1 260 nm – 1 360 nm and 1 460 nm – 1 580 nm
Attenuation tolerance:	0,5 dB for attenuators ≤ 5 dB, 10 % of nominal attenuation value for attenuators > 5 dB

5.1.2 Test method

5.1.2.1 Spectral attenuation loss (according to IEC 61300-3-7)

For the ease of the data processing the measured values were reported for the discrete wavelengths: 1 260, 1 280, 1 310, 1 330, 1 360, 1 460, 1 490, 1 520, 1 550, 1 570 and 1 580 nm. The spectral width was 2 nm. Some laboratories also reported values with a spectral width of 10 nm. Each lab performed the measurements with 2 sets of reference connectors and adapters:

– measurements with common reference connectors and adapter (same references for all the test laboratories),
– measurements with own lab reference connectors and adapter.

Uncertainty of each loss measurement at the above mentioned wavelength range was better than 0,1 dB.

5.1.2.2 Polarisation dependent loss (PDL) (according to IEC 61300-3-2, option 1)

PDL was measured at 1 310 nm and 1 550 nm, with common reference plugs. Selected measurements method was “all states method”. The accuracy of each PDL measurement was better than 0,1 dB.

5.1.3 Test laboratories involved in RRT on SC/PC plug style attenuators

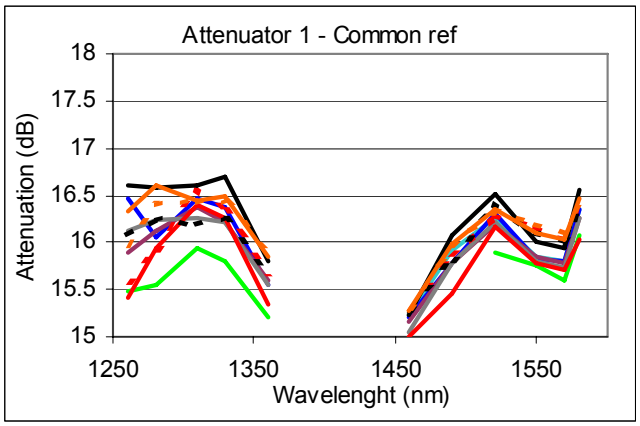
The following laboratories were involved in this round robin test (in alphabetic order):

– Adamant Kogyo Co., Ltd. (Japan)
– Diamond (Switzerland)
– Huber and Suhner (Switzerland)
– Telekomunikacja Polska (Poland)

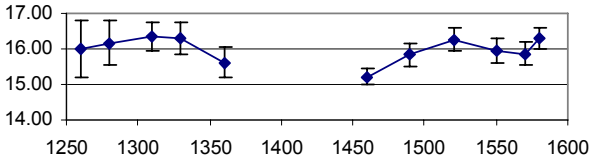
– TILab (Telecom Italia Laboratories) (Italy)
– Tyco Electronics-AMP (the Netherlands)
– Tyco Electronics-Raychem (Belgium)

5.1.4 Measurement results of SC/PC plug style attenuators

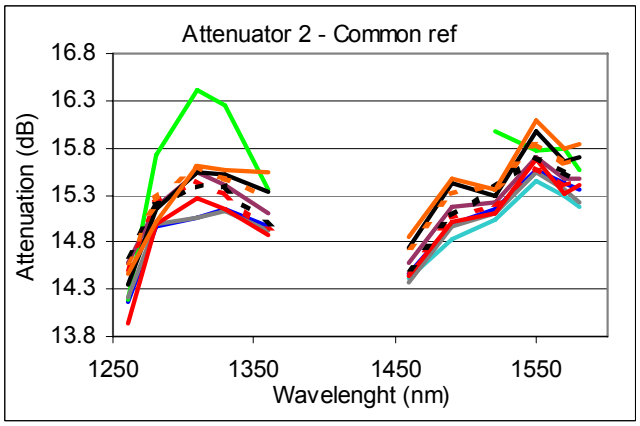
An overview of all spectral attenuation measurements per attenuator is given in Figures 1, 2 and 3. The detailed measurement results for each individual laboratory can be found in Annex A.



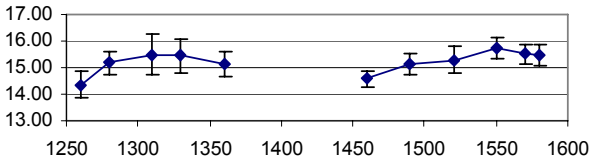
a) Attenuator 1 – Common reference



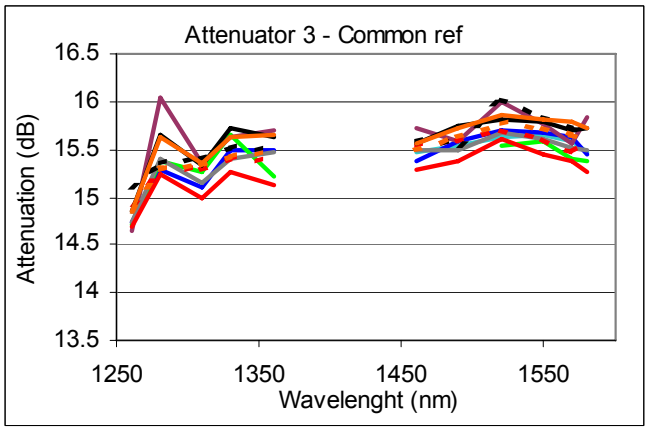
b) Average ± 2σ of attenuator 1



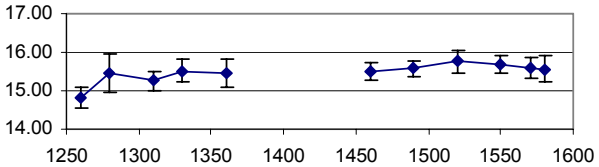
c) Attenuator 2 – Common reference



d) Average ± 2σ of attenuator 2

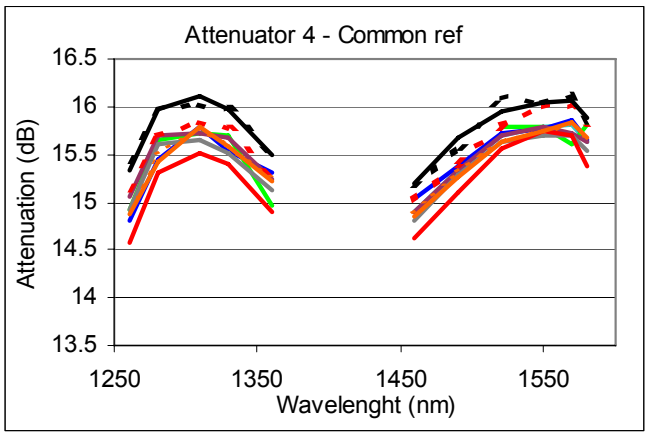


e) Attenuator 3 – Common reference

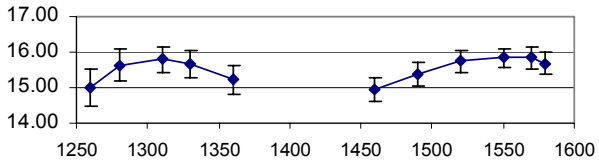


f) Average ± 2σ of attenuator 3

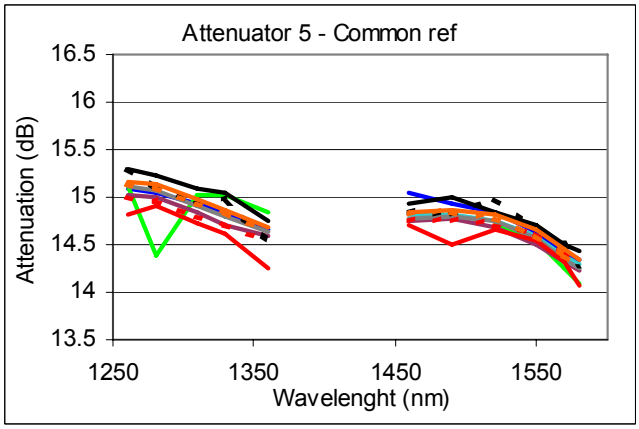
Figure 1 – 15 dB attenuators – All lab. results – Common reference



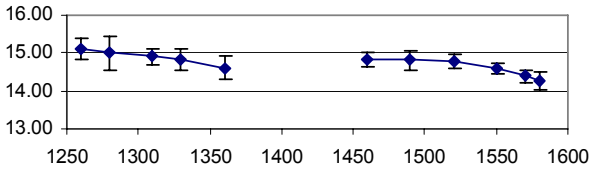
g) **Attenuator 4 – Common reference**



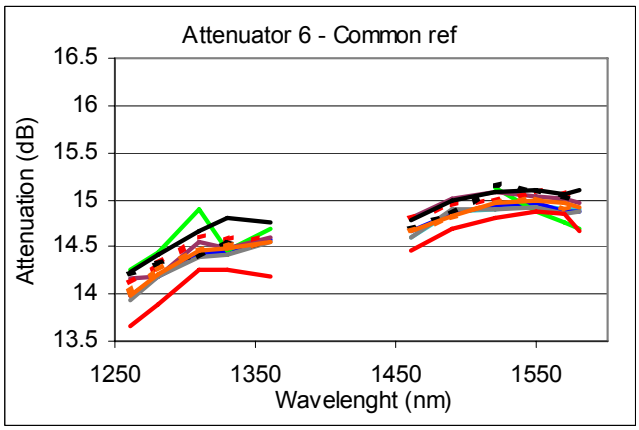
h) **Average ± 2σ of attenuator 4**



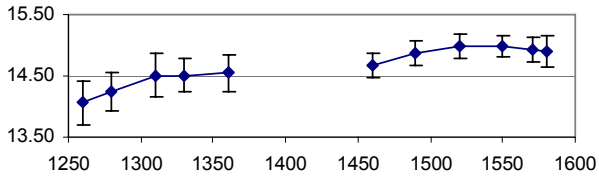
i) **Attenuator 5 – Common reference**



j) **Average ± 2σ of attenuator 5**

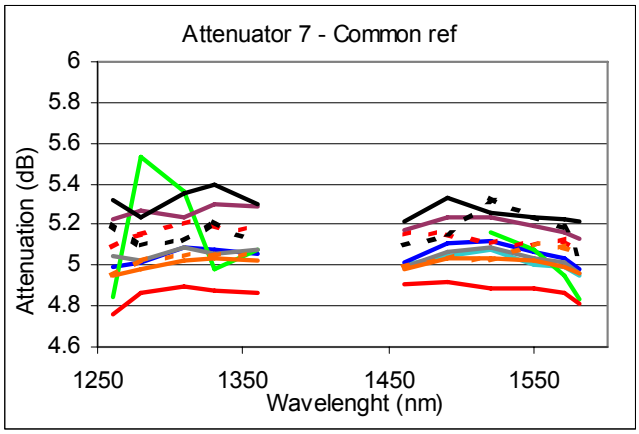


k) **Attenuator 6 – Common reference**

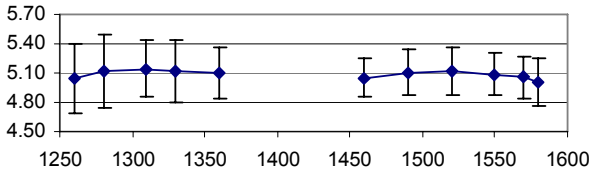


l) **Average ± 2σ of attenuator 6**

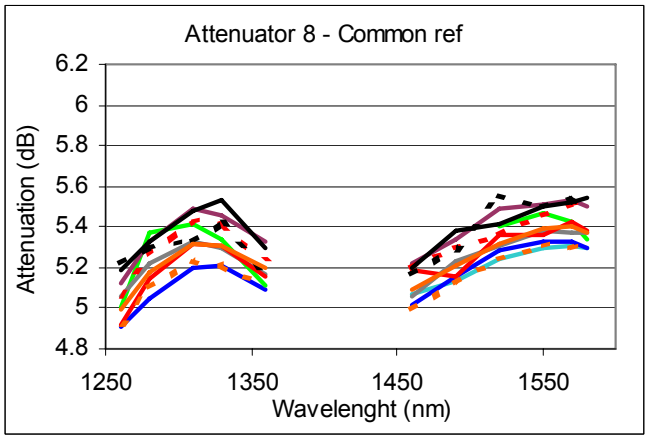
Figure 1 – 15 dB attenuators – All lab. results – Common reference *(continued)*



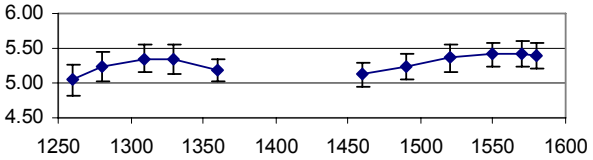
a) **Attenuator 7 – Common reference**



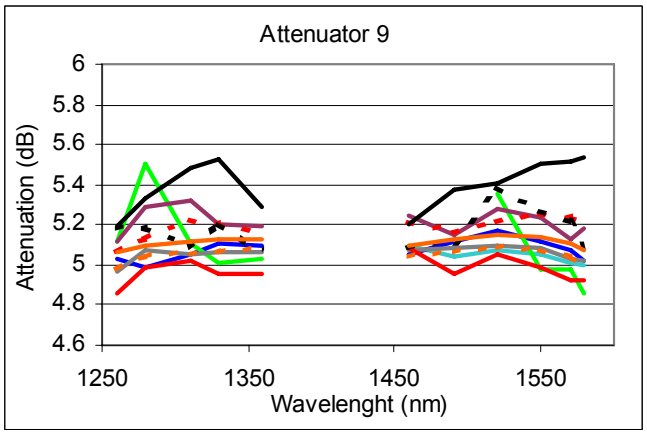
b) **Average ± 2σ of attenuator 7**



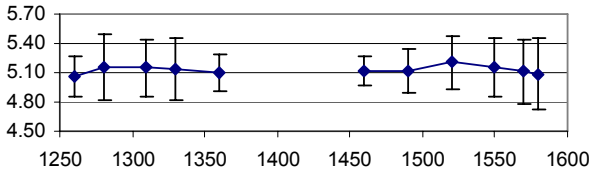
c) **Attenuator 8 – Common reference**



d) **Average ± 2σ of attenuator 8**

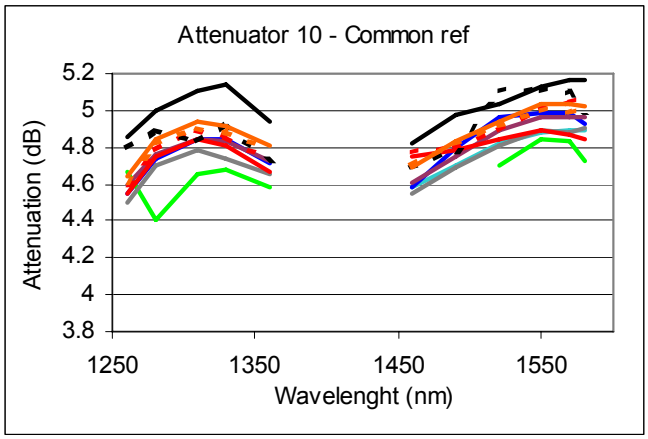


e) **Attenuator 9 – Common reference**

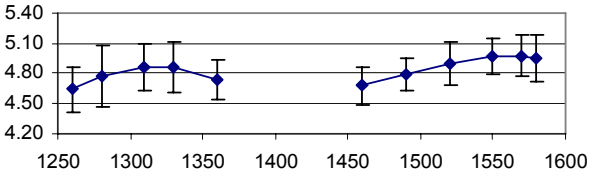


f) **Average ± 2σ of attenuator 9**

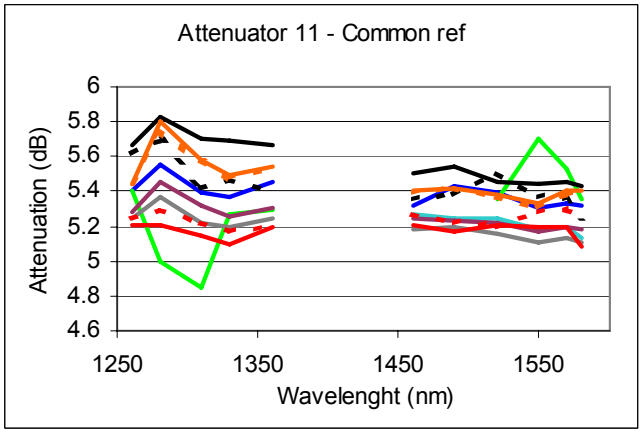
Figure 2 – 5 dB attenuators – All lab. results



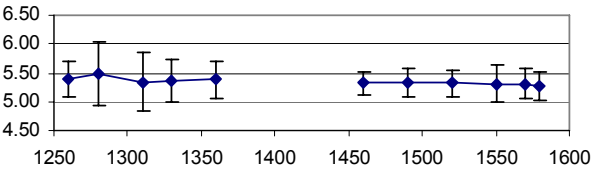
g) **Attenuator 10 – Common reference**



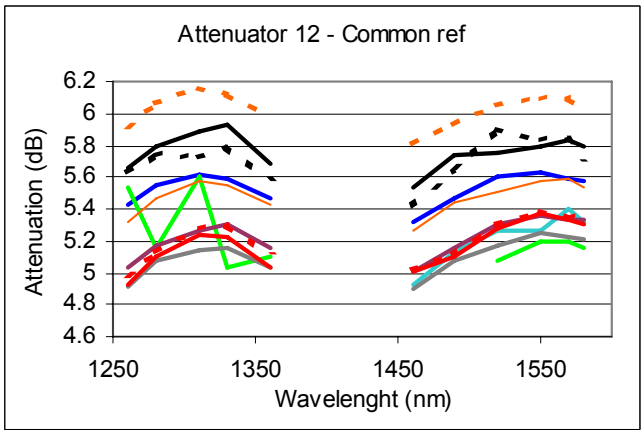
h) **Average ± 2σ of attenuator 10**



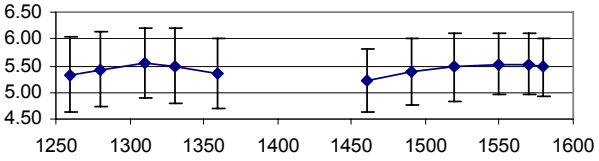
i) **Attenuator 11 – Common reference**



j) **Average ± 2σ of attenuator 11**

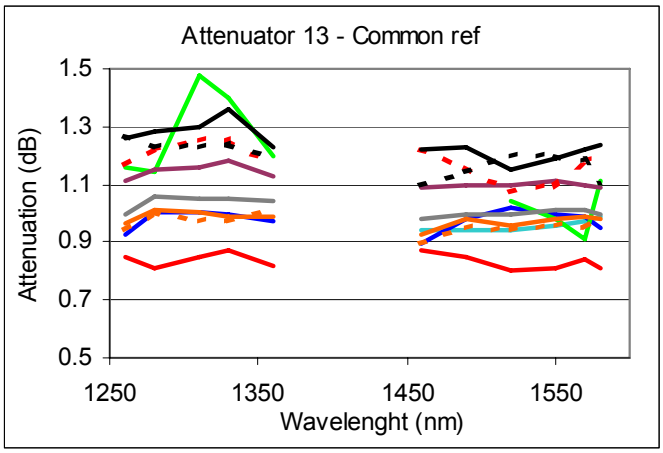


k) **Attenuator 12 – Common reference**

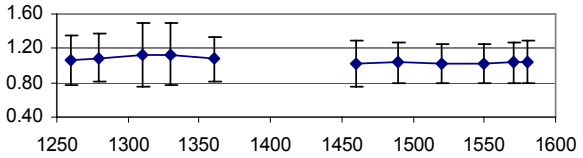


l) **Average ± 2σ of attenuator 12**

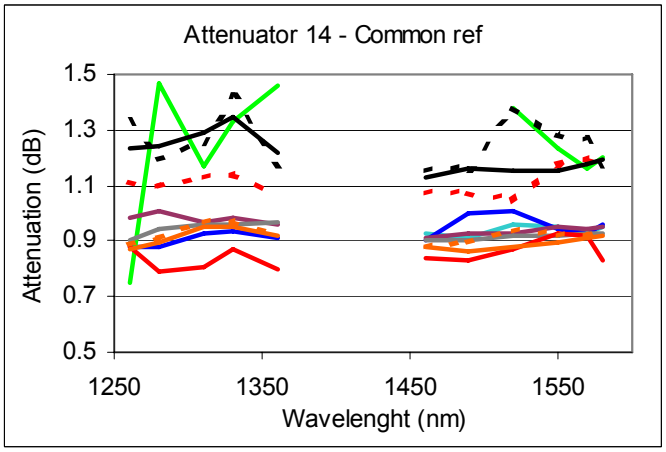
Figure 2 – 5 dB attenuators – All lab. results *(continued)*



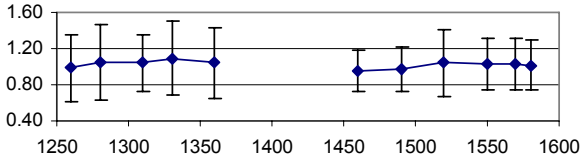
a) **Attenuator 13 – Common reference**



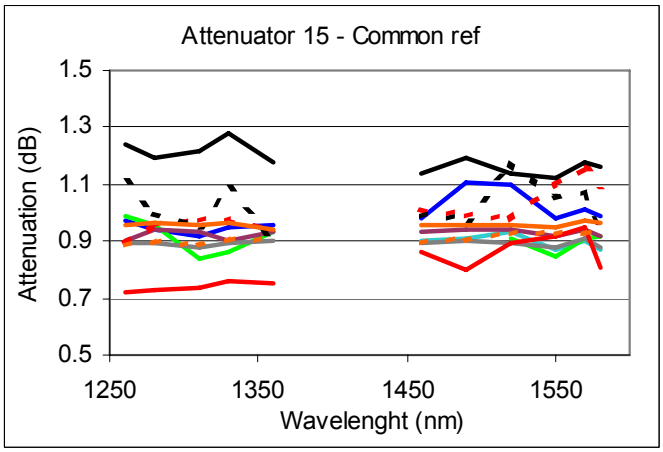
b) **Average ± 2σ of attenuator 13**



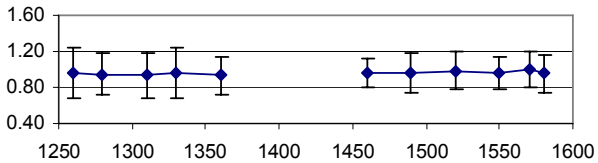
c) **Attenuator 14 – Common reference**



d) **Average ± 2σ of attenuator 14**

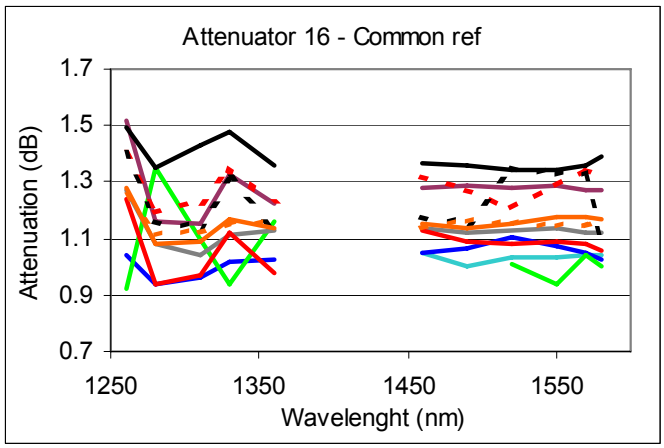


e) **Attenuator 14 – Common reference**

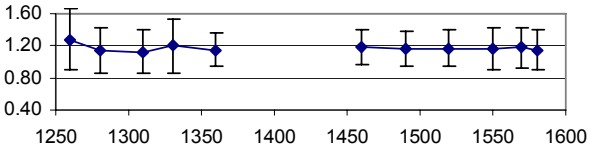


f) **Average ± 2σ of attenuator 14**

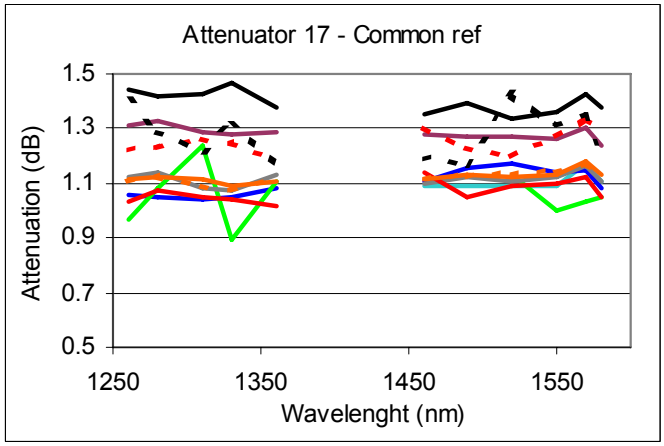
Figure 3 – 1 dB attenuators – All lab. results



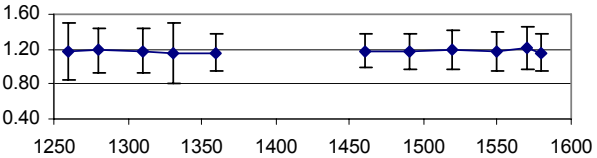
g) Attenuator 14 – Common reference



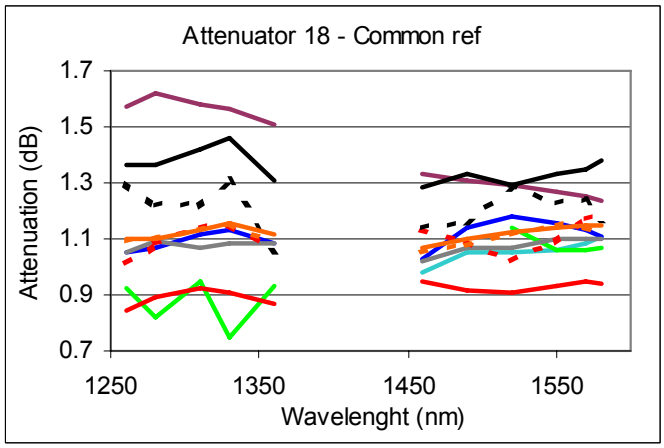
h) Average ± 2σ of attenuator 14



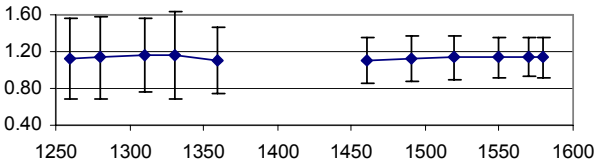
i) Attenuator 14 – Common reference



j) Average ± 2σ of attenuator 14



k) Attenuator 14 – Common reference



l) Average ± 2σ of attenuator 14

Figure 3 – 1 dB attenuators – All lab. results *(continued)*

5.1.5 Summary of attenuation measurements results of SC/PC plug style attenuators

When taking the performance criteria used to purchase these fixed attenuators, the pass/fail results would allow only 9 of the 18 attenuators to pass all 7 laboratories (see Table 1):

– attenuators with nominal attenuation value ≤ 5 dB: tolerance level of 0,5 dB.

– attenuators with nominal attenuation value > 5 dB: tolerance level of 10 % on nominal value.

Table 1 – Pass/fail result

Overview pass/fail with reference connectors and adapter							
	Laboratories						
	A	B	C	D	E	F	G
Attenuator							
1	FAILED	Pass	Pass	Pass	Pass	FAILED	FAILED
2	Pass	Pass	Pass	Pass	Pass	Pass	Pass
3	Pass	Pass	Pass	Pass	Pass	Pass	Pass
4	Pass	Pass	Pass	Pass	Pass	Pass	Pass
5	Pass	Pass	Pass	Pass	Pass	Pass	Pass
6	Pass	Pass	Pass	Pass	Pass	Pass	Pass
7	Pass	Pass	Pass	Pass	Pass	Pass	Pass
8	FAILED	FAILED	FAILED	Pass	FAILED	Pass	Pass
9	Pass	Pass	Pass	Pass	Pass	Pass	Pass
10	FAILED	FAILED	Pass	Pass	Pass	FAILED	FAILED
11	FAILED	FAILED	Pass	Pass	Pass	FAILED	FAILED
12	FAILED	FAILED	Pass	FAILED	FAILED	FAILED	FAILED
13	Pass	Pass	Pass	Pass	Pass	Pass	Pass
14	Pass	Pass	Pass	Pass	Pass	Pass	Pass
15	Pass	Pass	Pass	Pass	Pass	Pass	Pass
16	Pass	Pass	FAILED	Pass	Pass	Pass	Pass
17	Pass	Pass	Pass	Pass	Pass	Pass	FAILED
18	Pass	Pass	FAILED	Pass	Pass	Pass	Pass

Relaxed performance criteria for the spectral attenuation were suggested:

– attenuators with nominal attenuation value ≤ 5 dB: tolerance level of 0,75 dB.

– attenuators with nominal attenuation value > 5 dB: tolerance level of 15 % on nominal value.

With these relaxed performance criteria 13 of the 18 attenuators in this round robin test would have passed all 7 laboratories tests with the reference connectors and adapter (2 nm resolution). Results are listed in Table 2.

Table 2 – Pass/fail result with relaxed performance critera

Overview pass/fail with reference connectors and adapter							
	Laboratories						
	A	B	C	D	E	F	G
Attenuator							
1	FAILED	Pass	Pass	Pass	Pass	Pass	Pass
2	Pass	Pass	Pass	Pass	Pass	Pass	Pass
3	Pass	Pass	Pass	Pass	Pass	Pass	Pass
4	Pass	Pass	Pass	Pass	Pass	Pass	Pass
5	Pass	Pass	Pass	Pass	Pass	Pass	Pass
6	Pass	Pass	Pass	Pass	Pass	Pass	Pass
7	Pass	Pass	Pass	Pass	Pass	Pass	Pass
8	Pass	FAILED	Pass	Pass	Pass	Pass	Pass
9	Pass	Pass	Pass	Pass	Pass	Pass	Pass
10	FAILED	Pass	Pass	Pass	Pass	Pass	Pass
11	Pass	Pass	Pass	Pass	Pass	FAILED	FAILED
12	Pass	Pass	Pass	FAILED	FAILED	FAILED	Pass
13	Pass	Pass	Pass	Pass	Pass	Pass	Pass
14	Pass	Pass	Pass	Pass	Pass	Pass	Pass
15	Pass	Pass	Pass	Pass	Pass	Pass	Pass
16	Pass	Pass	Pass	Pass	Pass	Pass	Pass
17	Pass	Pass	Pass	Pass	Pass	Pass	Pass
18	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Any specification for this technology of plug style attenuators that states tighter tolerance values than given in the above mentioned relaxed criteria should be considered as non realistic at this moment.

5.1.6 Random mating performance with grade B connectors

One of the test laboratories provided the full spectral attenuation plots of the fixed plug style attenuators measured with reference connectors and measured with random selected connectors (connectors according to IEC 61755-1 attenuation grade B and return loss grade 2). Measurement results are shown in Figure 4.

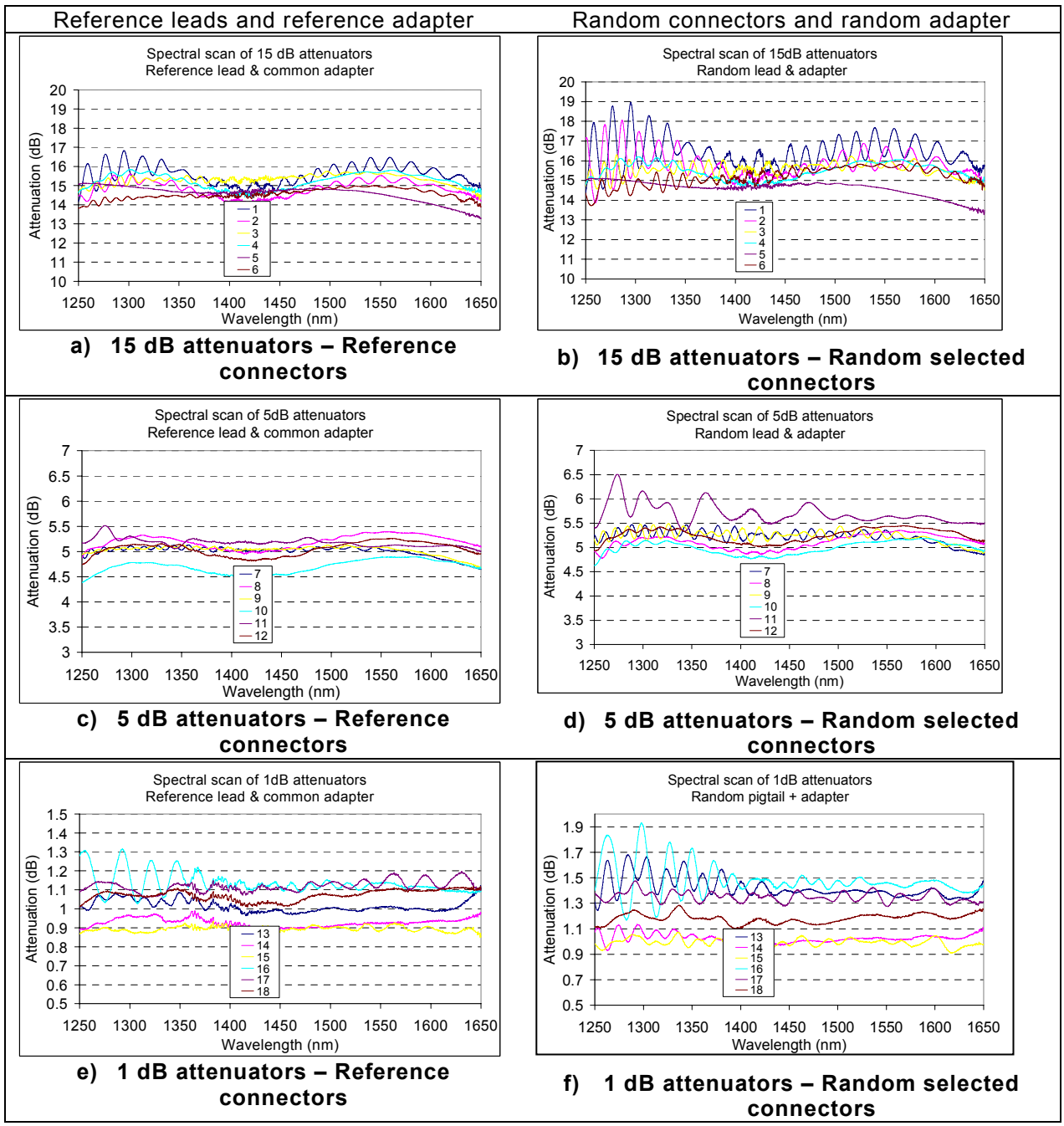
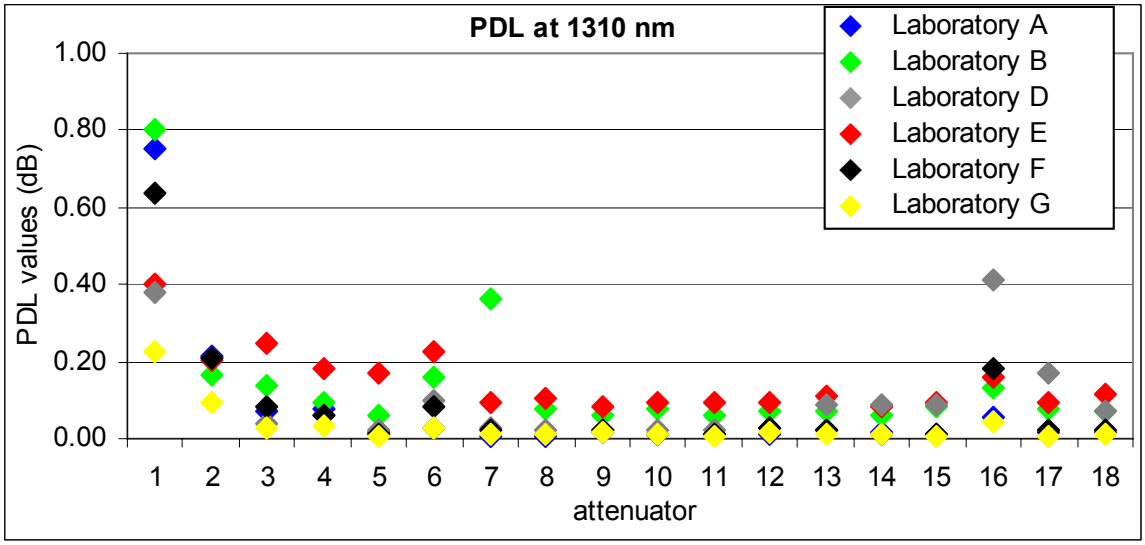


Figure 4 – Spectral scan of attenuators

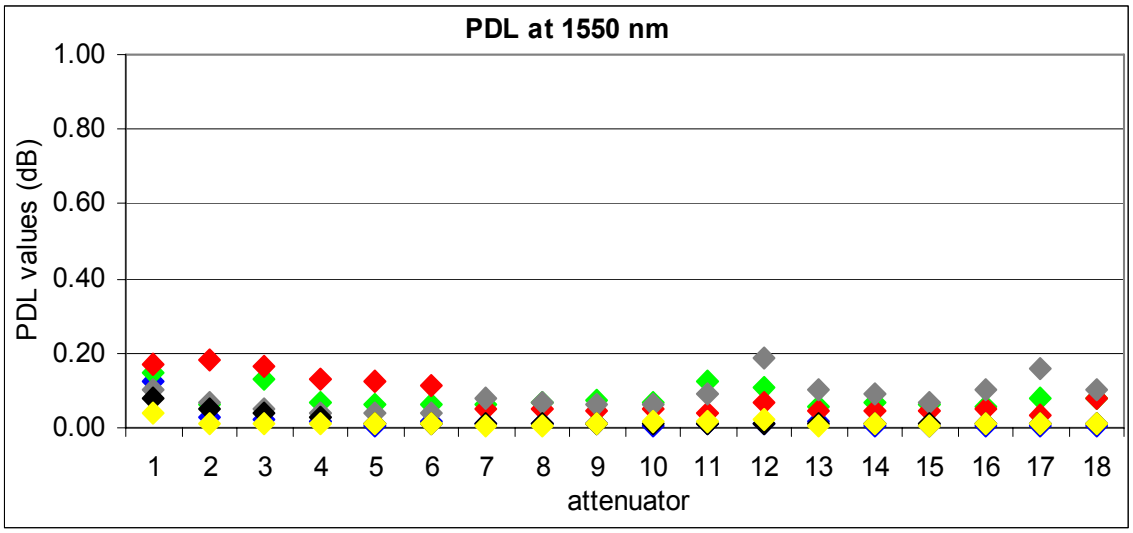
Physical phenomena like modal noise interference are largely influencing the repeatability of the random mating results.

5.1.7 Overview of PDL results for SC/PC plug style attenuators

PDL measurement results also show a larger variation of values for measurements in the 1 310 nm window (see Figure 5). The detailed measurement results for each individual test laboratory can be found in Annex A.



a) PDL at 1 310 nm



b) PDL at 1 550 nm

Figure 5 – Overview of PDL measurements results for SC/PC plug style attenuators

5.2 Measurement results for SC/APC plug style attenuators

5.2.1 SC/APC plug style attenuator test samples

In total 18 SC/APC plug style fixed attenuators were collected for this round robin test:

– 6 attenuators with nominal attenuation of 1 dB (labelled 1, 2, 3, 4, 5, and 6)
– 6 attenuators with nominal attenuation of 5 dB (labelled 7, 8, 9, 10, 11, and 12)
– 6 attenuators with nominal attenuation of 15 dB (labelled 13, 14, 15, 16, 17, and 18)

The attenuators were obtained from various suppliers. The attenuating principle of all devices is based on the use of high attenuating fibre.

The performance grade of these attenuators is defined as:

Operating wavelength range:	1260 nm-1360 nm and 1460 nm-1580 nm
Attenuation tolerance:	0,5 dB for attenuators ≤ 5 dB, 10 % of nominal attenuation value for attenuators > 5 dB

5.2.2 Test method

5.2.2.1 General

All participating test laboratories measured spectral attenuation and polarisation dependent loss for each attenuator. For the sake of decreasing uncertainty all measurement procedures were specified in necessary details.

5.2.2.2 Spectral attenuation loss (according to IEC 61300-3-7)

The measured values were reported for the discrete wavelengths in the full spectral range from 1 260 nm to 1 650 nm with 5 nm steps. The spectral width was set at 2 nm. To minimize uncertainty of measured results, measuring equipment specifications and measurement procedures were clearly stated. Each test laboratory performed the measurements with 2 sets of plugs and adapters:

- measurements with common reference plugs and adapter (the same references for all the test laboratories),
- measurements with own 'IEC 61755-1 Grade B' plugs and own adapter.

Estimated measurement uncertainty did not exceed 0,1 dB for the whole measurement range.

5.2.2.3 Attenuation at 1 310 nm and 1 550 nm measured with LED source and power meter (according to IEC 61300-3-4)

The measurements were performed with common reference plugs at two wavelengths 1 310 nm and 1 550 nm. The accuracy of each attenuation measurement was better than 0,1 dB.

5.2.2.4 Polarisation dependent loss (PDL) (according to IEC 61300-3-2 option 1).

PDL was measured at 1 310 nm and 1 550 nm, with common reference plugs. Selected measurements method was "all states method". The accuracy of each PDL measurement was better than 0,1 dB.

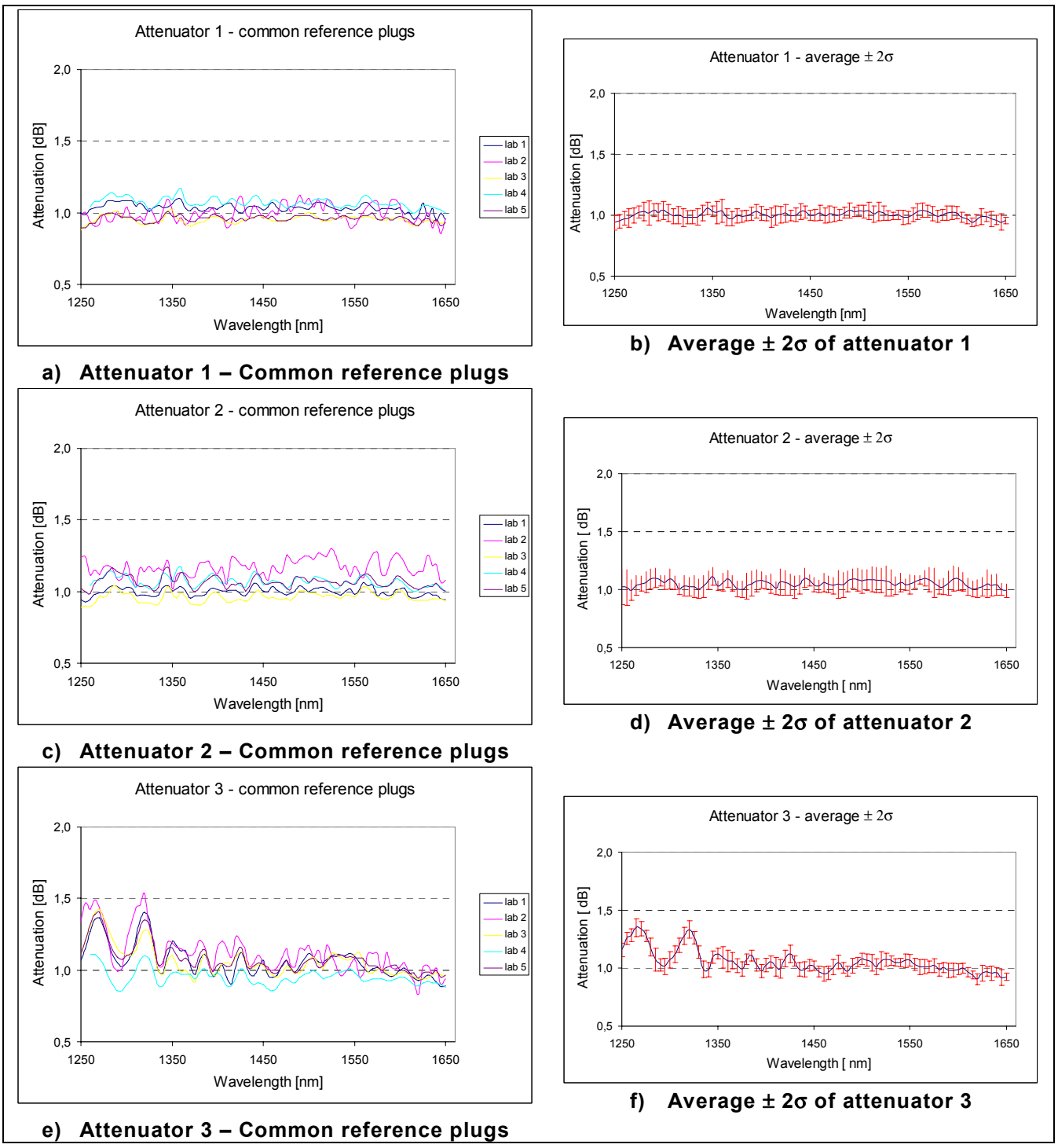
5.2.3 Test laboratories involved in RRT on SC/APC plug style attenuators

The following laboratories were involved in this round robin test (in alphabetical order):

– Adamant Kogyo Co., Ltd. (Japan)
– Diamond (Switzerland)
– Huber and Suhner (Switzerland)
– Telekomunikacja Polska (Poland)
– Tyco Electronics (The Netherlands)

5.2.4 Measurement results of SC/APC plug style attenuators

Figures 6, 7 and 8 show the overview of all the spectral attenuation measurements for 1 dB, 5 dB and 15 dB attenuators respectively. The detailed measurement results for each individual laboratory can be found in Annex B.



a) **Attenuator 1 – Common reference plugs**

b) **Average ± 2σ of attenuator 1**

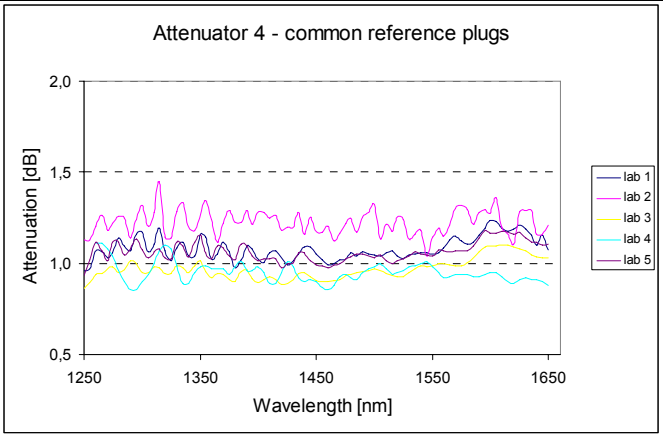
c) **Attenuator 2 – Common reference plugs**

d) **Average ± 2σ of attenuator 2**

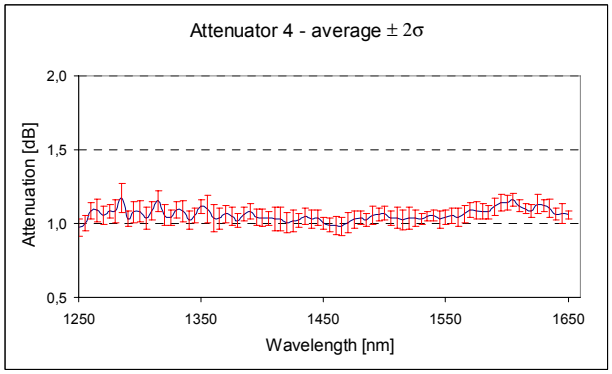
e) **Attenuator 3 – Common reference plugs**

f) **Average ± 2σ of attenuator 3**

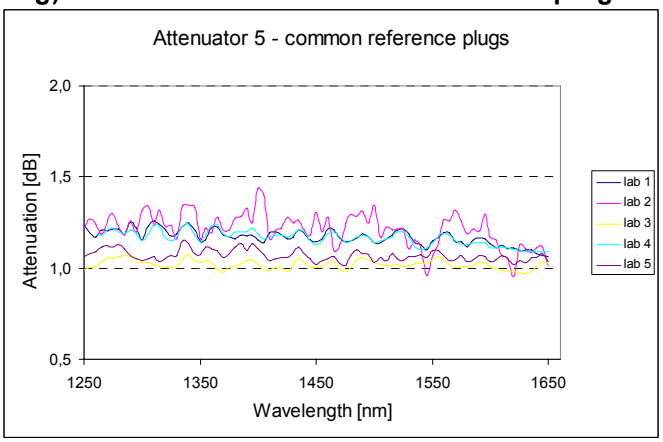
Figure 6 – 1 dB attenuators – All lab. results – Common reference



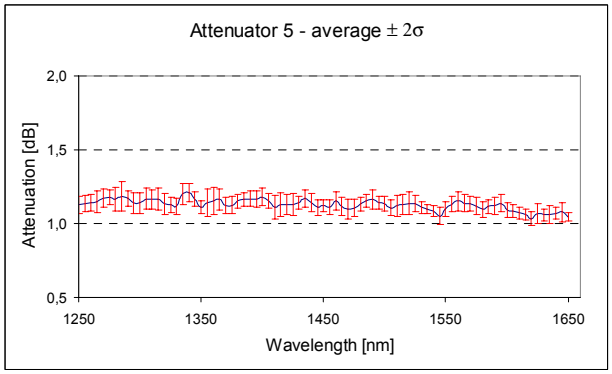
g) **Attenuator 4 – Common reference plugs**



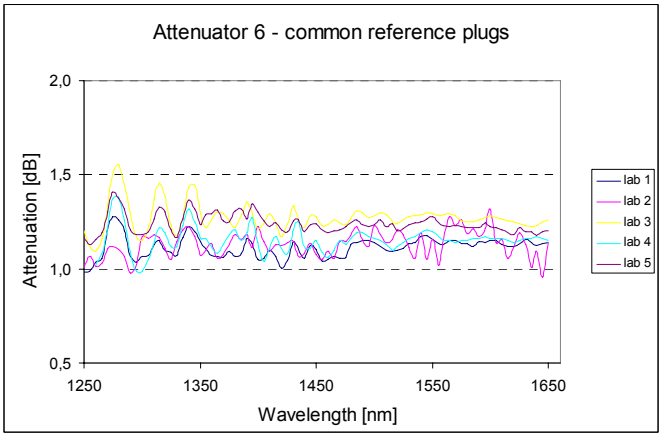
h) **Average ± 2σ of attenuator 4**



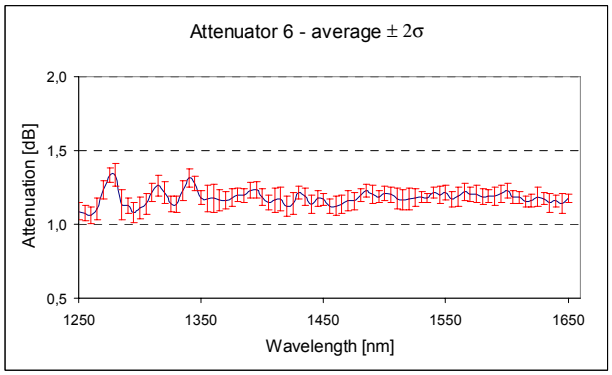
i) **Attenuator 5 – Common reference plugs**



j) **Average ± 2σ of attenuator 5**

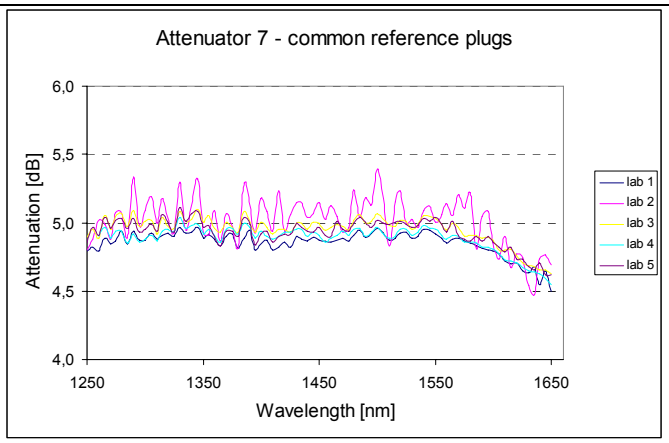


k) **Attenuator 6 – Common reference plugs**

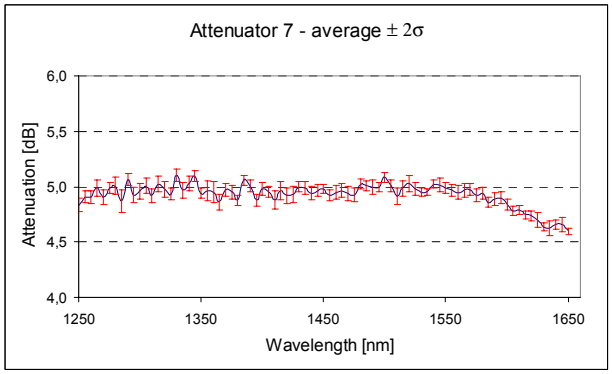


l) **Average ± 2σ of attenuator 6**

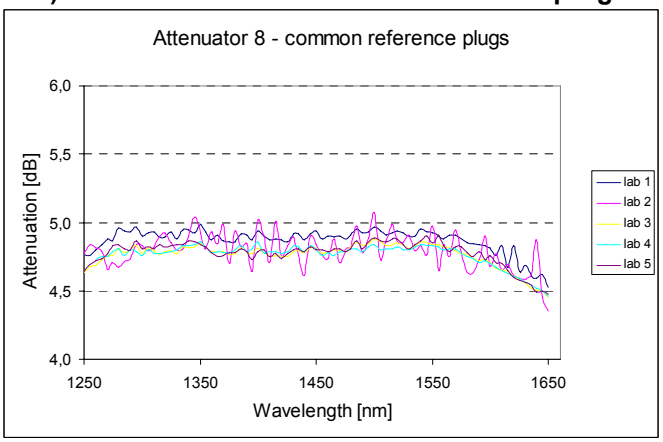
Figure 6 – 1 dB attenuators – All lab. results – Common reference *(continued)*



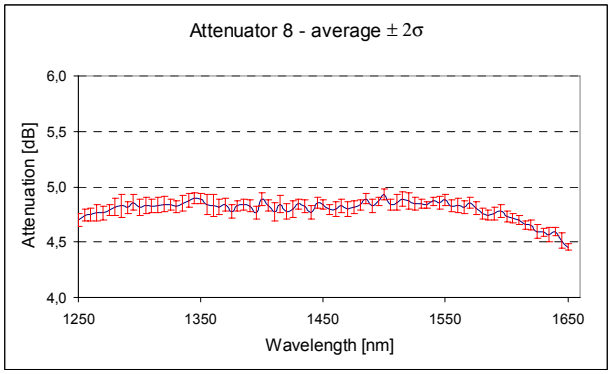
a) **Attenuator 7 – Common reference plugs**



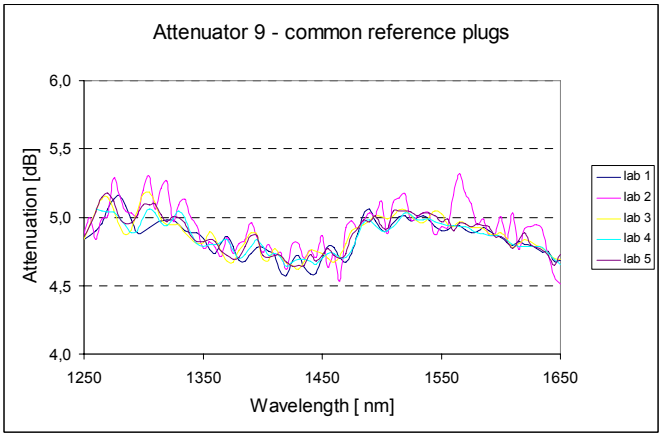
b) **Average ± 2σ of attenuator 7**



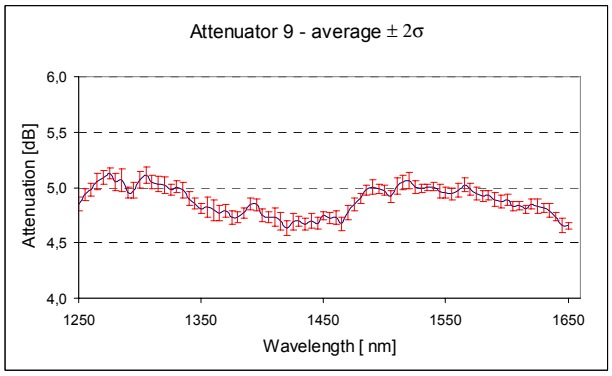
c) **Attenuator 8 – Common reference plugs**



d) **Average ± 2σ of attenuator 8**

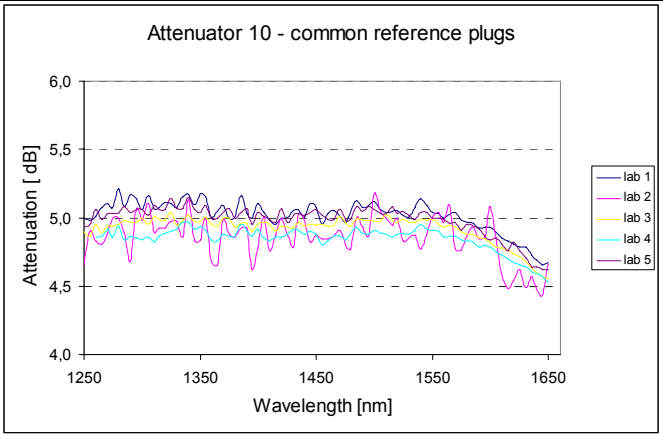


e) **Attenuator 9 – Common reference plugs**

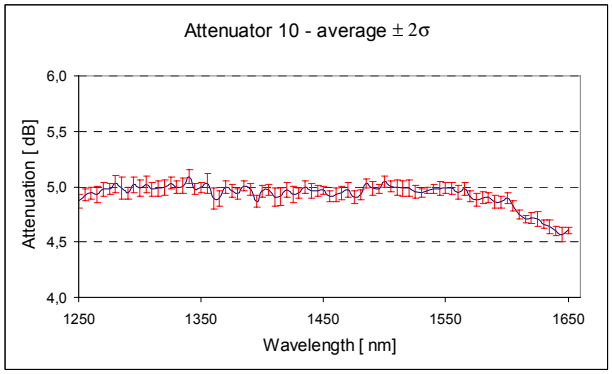


f) **Average ± 2σ of attenuator 9**

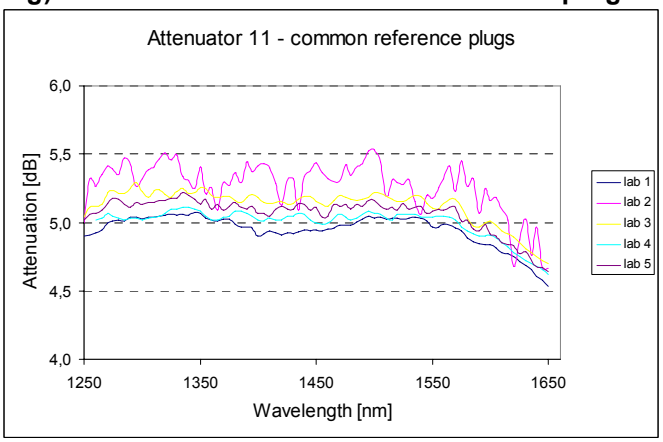
Figure 7 – 5 dB attenuators – All lab. results – Common reference



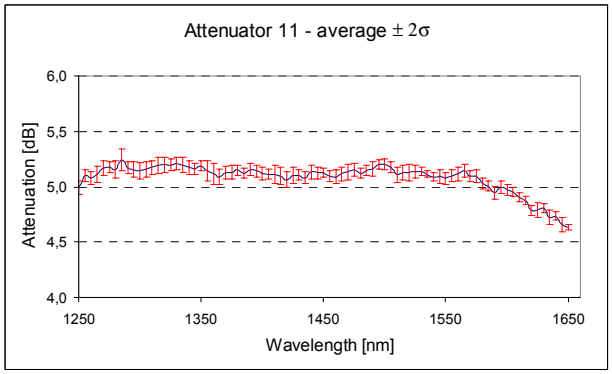
g) **Attenuator 10 – Common reference plugs**



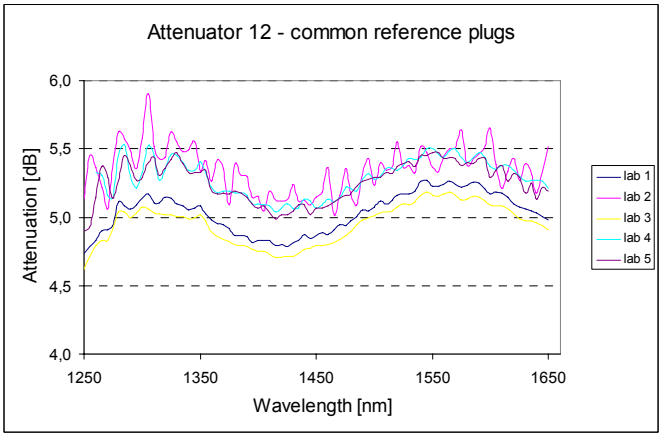
h) **Average ± 2σ of attenuator 10**



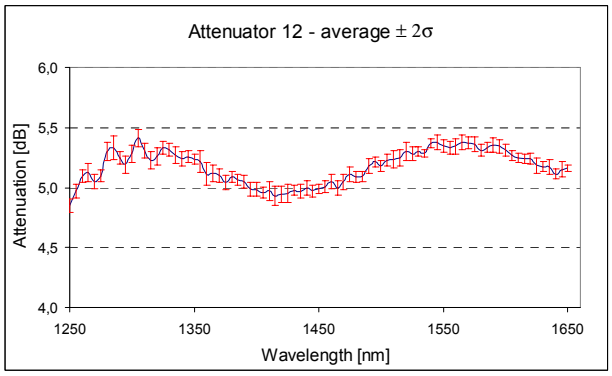
i) **Attenuator 11 – Common reference plugs**



j) **Average ± 2σ of attenuator 11**

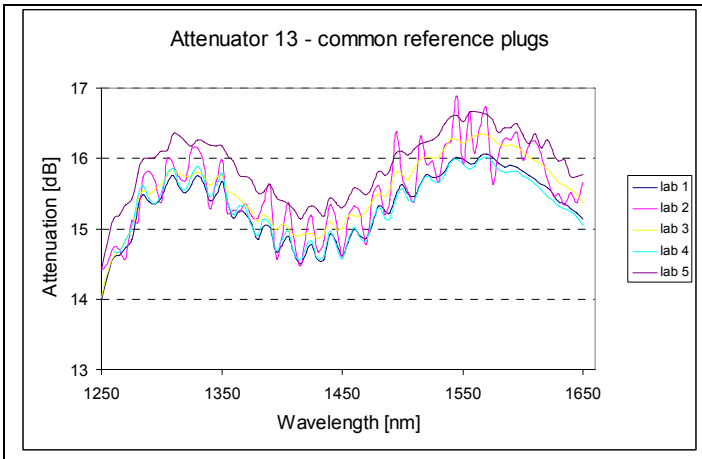


k) **Attenuator 12 – Common reference plugs**

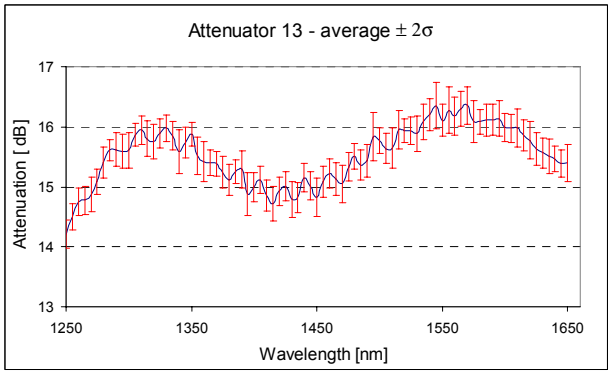


l) **Average ± 2σ of attenuator 12**

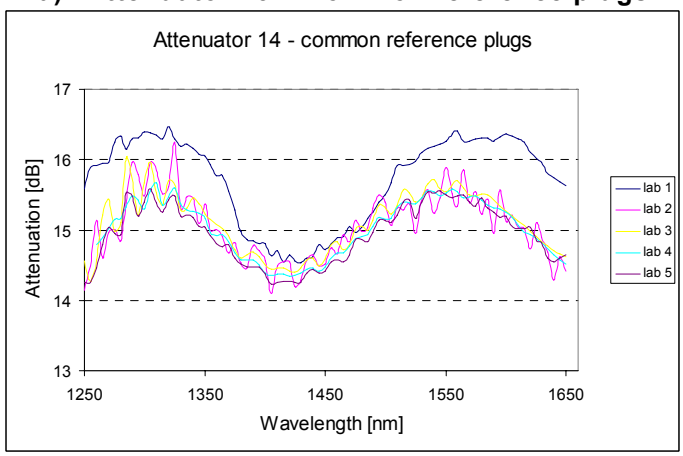
Figure 7 – 5 dB attenuators – All lab. results – Common reference *(continued)*



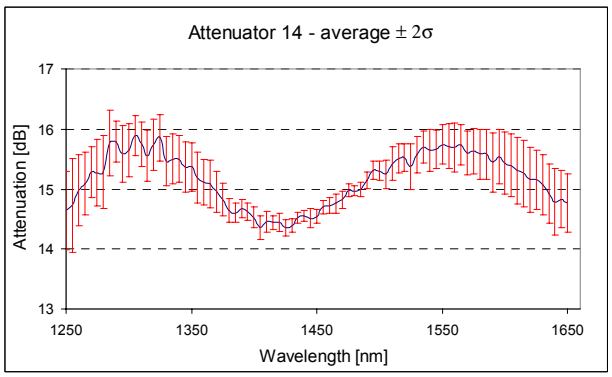
a) **Attenuator 13 – Common reference plugs**



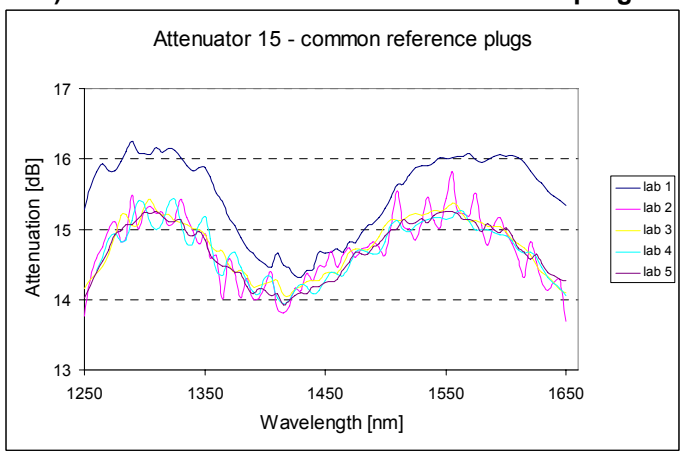
b) **Average ± 2σ of attenuator 13**



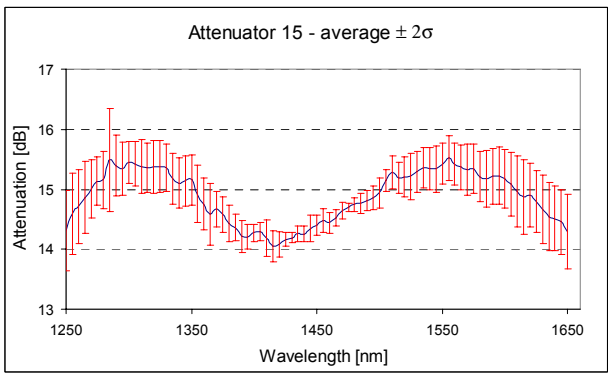
c) **Attenuator 14 – Common reference plugs**



d) **Average ± 2σ of attenuator 14**

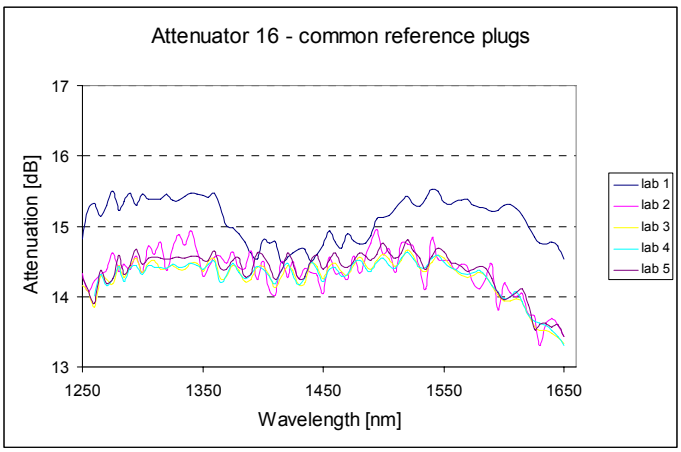


e) **Attenuator 15 – Common reference plugs**

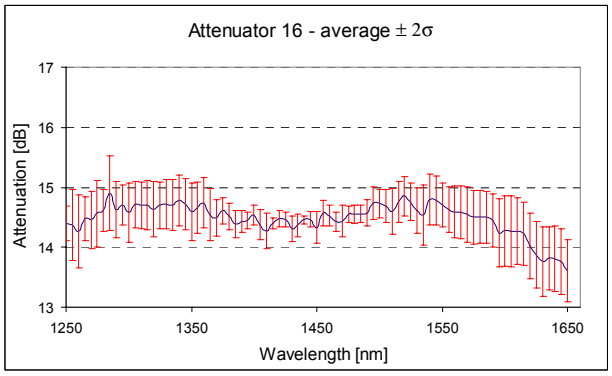


f) **Average ± 2σ of attenuator 15**

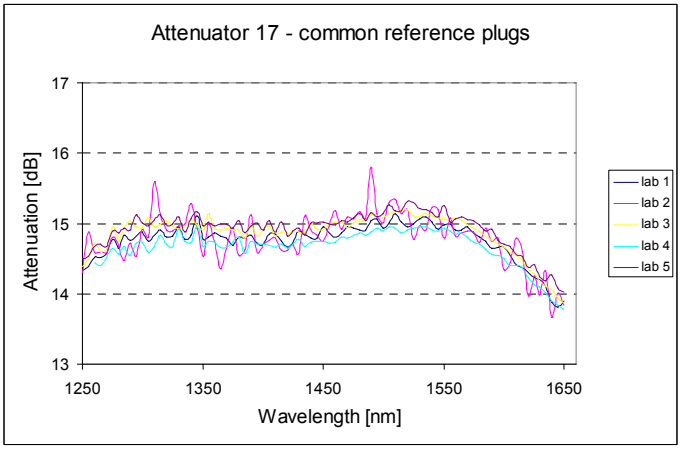
Figure 8 – 15 dB attenuators – All lab. results



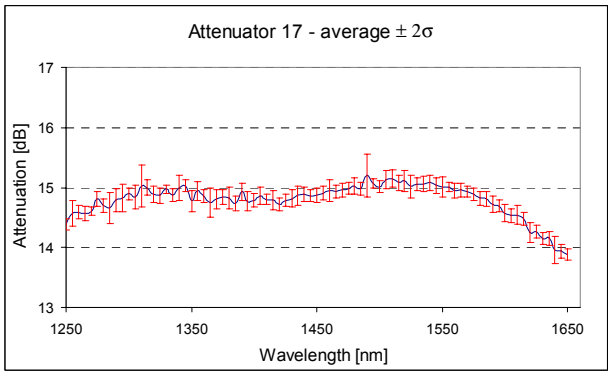
g) Attenuator 6 – Common reference plugs



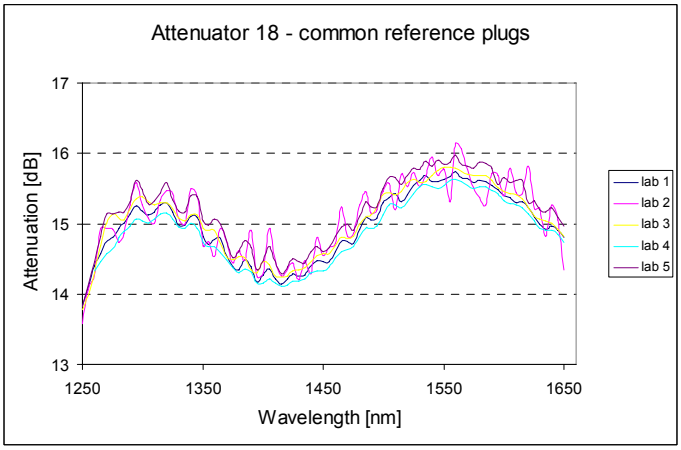
h) Average ± 2σ of attenuator 6



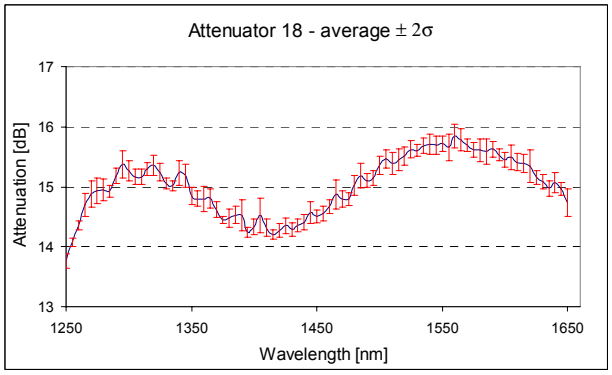
i) Attenuator 6 – Common reference plugs



j) Average ± 2σ of attenuator 6



k) Attenuator 6 – Common reference plugs



l) Average ± 2σ of attenuator 6

Figure 8 – 15 dB attenuators – All lab. results *(continued)*

5.2.5 Summary of attenuation measurements results of SC/APC plug style attenuators

When taking the performance requirement used to procure these fixed attenuators, the pass/fail results for measurements against reference plugs and adapter would allow only 12 of

the 18 attenuators to pass all 5 test laboratories (see Table 3). For the described case following pass/fail criteria apply:

– for attenuators with nominal attenuation value ≤ 5 dB: tolerance level of ± 0,5 dB.

– for attenuators with nominal attenuation value > 5 dB: tolerance level of ± 10 % on nominal value.

Table 3 – Pass/fail result of original specification

Overview pass/fail with reference plugs and adapter					
Attenuator	Laboratory				
	A	B	C	D	E
1	pass	pass	pass	pass	pass
2	pass	pass	pass	pass	pass
3	pass	FAILED	pass	pass	pass
4	pass	pass	pass	pass	pass
5	pass	pass	pass	pass	pass
6	pass	pass	FAILED	pass	pass
7	pass	pass	pass	pass	pass
8	pass	FAILED	FAILED	pass	pass
9	pass	pass	pass	pass	pass
10	pass	pass	pass	pass	pass
11	pass	pass	pass	pass	pass
12	pass	FAILED	pass	pass	pass
13	pass	FAILED	pass	pass	FAILED
14	pass	pass	pass	pass	pass
15	pass	pass	pass	pass	pass
16	pass	FAILED	FAILED	FAILED	pass
17	pass	pass	pass	pass	pass
18	pass	pass	pass	pass	pass

A relaxed pass/fail performance requirement for the spectral attenuation was proposed:

– for attenuators with nominal attenuation value ≤ 5 dB: tolerance level of ± 0,75 dB,

– for attenuators with nominal attenuation value > 5 dB: tolerance level of ± 15 % on nominal value.

It appears that with this relaxed criteria 17 of 18 attenuators in this round robin test would have passed all 5 laboratories tests with the reference plugs and adapter. Results are listed in Table 4.

Table 4 – Pass/fail result with relaxed optical performance critera

Overview pass/fail with reference plugs and adapter					
Attenuator	Laboratory				
	A	B	C	D	E
1	pass	pass	pass	pass	pass
2	pass	pass	pass	pass	pass
3	pass	pass	pass	pass	pass
4	pass	pass	pass	pass	pass
5	pass	pass	pass	pass	pass
6	pass	pass	pass	pass	pass
7	pass	pass	pass	pass	pass
8	pass	pass	pass	pass	pass
9	pass	pass	pass	pass	pass
10	pass	pass	pass	pass	pass
11	pass	pass	pass	pass	pass
12	pass	FAILED	pass	pass	pass
13	pass	pass	pass	pass	pass
14	pass	pass	pass	pass	pass
15	pass	pass	pass	pass	pass
16	pass	pass	pass	pass	pass
17	pass	pass	pass	pass	pass
18	pass	pass	pass	pass	pass

When taking the performance requirement used to procure these fixed attenuators, the pass/fail results for random mated measurements would allow only 6 of the 18 attenuators to pass all 5 test laboratories (see Table 5). For the described case following pass/fail criteria apply:

– for attenuators with nominal attenuation value ≤ 5 dB: tolerance level of ± 0,5 dB.

– for attenuators with nominal attenuation value > 5 dB: tolerance level of ± 10 % on nominal value.

Table 5 – Pass/fail result of original specification

Overview pass/fail with grade B plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
1	pass	pass	pass	pass	pass
2	pass	pass	pass	pass	pass
3	FAILED	pass	pass	pass	FAILED
4	pass	pass	FAILED	pass	pass
5	pass	pass	FAILED	pass	pass
6	pass	pass	FAILED	pass	pass
7	pass	pass	FAILED	pass	pass
8	FAILED	pass	FAILED	pass	pass
9	pass	pass	FAILED	FAILED	pass
10	pass	pass	pass	pass	pass

Overview pass/fail with grade B plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
11	pass	pass	pass	FAILED	FAILED
12	pass	FAILED	pass	FAILED	FAILED
13	pass	FAILED	FAILED	pass	pass
14	pass	pass	FAILED	FAILED	pass
15	pass	pass	pass	pass	pass
16	FAILED	FAILED	pass	FAILED	FAILED
17	pass	pass	pass	pass	pass
18	pass	pass	pass	pass	pass

Relaxing pass/fail requirement for the spectral attenuation:

– for attenuators with nominal attenuation value ≤ 5 dB: tolerance level of 0,75 dB,

– for attenuators with nominal attenuation value > 5 dB: tolerance level of 15 % on nominal value.

It appears that 14 of 18 attenuators in this round robin test would have passed all 5 laboratories tests with the reference plugs and adapter. Results are listed in Table 6.

Table 6 – Pass/fail result with relaxed optical performance critera

Overview pass/fail with grade B plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
1	pass	pass	pass	pass	pass
2	pass	pass	pass	pass	pass
3	pass	pass	pass	pass	FAILED
4	pass	pass	pass	pass	pass
5	pass	pass	pass	pass	pass
6	pass	pass	pass	pass	pass
7	pass	pass	pass	pass	pass
8	pass	pass	pass	pass	pass
9	pass	pass	pass	FAILED	pass
10	pass	pass	pass	pass	pass
11	pass	pass	pass	FAILED	pass
12	pass	FAILED	pass	FAILED	FAILED
13	pass	pass	pass	pass	pass
14	pass	pass	pass	pass	pass
15	pass	pass	pass	pass	pass
16	pass	pass	pass	pass	pass
17	pass	pass	pass	pass	pass
18	pass	pass	pass	pass	pass

Attenuation measurements according to IEC 61300-3-4 with LED light source at 1 310 nm are presented in Table 7 while measurements results at 1 550 nm are included in Table 8. All the attenuators passed tight criteria of measurements against reference plugs for both

wavelengths. Wideband source measurements with LED source and power meter proved high uniformity of results obscuring unwanted effects like modal noise.

Table 7 – LED measurements results at 1 310 nm (green colour = pass)

Overview pass/fail with reference plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
1	1,05	0,91	1,02	0,96	0,97
2	0,98	1,08	1,07	1,13	1,02
3	1,23	1,09	1,14	1,04	1,17
4	1,11	1,01	1,20	1,32	1,01
5	1,26	1,07	1,21	1,15	1,08
6	1,13	1,10	1,17	1,14	1,28
7	4,88	5,07	5,02	4,93	5,02
8	4,93	4,83	4,93	4,89	4,81
9	4,95	5,16	4,98	4,98	4,98
10	5,07	4,91	5,17	5,03	5,08
11	5,04	5,19	5,26	5,13	5,14
12	5,10	5,40	5,14	5,24	5,29
13	15,76	16,23	15,38	15,53	16,15
14	16,35	15,54	15,09	15,39	15,22
15	16,16	15,05	15,05	15,04	14,98
16	15,39	14,38	14,54	14,40	14,45
17	14,83	14,74	14,95	14,76	14,96
18	15,17	15,14	14,97	15,05	15,20

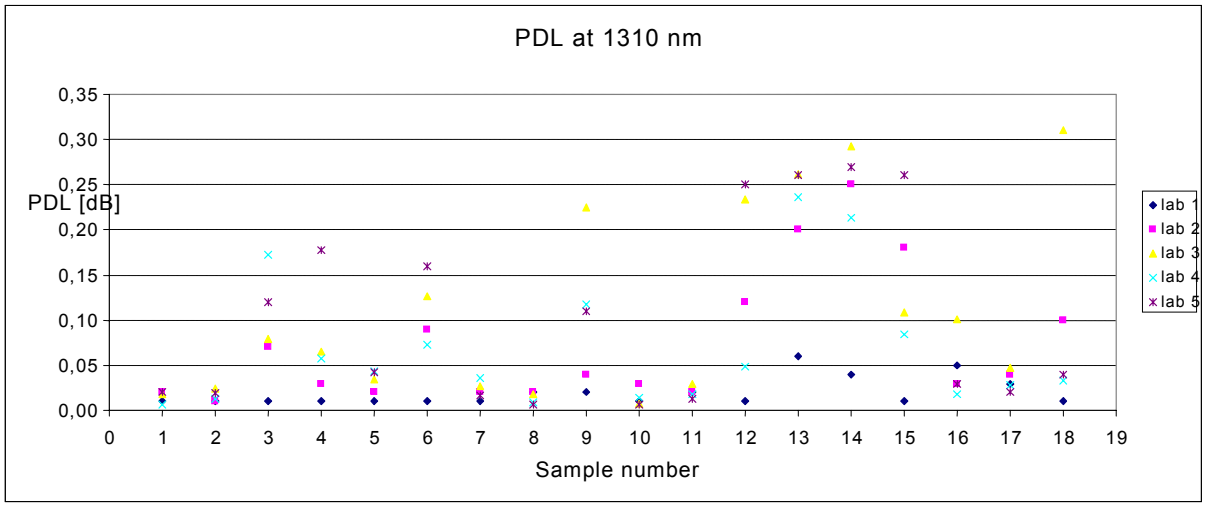
Table 8 – LED measurements results at 1 550 nm (green colour = pass)

Overview pass/fail with reference plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
1	1,02	1,12	0,99	1,05	0,99
2	0,98	1,12	0,99	1,08	1,05
3	1,10	1,00	1,00	0,97	1,07
4	1,05	0,98	1,04	1,40	1,04
5	1,15	1,07	1,19	1,09	1,05
6	1,16	1,20	1,16	1,16	1,26
7	4,92	5,24	4,92	4,88	4,96
8	4,92	4,82	4,82	4,85	4,82
9	4,90	5,08	4,94	4,92	4,96
10	5,04	4,92	4,97	4,98	5,01
11	4,97	5,14	5,10	5,02	5,07
12	5,23	5,34	5,19	5,35	5,35
13	15,98	16,41	15,67	15,81	16,27
14	16,26	15,57	15,38	15,40	15,34
15	16,01	15,15	15,03	15,09	15,00

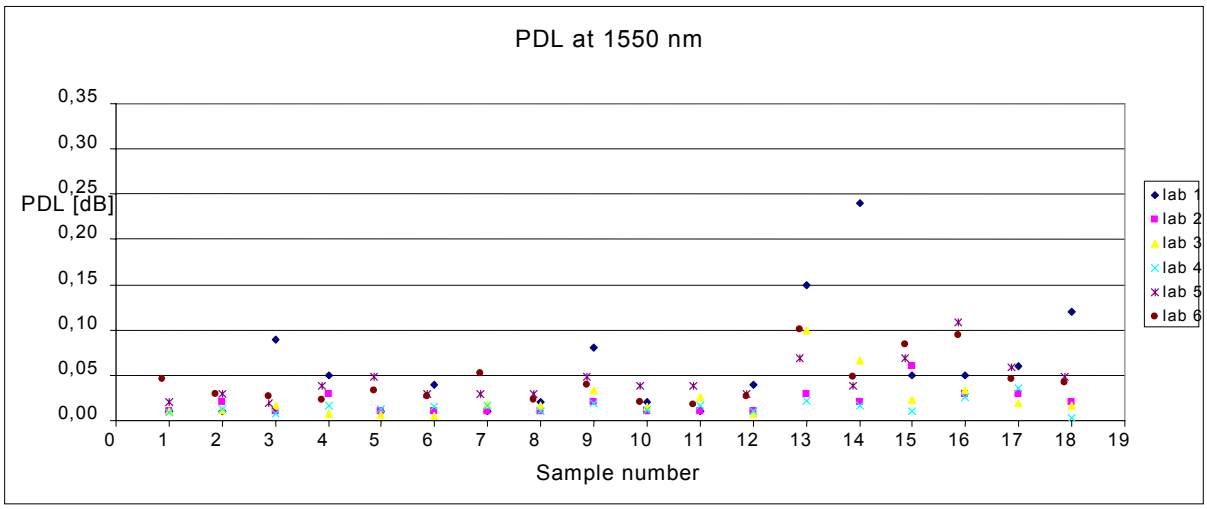
Overview pass/fail with reference plugs and adapter					
Attenuator	Test laboratory				
	A	B	C	D	E
16	15,34	14,41	14,30	14,37	14,41
17	14,97	14,97	14,94	14,86	15,03
18	15,62	15,56	15,40	15,43	15,62

5.2.6 Overview of PDL results for SC/APC plug style attenuators

PDL measurement results presented on Figure 9 shows a larger variation of values for measurements in the 1 310 nm window. The detailed measurement results for each individual laboratory can be found in Annex B.



a) PDL at 1 310 nm



b) PDL at 1 550 nm

Figure 9 – Overview of PDL measurements results for SC/APC style attenuators

6 Mechanical interface issues with SC plug style attenuators

The non reproducibility of the spectral attenuation measurements with wideband light source could indicate possible mechanical interface issues. Thorough analysis of mechanical behaviour of "plug-attenuator-adapter-plug" and "transceiver-attenuator-plug" configurations (see Figure 11) was done. The relevant dimensions H_m and H_f in Figure 10 are based on the corresponding dimensions of parameter *H* in the SC mechanical interface standard IEC 61754-4.

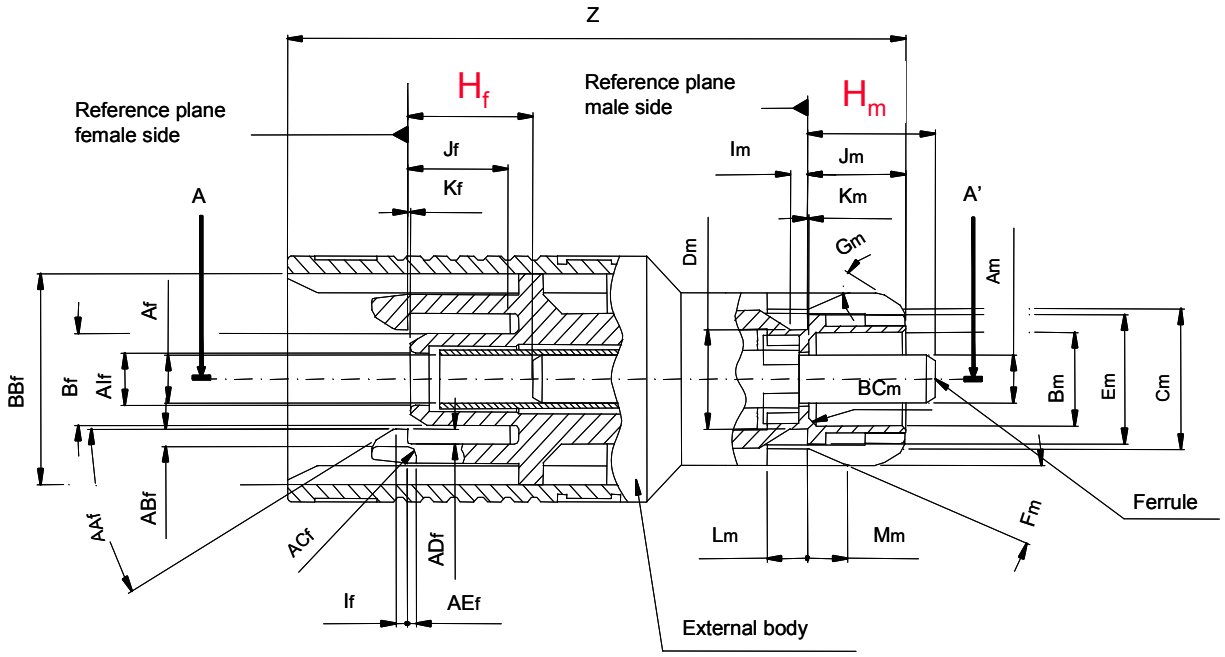


Figure 10 – SC plug style attenuator dimensions

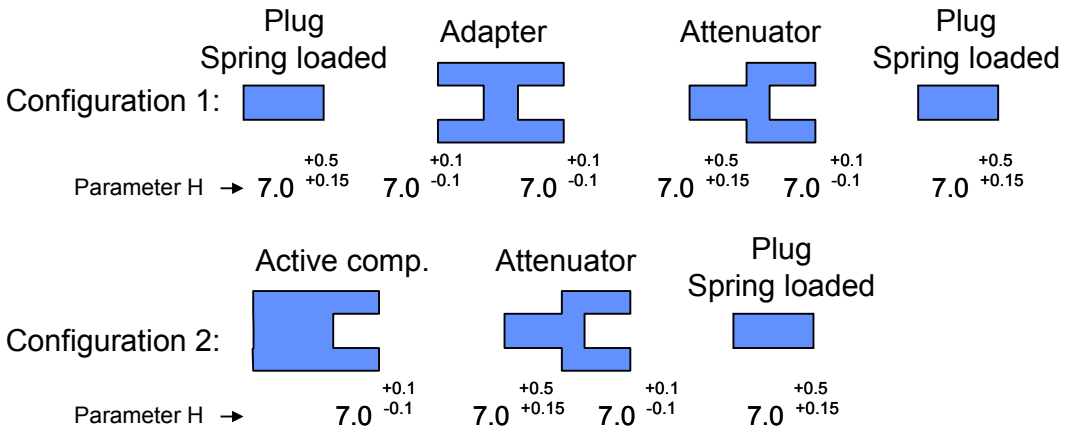


Figure 11 – Possible configurations for plug style attenuator

Analysis results are presented in Table 9. The table presents the worst case behaviour of the two considered working configurations of SC plug style attenuators. Worst case 1 denotes a case when all the plug components meet the maximum mechanical tolerances and the adapter components meet the minimum mechanical tolerances. Worst case 2 denotes a case when all the plug components meet the minimum mechanical tolerances and all adapter components meet the minimum mechanical tolerances. The analysis was done for both fixed and floating (with free travel distance > 0,6 mm) ferrule designs of the attenuator.

Table 9 – SC plug style attenuator behaviour analysis for different working configurations

Standard	Configuration	Worst case	Attenuator's ferrule fixture type	
			Fixed	Floating
IEC 61754-4	Plug-Adapter-Attenuator-Plug	1	Over-travel (Damage)	Over-travel (Damage)
		2	Correct physical contact	Correct physical contact
	Transceiver-Attenuator-Plug	1	Over-travel (Damage)	Over-travel (Damage)
		2	Over-travel (Damage)	Correct physical contact

Table 9 shows that for each configuration and each ferrule fixture type at least one case can occur for which ferrule damage or lack of physical contact will be seen. The table does not take into account the additional travel of the ferrule that will occur when the attenuator or connector plug is inserted into an adapter by pushing the plug as far as possible into the adapter. This will make the cases already marked with "over-travel" even more critical for end face damage. The most critical situation takes place when a plug style attenuator is plugged into a transceiver with a fixed ferrule.

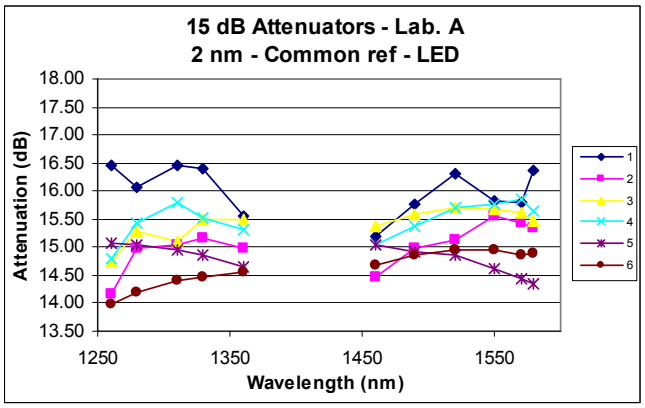
Main conclusion is that there is no room for additional tolerances in the existing interface standard for the SC connector and adapter. SC plug style attenuators should be made with fixed values for parameters H_f and H_m without any tolerance range.

Annex A
(informative)

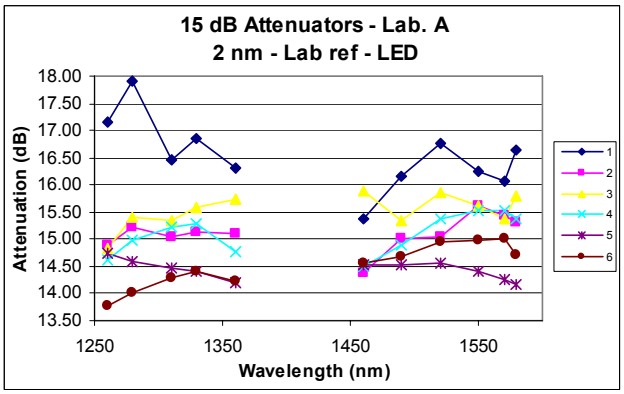
Individual test laboratory results of SC/PC attenuators

A.1 Laboratory A results

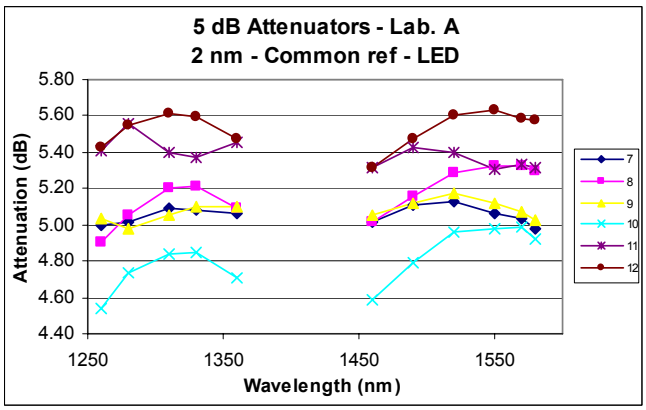
Laboratory A made spectral attenuation measurements using two different light sources: a broadband LED and a tuneable laser in the 1 550 nm window. The results are given in Figure A.1 (LED) and Figure A.2 (LASER). PDL measurements at 1 310 nm and 1 550 nm are reported in Table A.1.



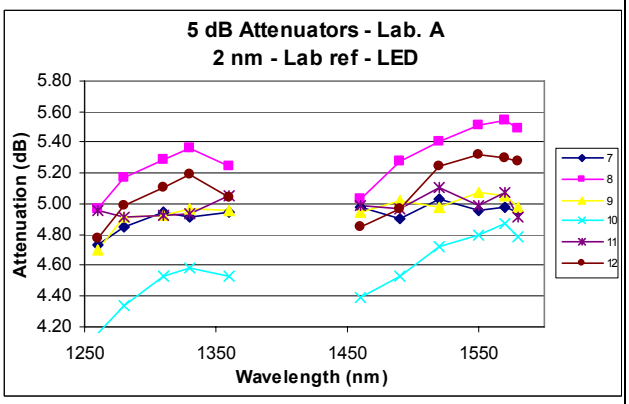
a) 15 dB attenuators – Lab. A – Common reference



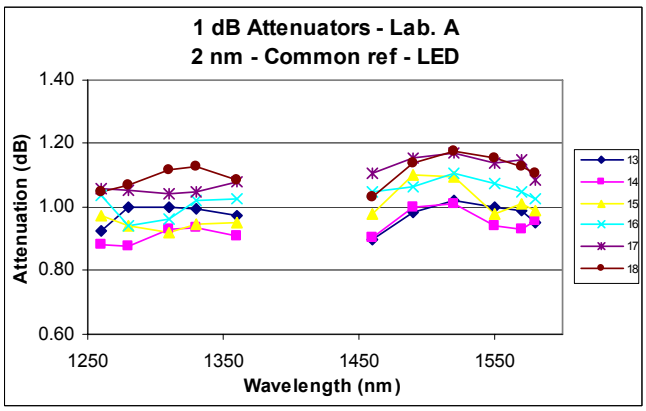
b) 15 dB attenuators – Lab. A – Laboratory reference



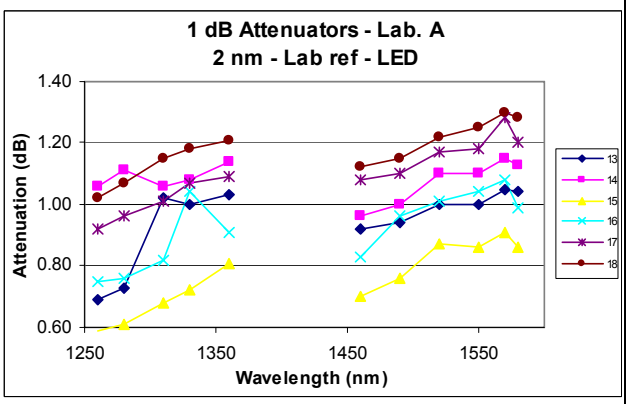
c) 5 dB attenuators – Lab. A – Common reference



d) 5 dB attenuators – Lab. A – Laboratory reference

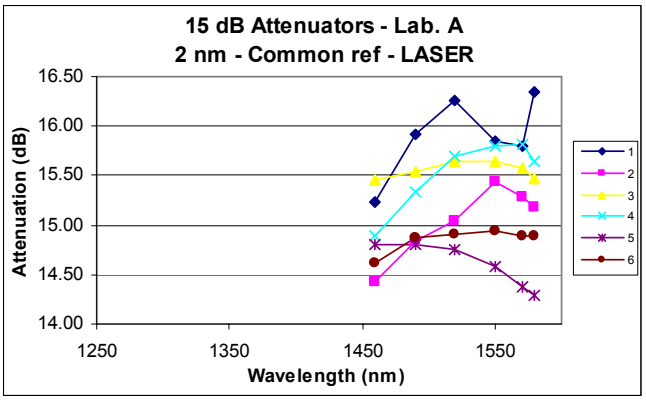


e) 1 dB attenuators – Lab. A – Common reference

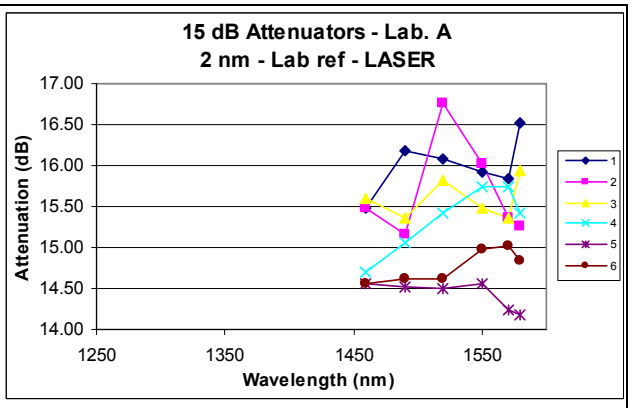


f) 1 dB attenuators – Lab. A – Laboratory reference

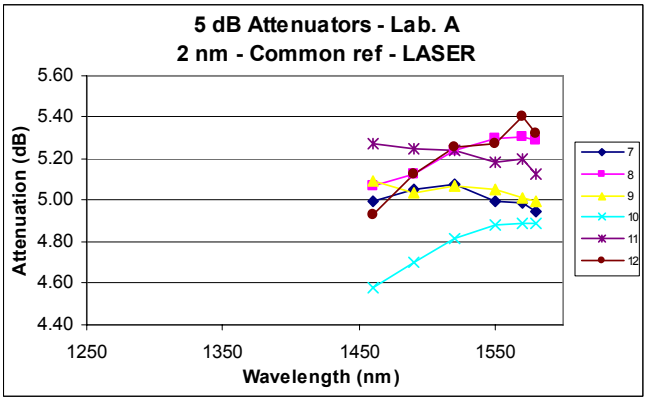
Figure A.1 – Laboratory A results with 2 nm resolution (LED light source)



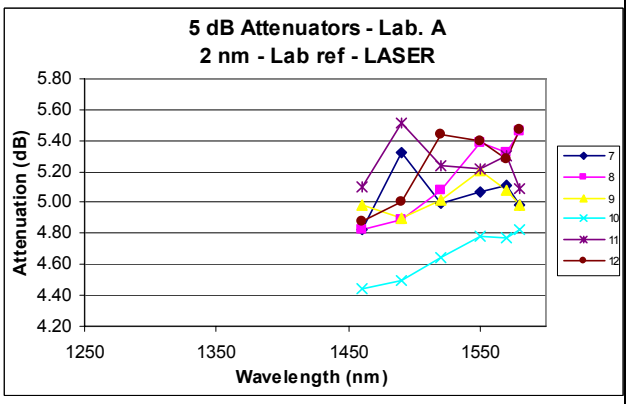
a) 15 dB attenuators – Lab. A – Common reference



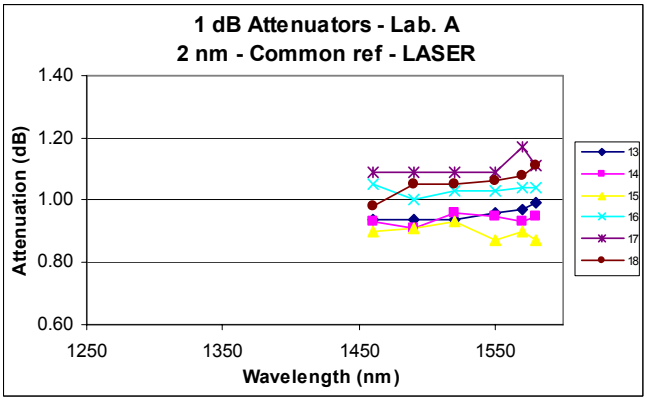
b) 15 dB attenuators – Lab. A – Laboratory reference



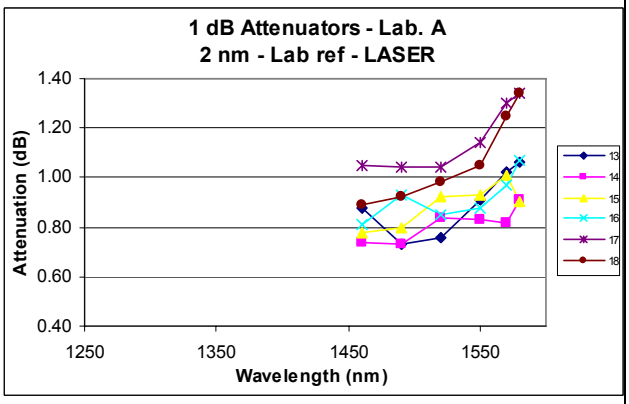
c) 5 dB attenuators – Lab. A – Common reference



d) 5 dB attenuators – Lab. A – Laboratory reference



e) 1 dB attenuators – Lab. A – Common reference



f) 1 dB attenuators – Lab. A – Laboratory reference

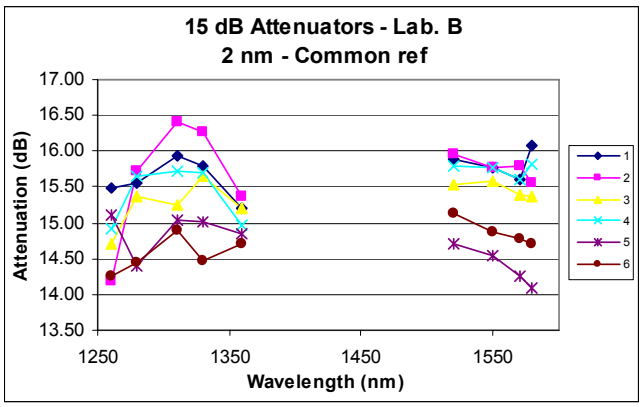
Figure A.2 – Laboratory A results with 2 nm resolution (LASER light source)

Table A.1 – PDL measurements from Laboratory A

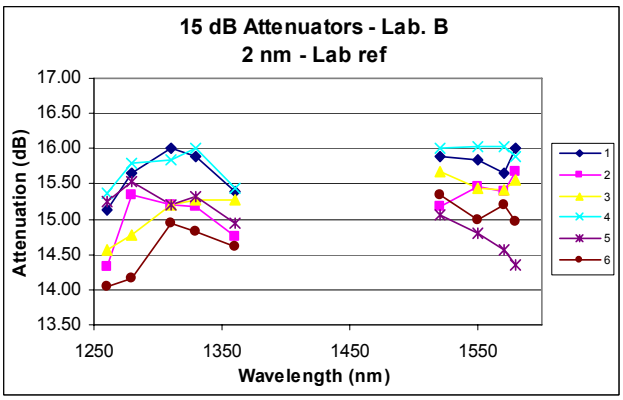
	LABORATORY A - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.75	0.21	0.07	0.08	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.05	0.02	0.02
1550 nm	0.12	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01

A.2 Laboratory B results

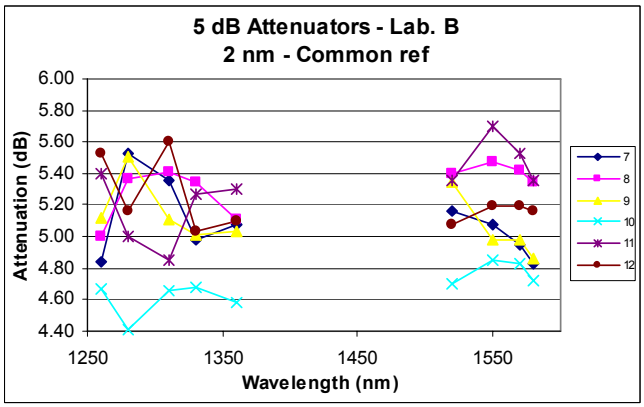
Laboratory B made spectral measurements with a 2 nm resolution. The attenuation results for all attenuators are shown in Figure A.3 (2 nm resolution). PDL measurements at 1 310 nm and 1 550 nm are shown in Table A.2.



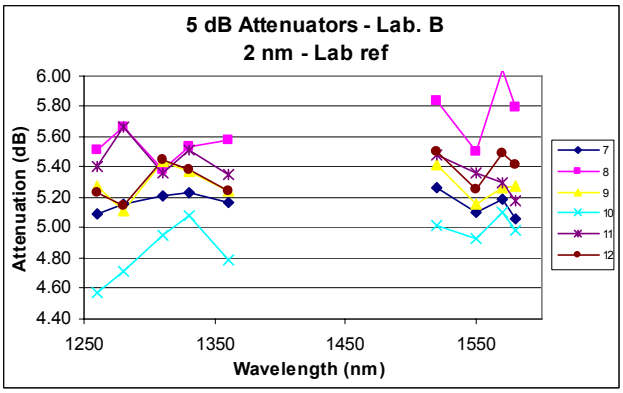
a) 15 dB attenuators – Lab. B – Common reference



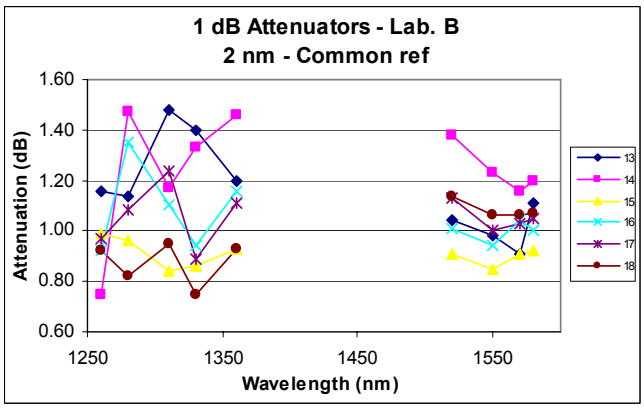
b) 15 dB attenuators – Lab. B – Laboratory reference



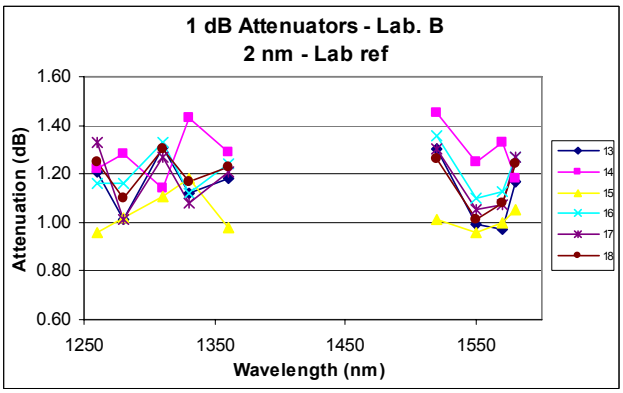
c) 5 dB attenuators – Lab. B – Common reference



d) 5 dB attenuators – Lab. B – Laboratory reference



e) 1 dB attenuators – Lab. B – Common reference



f) 1 dB attenuators – Lab. B – Laboratory reference

Figure A.3 – Laboratory B results with 2 nm resolution

Table A.2 – PDL measurements from Laboratory B

	LABORATORY B - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.8	0.16	0.14	0.09	0.06	0.16	0.36	0.08	0.06	0.08	0.06	0.07	0.07	0.06	0.08	0.13	0.08	0.07
1550 nm	0.15	0.06	0.13	0.07	0.06	0.06	0.06	0.07	0.07	0.07	0.12	0.11	0.06	0.07	0.07	0.06	0.08	0.08

A.3 Laboratory C results

Laboratory C made spectral attenuation measurements with a 2 nm resolution. The attenuation results for all attenuators are shown in Figure A.4 (2 nm resolution). No PDL measurements were made.

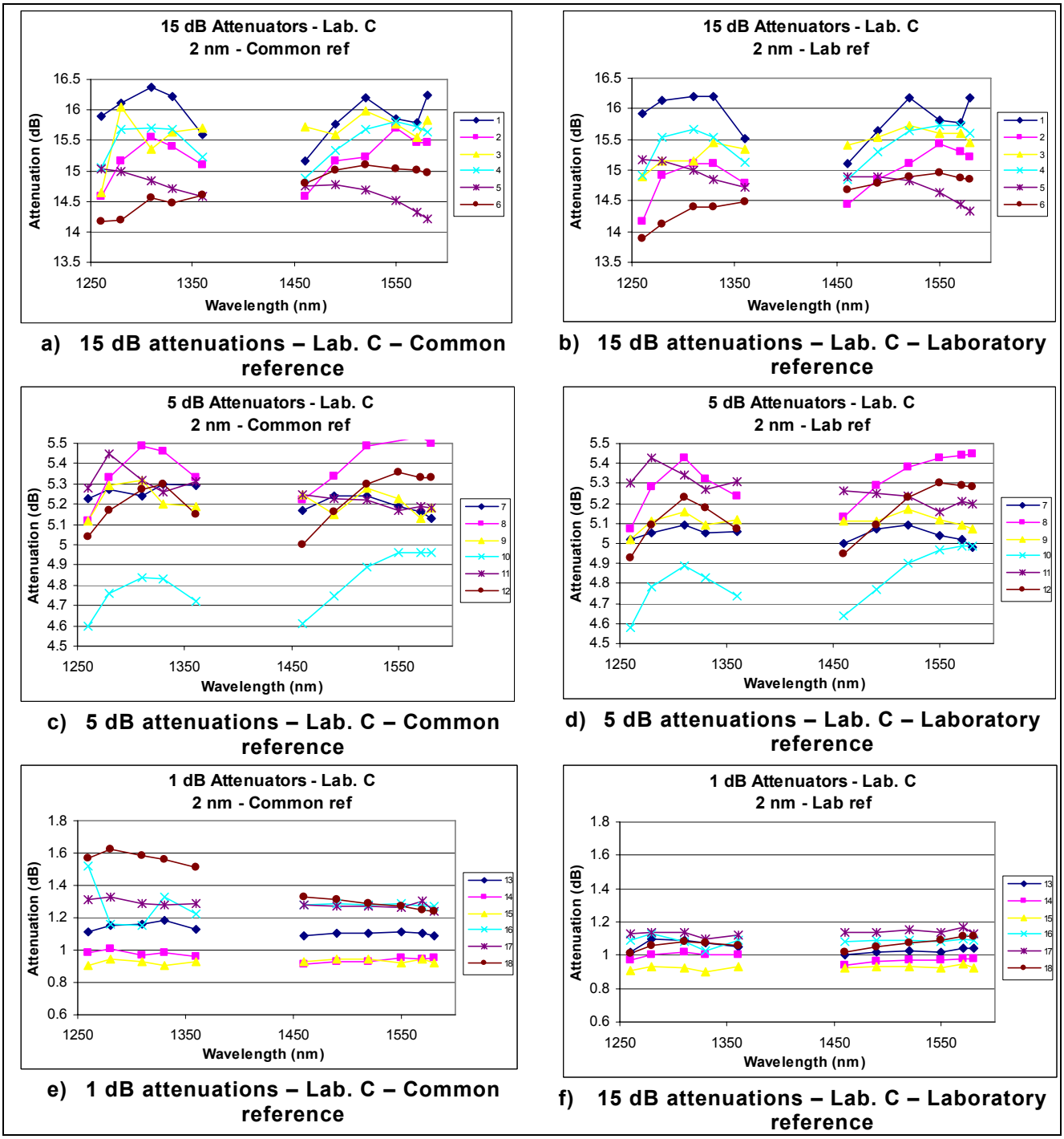
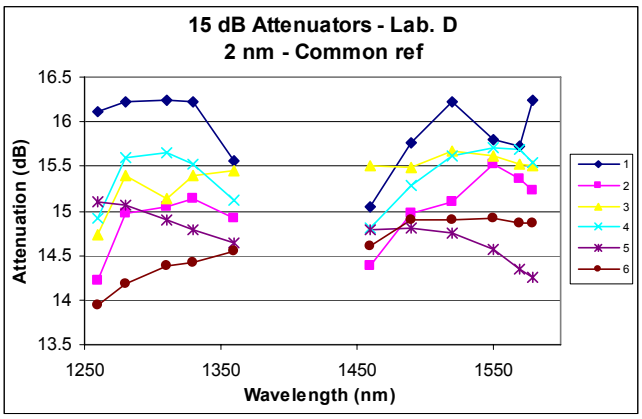


Figure A.4 – Laboratory C results with 2 nm resolution

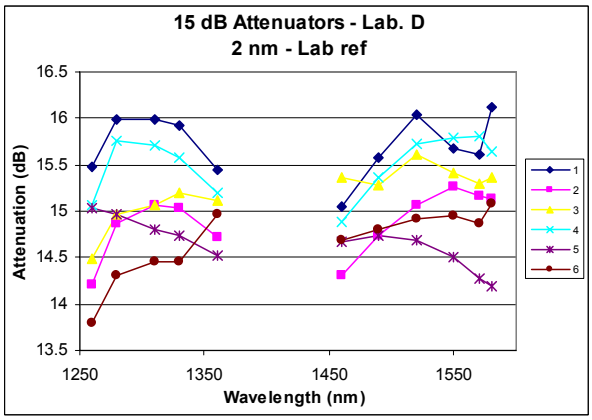
No PDL measurements were performed by laboratory C.

A.4 Laboratory D results

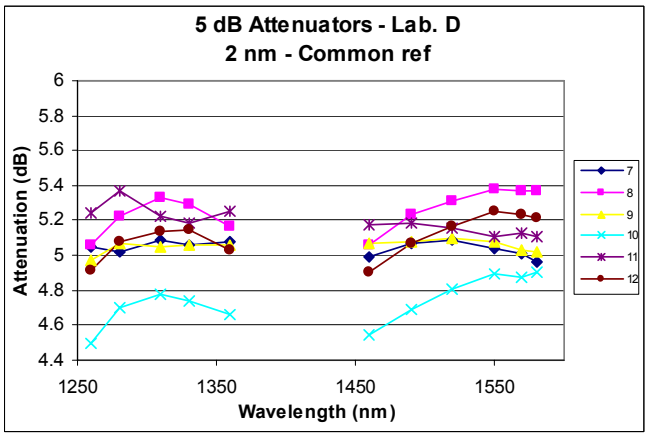
Laboratory D made spectral measurements with a 2 nm resolution. The attenuation results for all attenuators are shown in Figure A.5 (2 nm resolution). PDL measurements at 1 310 nm and 1 550 nm are shown in Table A.3.



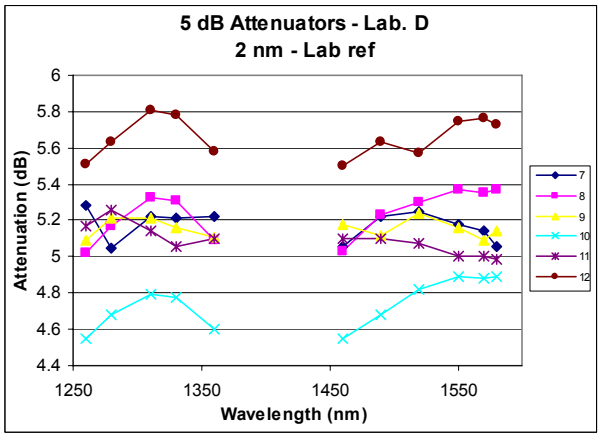
a) 15 dB attenuations – Lab. D – Common reference



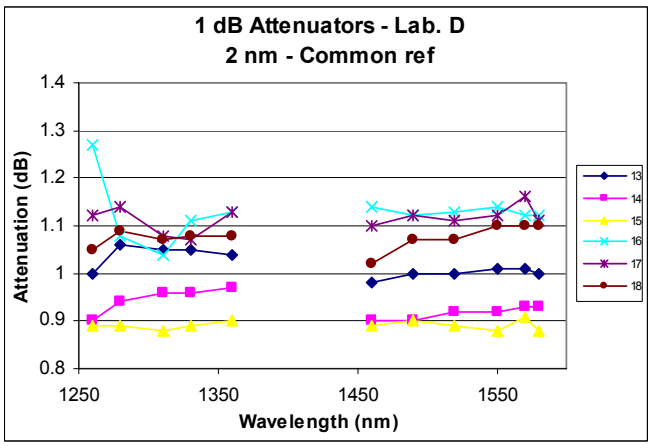
b) 15 dB attenuations – Lab. D – Laboratory reference



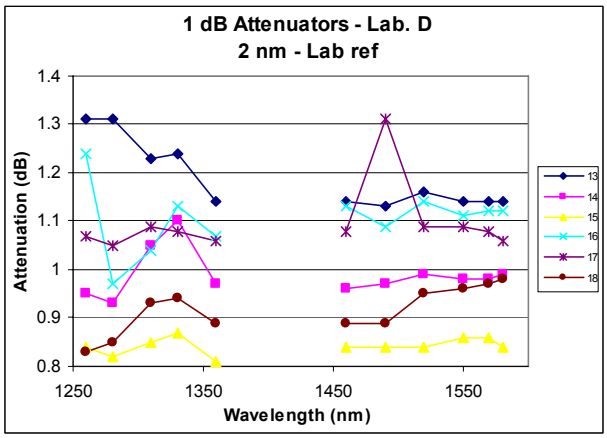
c) 5 dB attenuations – Lab. D – Common reference



d) 5 dB attenuations – Lab. D – Laboratory reference



e) 15 dB attenuations – Lab. D – Common reference



f) 15 dB attenuations – Lab. D – Laboratory reference

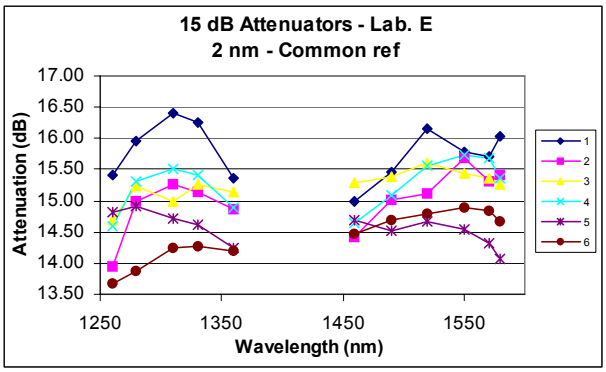
Figure A.5 – Laboratory D results with 2 nm resolution

Table A.3 – PDL measurements from laboratory E

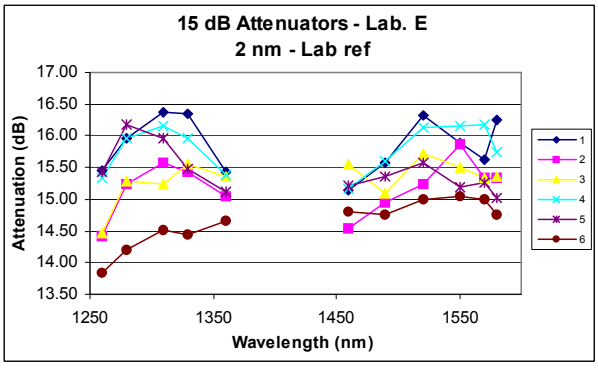
	LABORATORY D - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.38	0.21	0.04	0.06	0.02	0.1	0.03	0.02	0.02	0.02	0.02	0.03	0.09	0.09	0.09	0.41	0.17	0.07
1550 nm	0.1	0.07	0.05	0.04	0.04	0.04	0.08	0.07	0.06	0.06	0.09	0.19	0.1	0.09	0.07	0.1	0.16	0.1

A.5 Laboratory E results

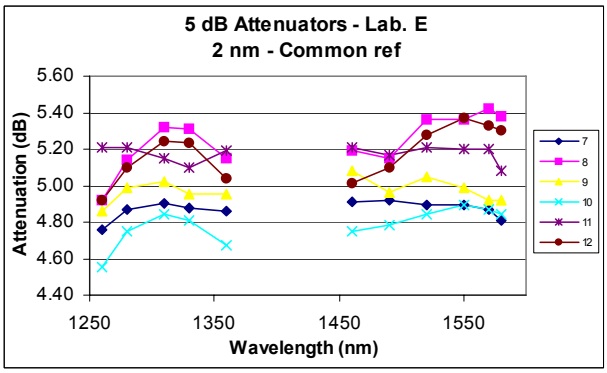
Laboratory E made spectral attenuation measurements with a 2 nm and 10 nm resolution. The attenuation results for all attenuators are shown in Figure A.6 (2 nm resolution) and Figure A.7 (10 nm resolution). PDL measurements at 1 310 nm and 1 550 nm are shown in Table A.4.



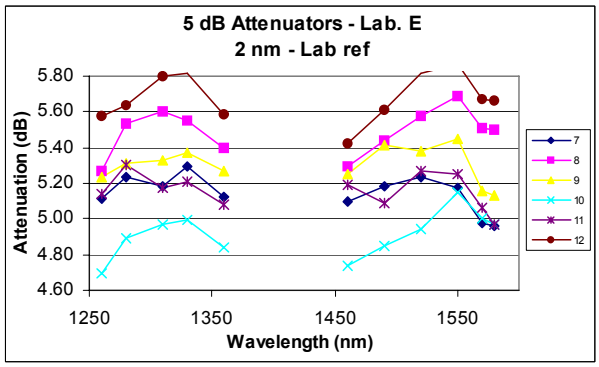
a) 15 dB attenuations – Lab. E – Common reference



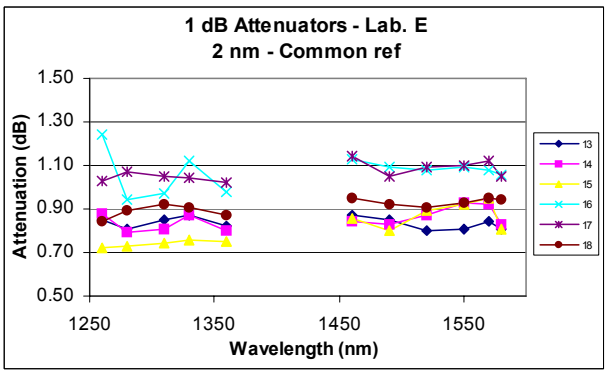
b) 15 dB attenuations – Lab. E – Laboratory reference



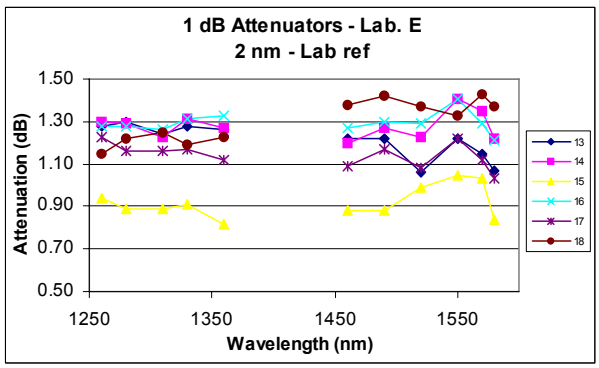
c) 5 dB attenuations – Lab. E – Common reference



d) 5 dB attenuations – Lab. E – Laboratory reference

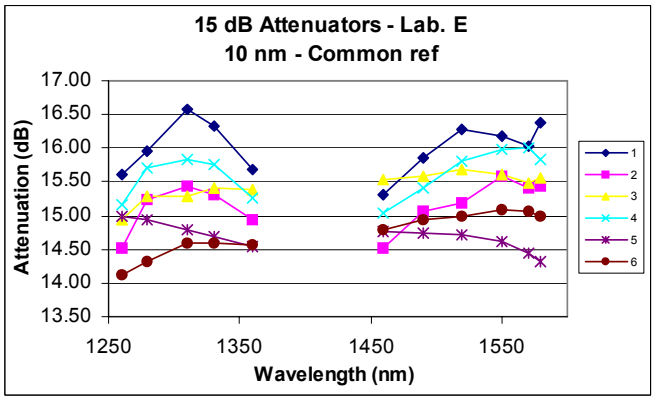


e) 1 dB attenuations – Lab. E – Common reference

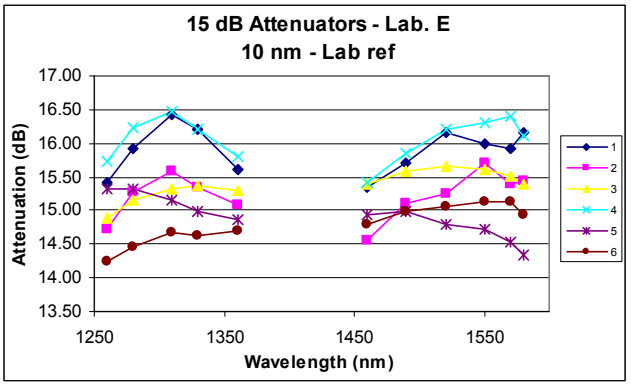


f) 1 dB attenuations – Lab. E – Laboratory reference

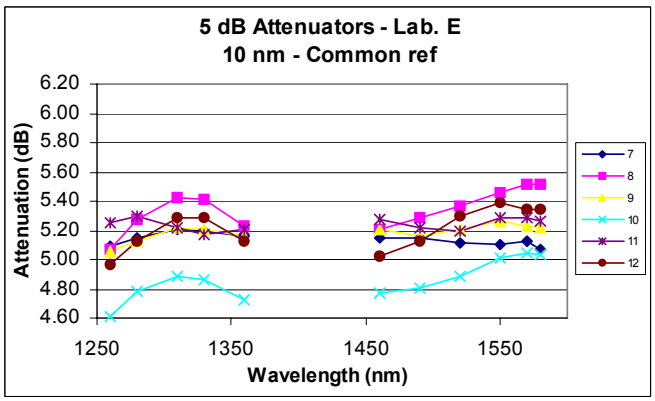
Figure A.6 – Laboratory E results with 2 nm resolution



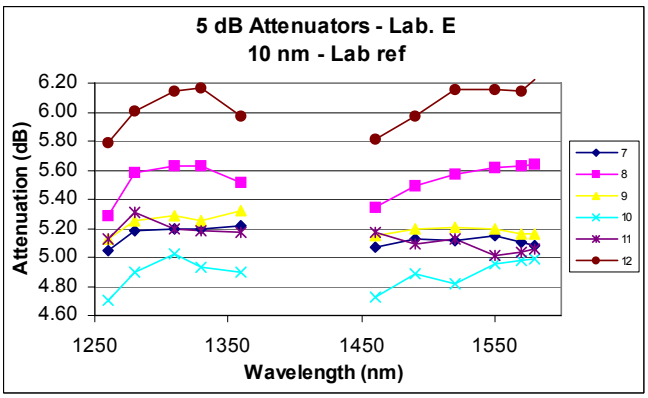
a) 15 dB attenuations – Lab. E – Common reference



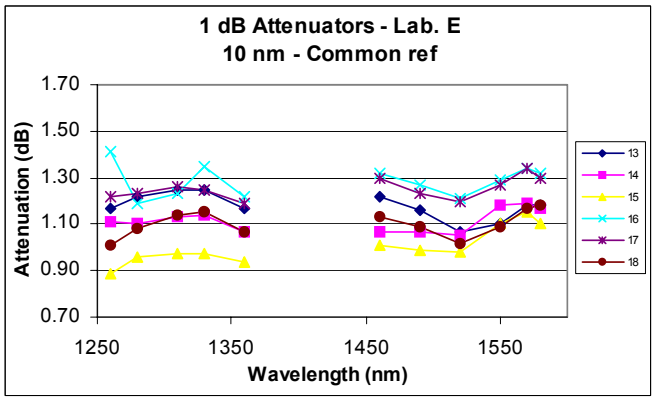
b) 15 dB attenuations – Lab. E – Laboratory reference



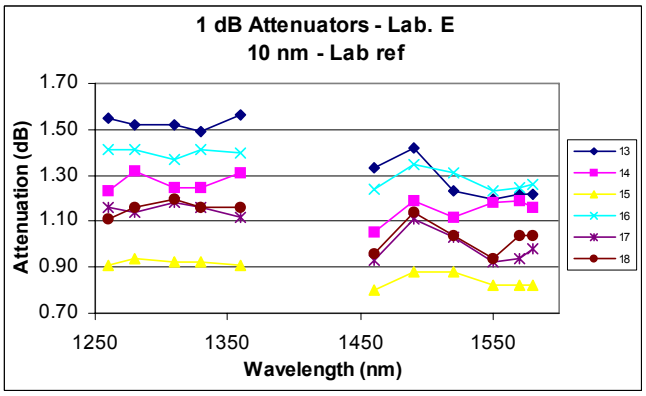
c) 5 dB attenuations – Lab. E – Common reference



d) 5 dB attenuations – Lab. E – Laboratory reference



e) 1 dB attenuations – Lab. E – Common reference



f) 1 dB attenuations – Lab. E – Laboratory reference

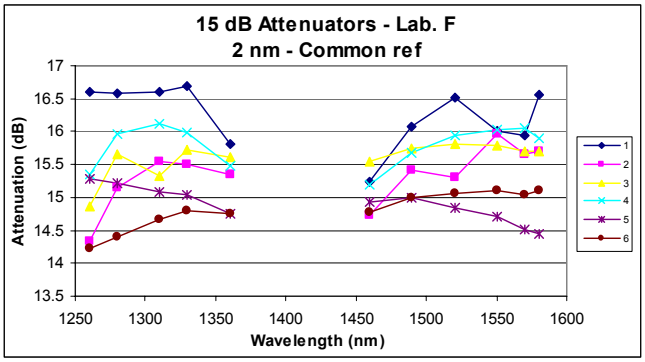
Figure A.7 – Laboratory E results with 10 nm resolution

Table A.4 – PDL measurements from laboratory E

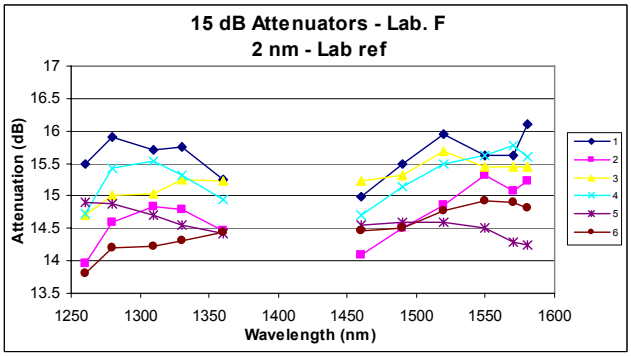
	LABORATORY E - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.40	0.20	0.25	0.18	0.17	0.23	0.10	0.10	0.08	0.09	0.10	0.09	0.11	0.08	0.10	0.16	0.09	0.12
1550 nm	0.17	0.18	0.17	0.13	0.13	0.11	0.05	0.05	0.04	0.05	0.04	0.07	0.04	0.04	0.04	0.05	0.04	0.08

A.6 Laboratory F results

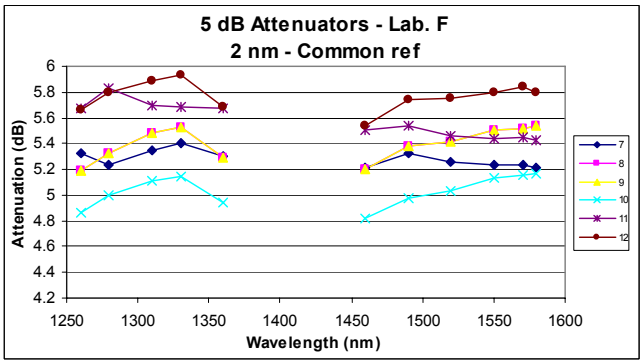
Laboratory F made spectral measurements with a 2 nm and 10 nm resolution. The attenuation results for all attenuators are shown in Figure A.8 (2 nm resolution) and Figure A.9 (10 nm resolution). PDL measurements at 1 310 nm and 1 550 nm are shown in Table A.5.



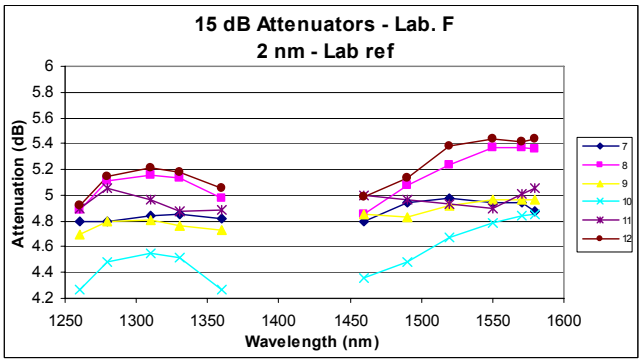
a) 15 dB attenuations – Lab. F – Common reference



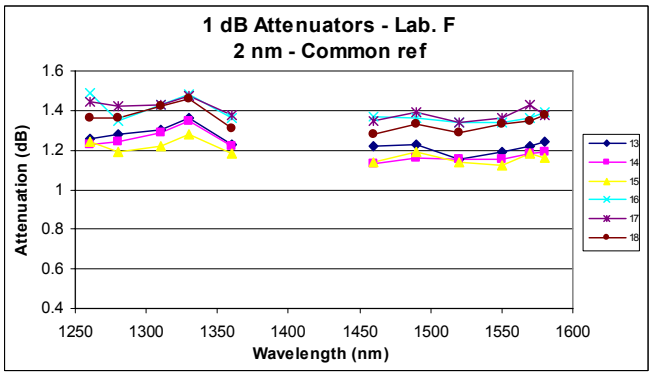
b) 15 dB attenuations – Lab. F – Laboratory reference



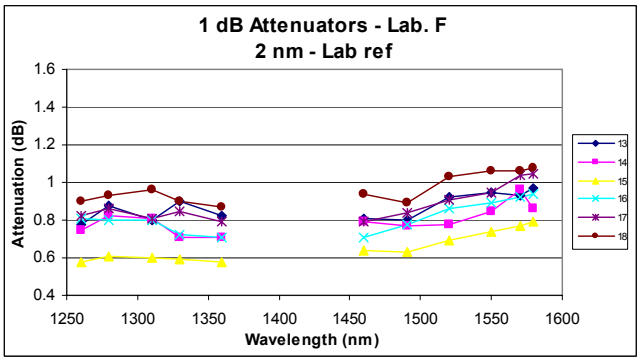
c) 5 dB attenuations – Lab. F – Common reference



d) 5 dB attenuations – Lab. F – Laboratory reference

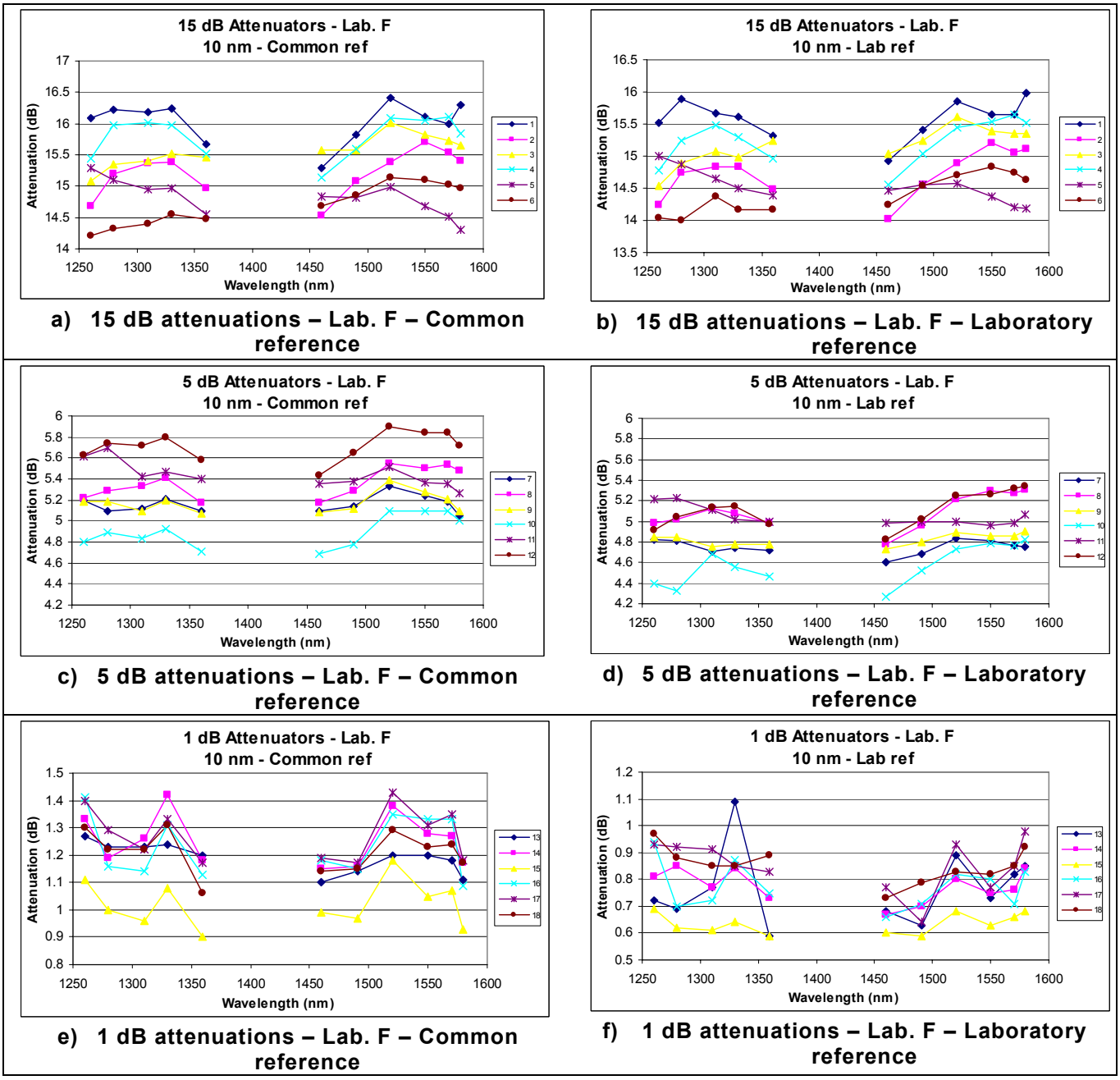


e) 1 dB attenuations – Lab. F – Common reference



f) 1 dB attenuations – Lab. F – Laboratory reference

Figure A.8 – Laboratory F results with 2 nm resolution



a) 15 dB attenuations – Lab. F – Common reference

b) 15 dB attenuations – Lab. F – Laboratory reference

c) 5 dB attenuations – Lab. F – Common reference

d) 5 dB attenuations – Lab. F – Laboratory reference

e) 1 dB attenuations – Lab. F – Common reference

f) 1 dB attenuations – Lab. F – Laboratory reference

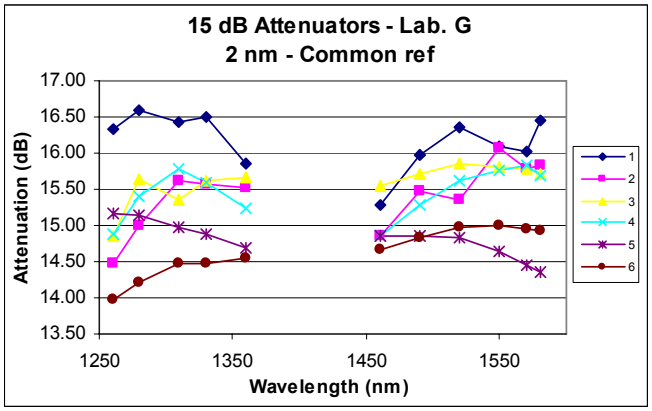
Figure A.9 – Laboratory F results with 10 nm resolution

Table A.5 – PDL measurements from Laboratory F

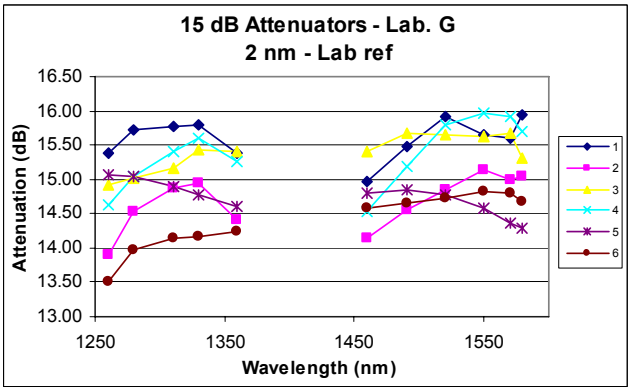
	Laboratory F - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.64	0.21	0.08	0.06	0.01	0.08	0.02	0.01	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.18	0.02	0.02
1550 nm	0.08	0.05	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

A.7 Laboratory G results

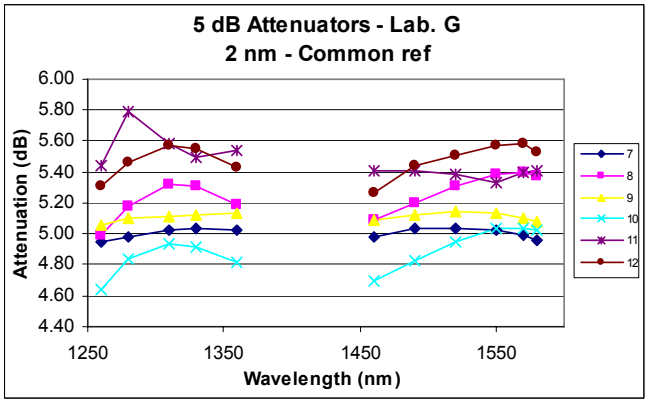
Laboratory G made spectral measurements with a 2 nm and 10 nm resolution. The attenuation results for all attenuators are shown in Figure A.10 (2 nm resolution) and Figure A.11 (10 nm resolution). PDL measurements at 1 310 nm and 1 550 nm are shown in Table A.6.



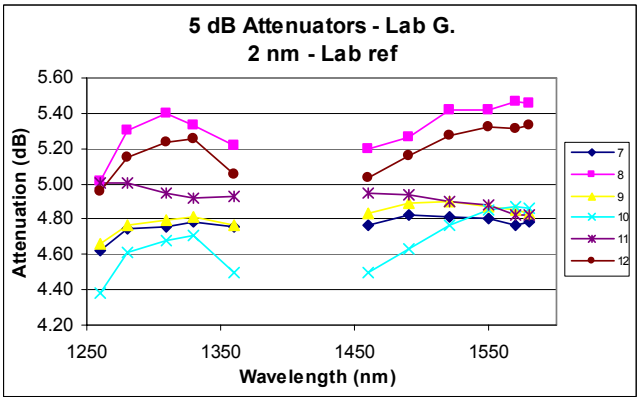
a) 15 dB attenuations – Lab. G – Common reference



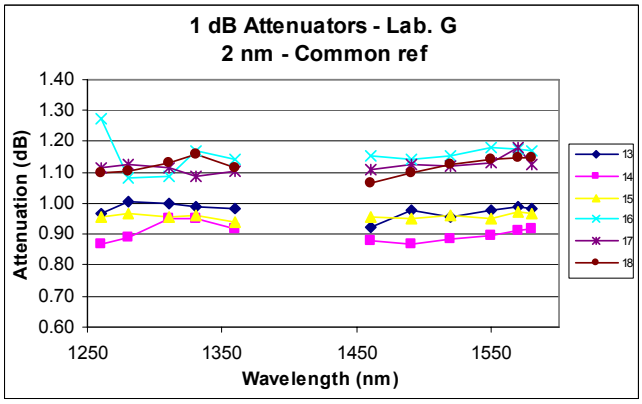
b) 15 dB attenuations – Lab. G – Laboratory reference



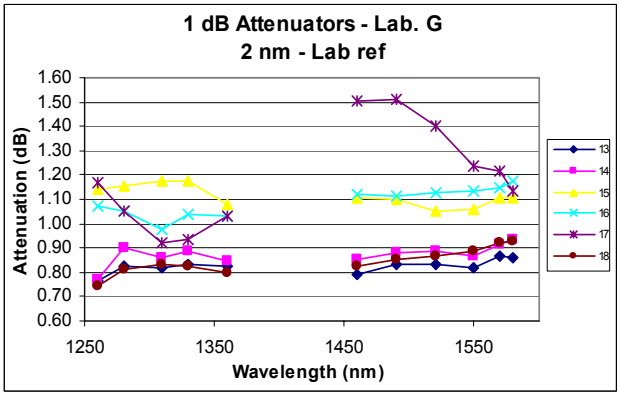
c) 5 dB attenuations – Lab. G – Common reference



d) 5 dB attenuations – Lab. G – Laboratory reference

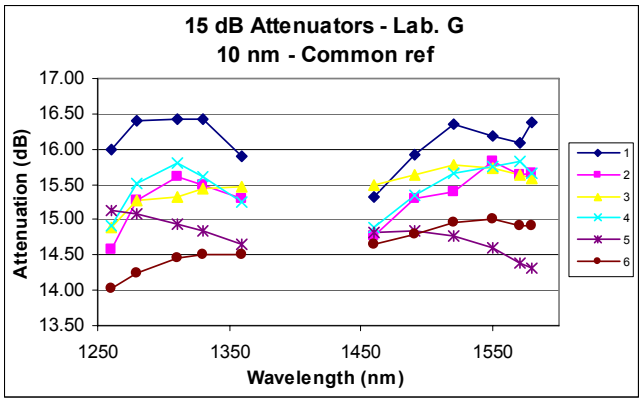


e) 1 dB attenuations – Lab. G – Common reference

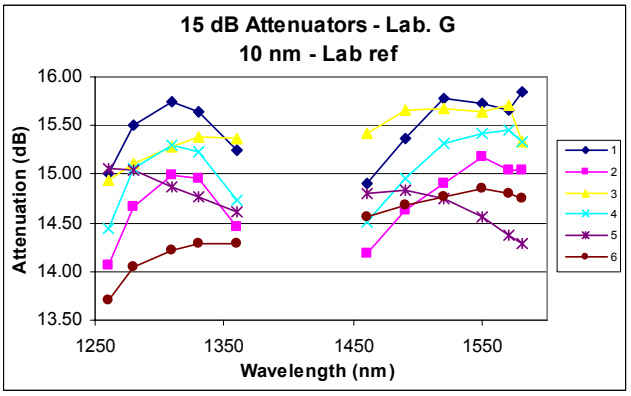


f) 1 dB attenuations – Lab. G – Laboratory reference

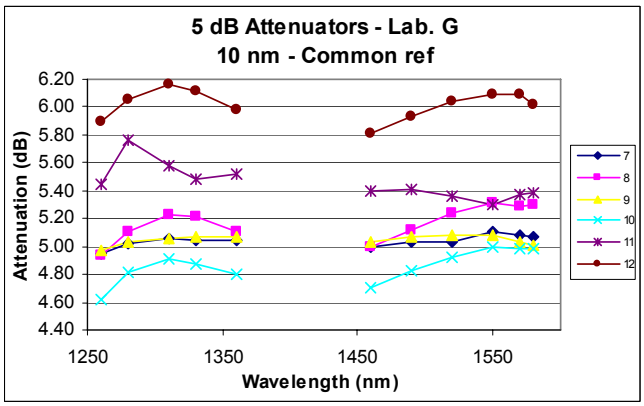
Figure A.10 – Laboratory G results with 2 nm resolution



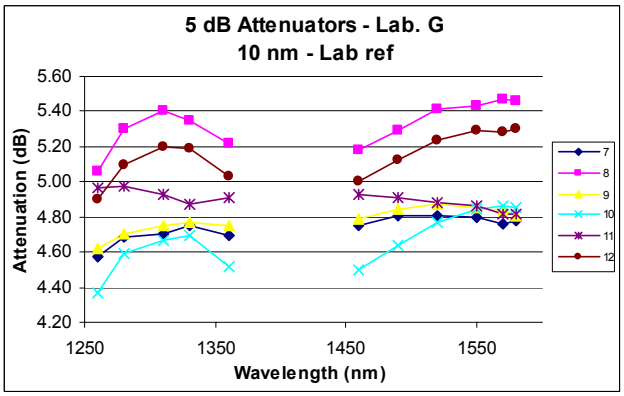
a) 15 dB attenuations – Lab. G – Common reference



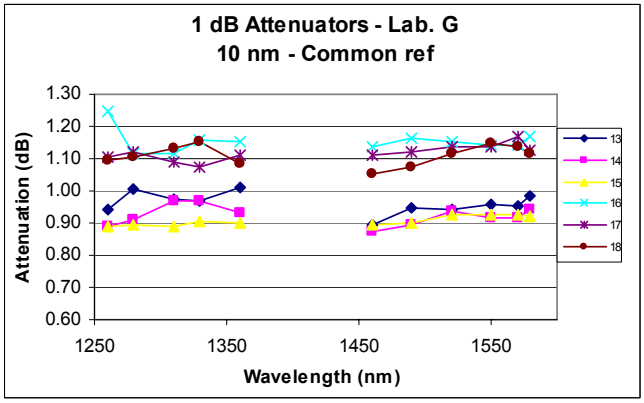
b) 15 dB attenuations – Lab. G – Laboratory reference



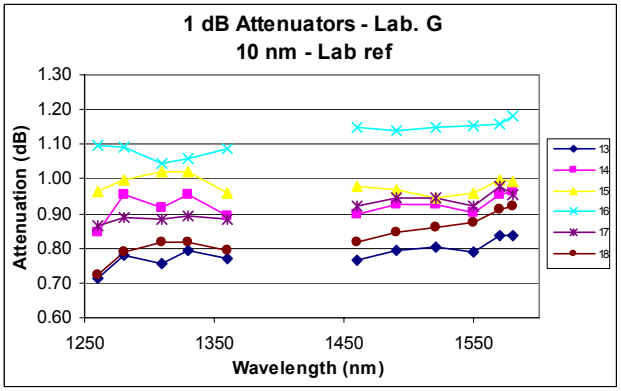
c) 5 dB attenuations – Lab. G – Common reference



d) 5 dB attenuations – Lab. G – Laboratory reference



e) 1 dB attenuations – Lab. G – Common reference



f) 1 dB attenuations – Lab. G – Laboratory reference

Figure A.11 – Laboratory G results with 10 nm resolution

Table A.6 – PDL measurements from laboratory G

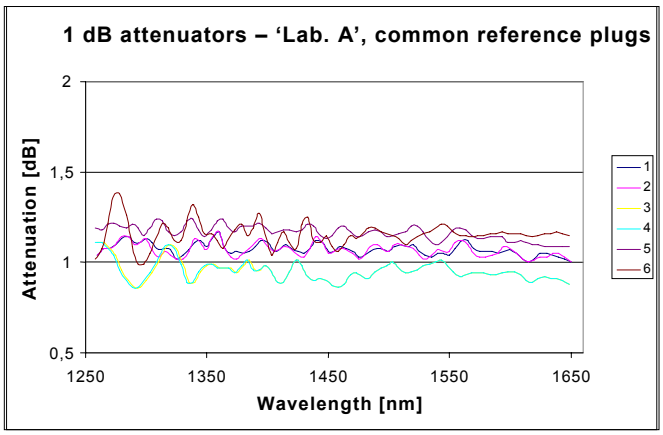
	LABORATORY G - PDL COMMON REF																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	0.22	0.09	0.03	0.03	0.01	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.01
1550 nm	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01

Annex B
(informative)

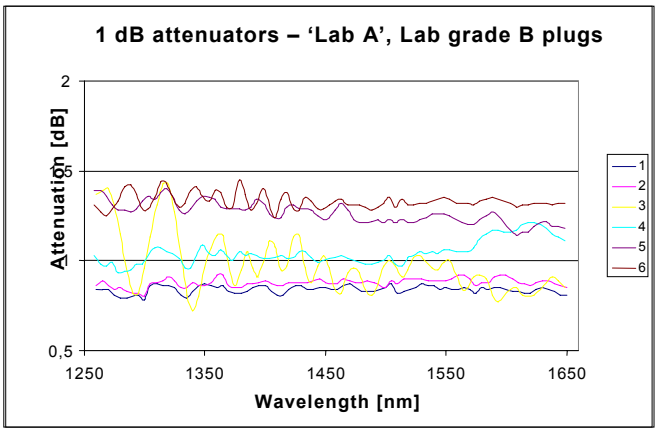
Individual test laboratory results of SC/APC plug style attenuators

B.1 Laboratory A results

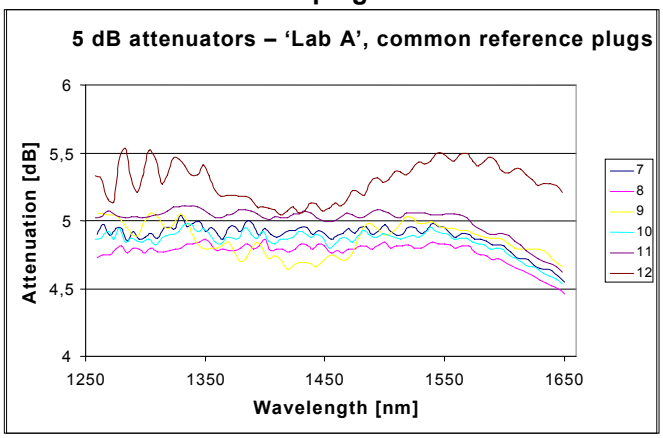
Figure B.1 shows the spectral insertion loss measurements results. Figure B.2 shows LED insertion loss measurements results. Table B.1 lists PDL measurements at 1 310 nm and 1 550 nm.



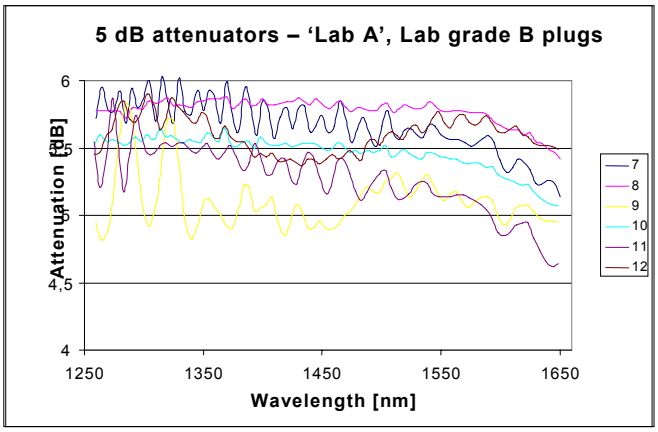
a) 1 dB attenuators – Lab. A – Common reference plugs



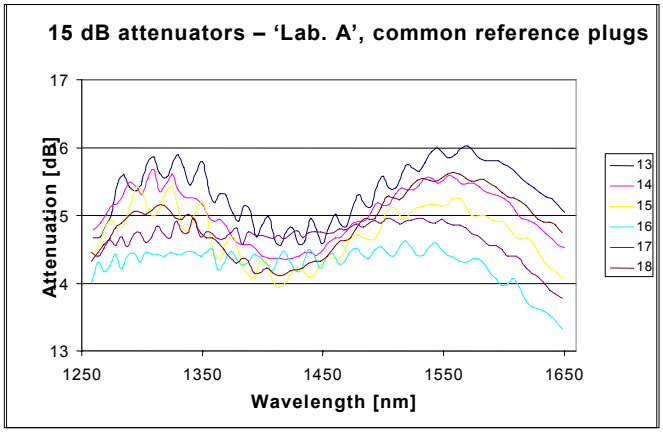
b) 1 dB attenuators – Lab. A – Laboratory grade B plugs



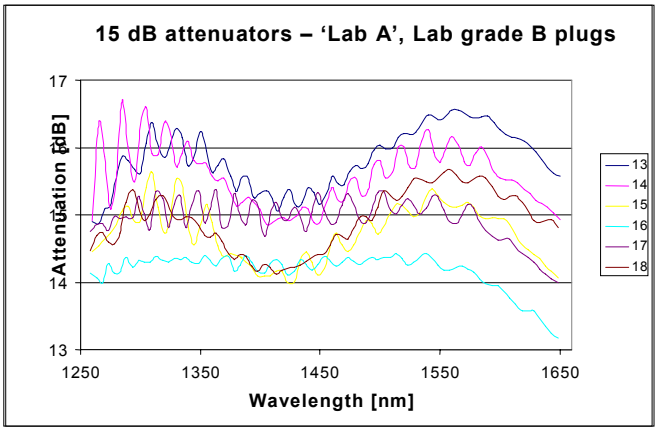
c) 5 dB attenuators – Lab. A – Common reference plugs



d) 5 dB attenuators – Lab. A – Laboratory grade B plugs

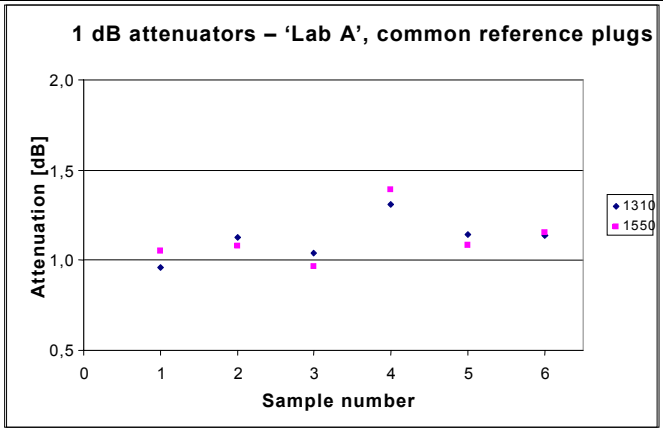


e) 15 dB attenuators – Lab. A – Common reference plugs

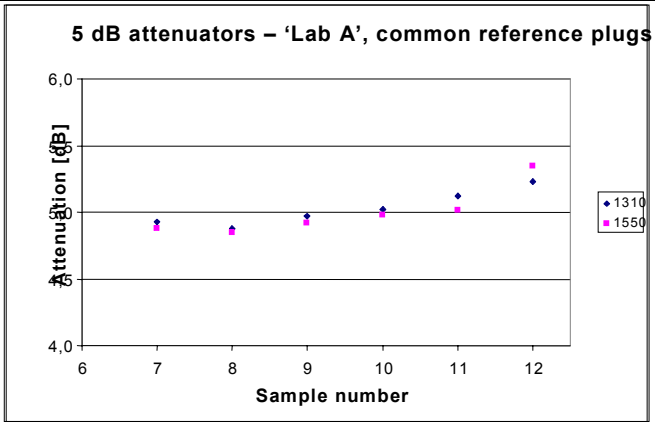


f) 15 dB attenuators – Lab. A – Laboratory grade B plugs

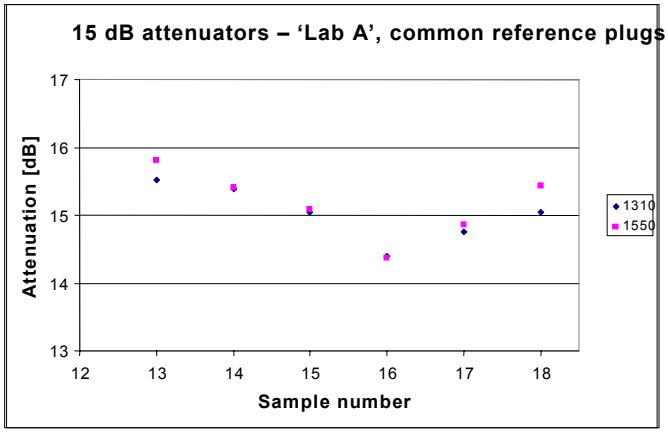
Figure B.1 – Laboratory A results – Spectral measurements



a) 1 dB attenuators – Lab. A – Common reference plugs



b) 5 dB attenuators – Lab. A – Common reference plugs



c) 15 dB attenuators – Lab. A – Common reference plugs

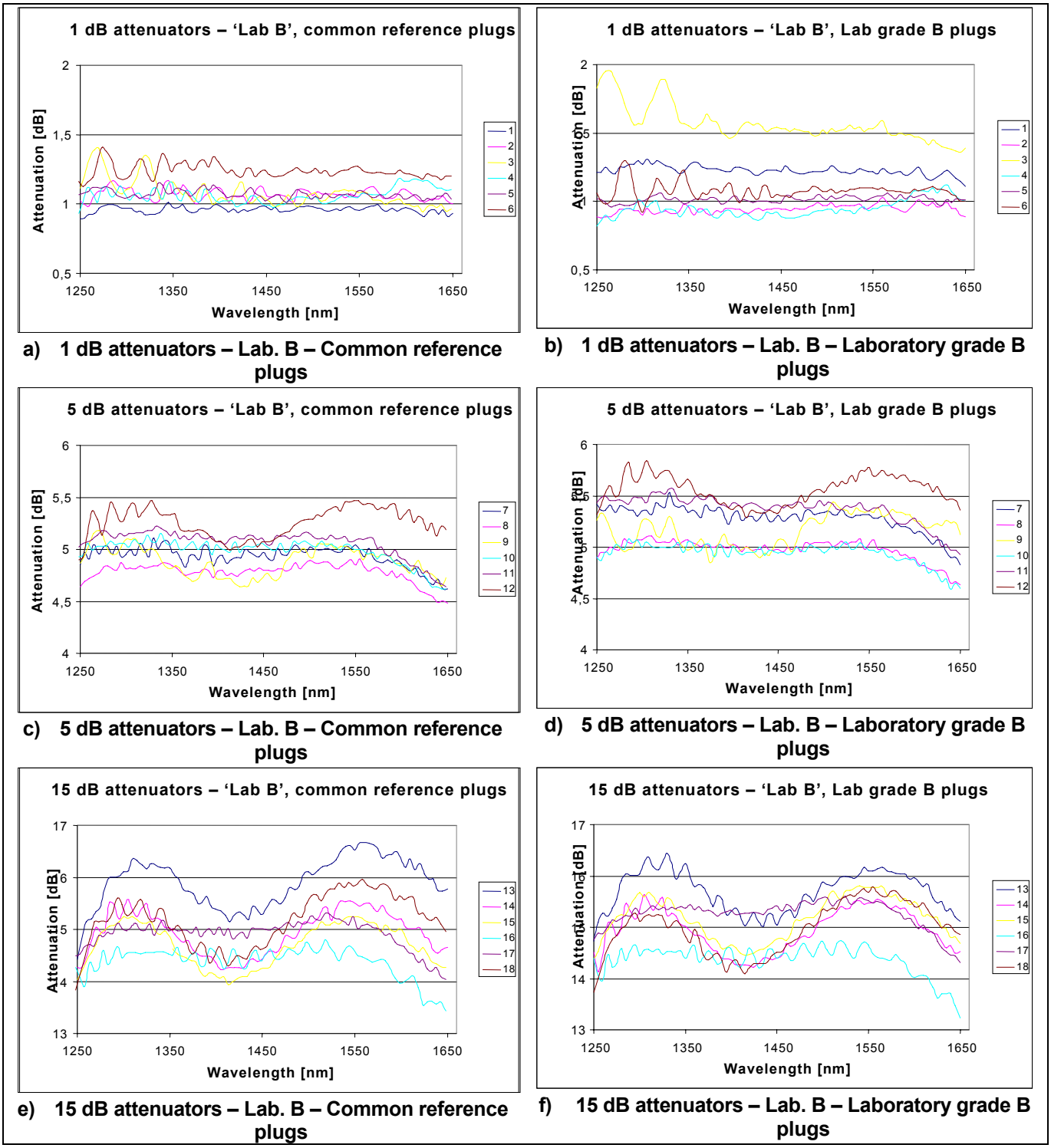
Figure B.2 – Laboratory A results – LED measurements

Table B.1 – PDL measurements from Laboratory A

	Lab. A – PDL measurements, common reference plugs																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 310 nm	0,02	0,02	0,12	0,18	0,04	0,16	0,02	0,01	0,11	0,01	0,01	0,25	0,26	0,27	0,26	0,03	0,02	0,04
1 550 nm	0,02	0,03	0,01	0,03	0,04	0,02	0,02	0,02	0,04	0,03	0,03	0,02	0,06	0,03	0,06	0,10	0,05	0,04

B.2 Laboratory B results

Figure B.3 shows the spectral insertion loss measurements results. Figure B.4 shows LED insertion loss measurements results. Table B.2 lists PDL measurements at 1 310 nm and 1 550 nm.



a) 1 dB attenuators – Lab. B – Common reference plugs

b) 1 dB attenuators – Lab. B – Laboratory grade B plugs

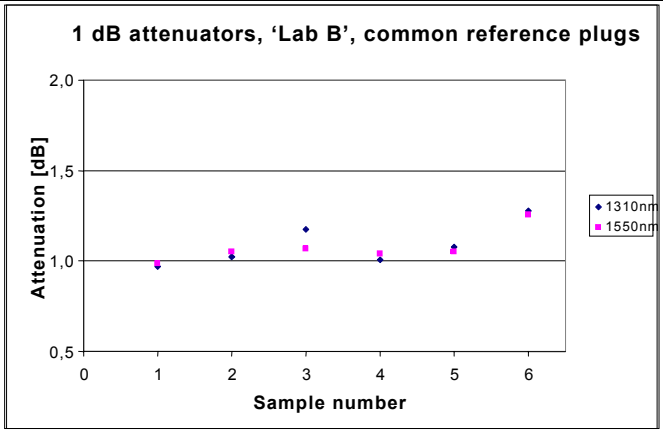
c) 5 dB attenuators – Lab. B – Common reference plugs

d) 5 dB attenuators – Lab. B – Laboratory grade B plugs

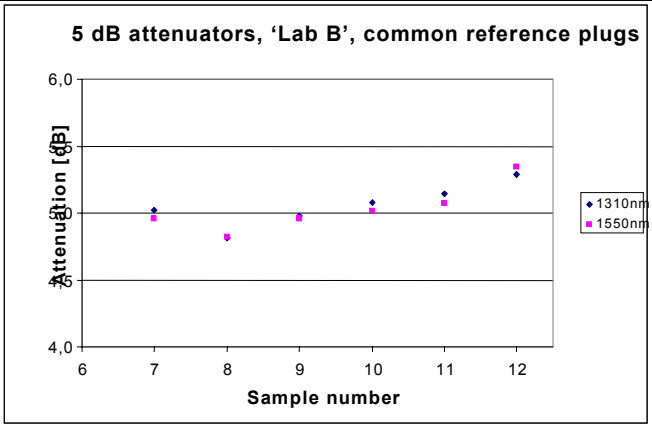
e) 15 dB attenuators – Lab. B – Common reference plugs

f) 15 dB attenuators – Lab. B – Laboratory grade B plugs

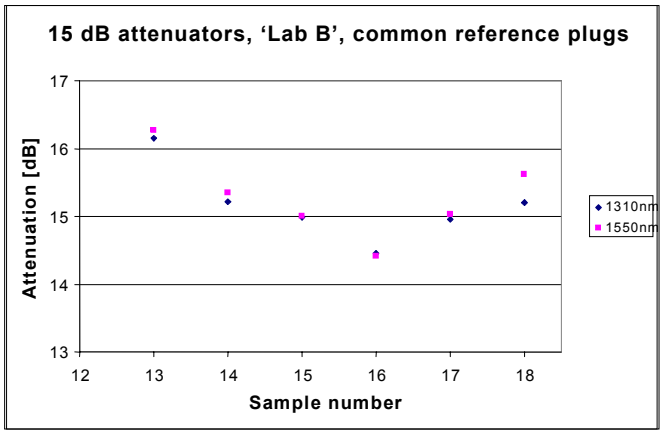
Figure B.3 – Laboratory B results – Spectral measurements



a) 1 dB attenuators – Lab. B – Common reference plugs



b) 5 dB attenuators – Lab. B – Common reference plugs



c) 15 dB attenuators – Lab. B – Common reference plugs

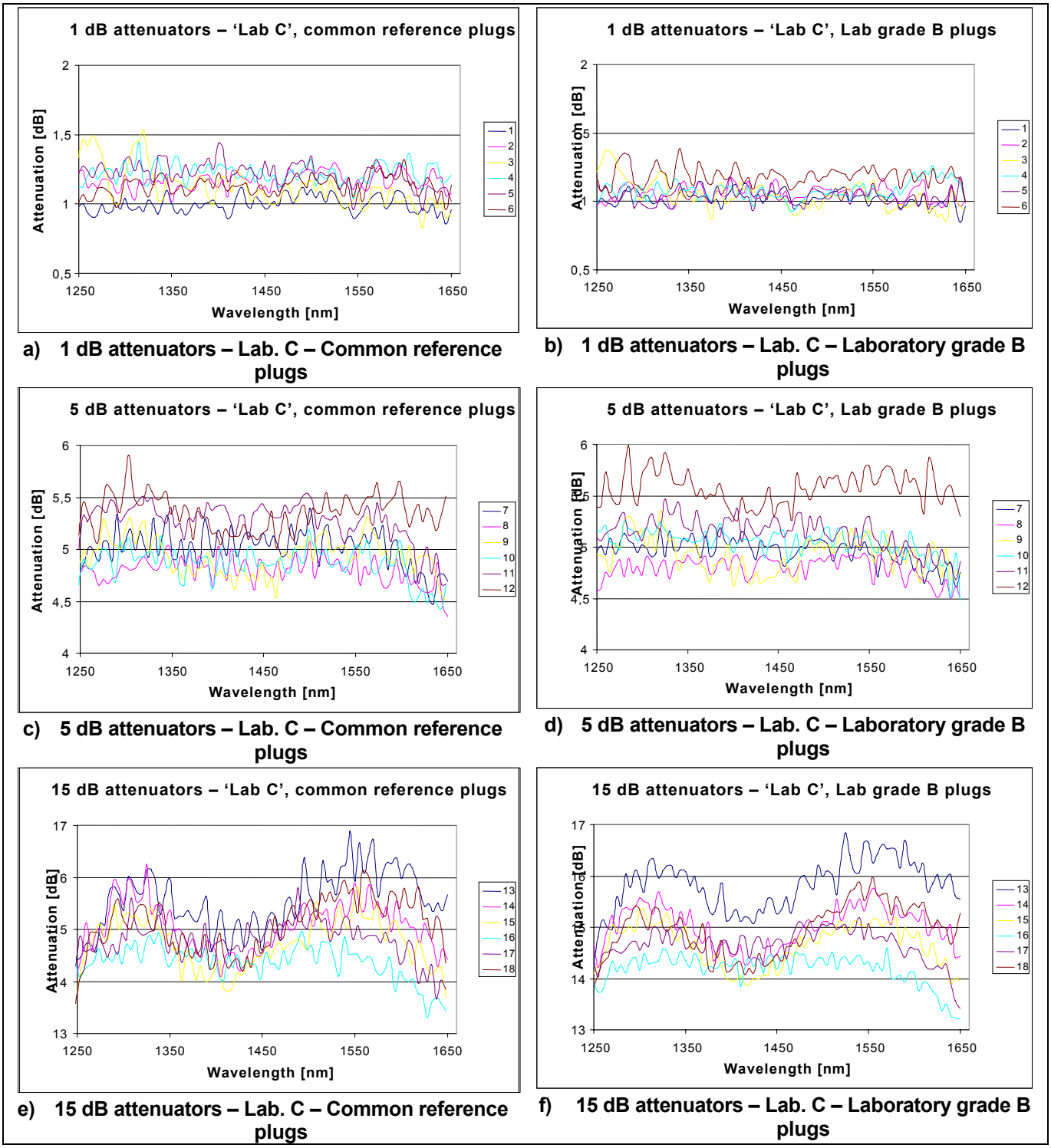
Figure B.4 – Laboratory B results – LED measurements

Table B.2 – PDL measurements from Laboratory B

	Lab. B – PDL measurements, common reference plugs																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1310 nm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1550 nm	0,04	0,02	0,02	0,01	0,02	0,02	0,04	0,01	0,03	0,01	0,01	0,02	0,09	0,04	0,08	0,09	0,04	0,03

B.3 Laboratory C results

Figure B.5 shows the spectral insertion loss measurements results. Figure B.6 shows LED insertion loss measurements results. Table B.3 lists PDL measurements at 1 310 nm and 1 550 nm.



a) 1 dB attenuators – Lab. C – Common reference plugs

b) 1 dB attenuators – Lab. C – Laboratory grade B plugs

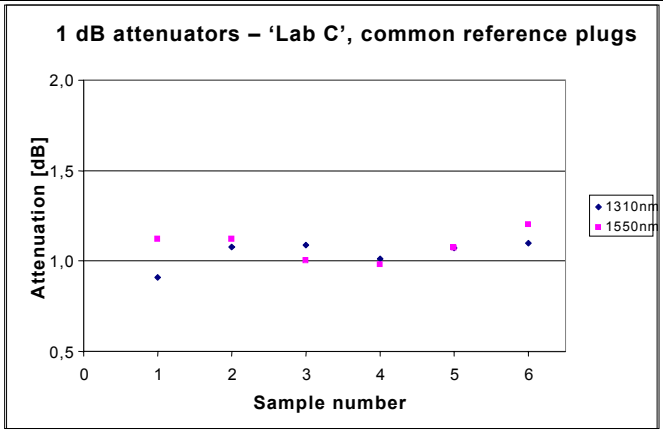
c) 5 dB attenuators – Lab. C – Common reference plugs

d) 5 dB attenuators – Lab. C – Laboratory grade B plugs

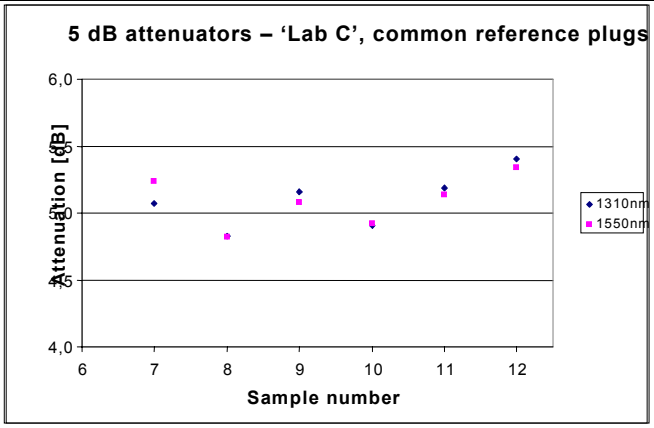
e) 15 dB attenuators – Lab. C – Common reference plugs

f) 15 dB attenuators – Lab. C – Laboratory grade B plugs

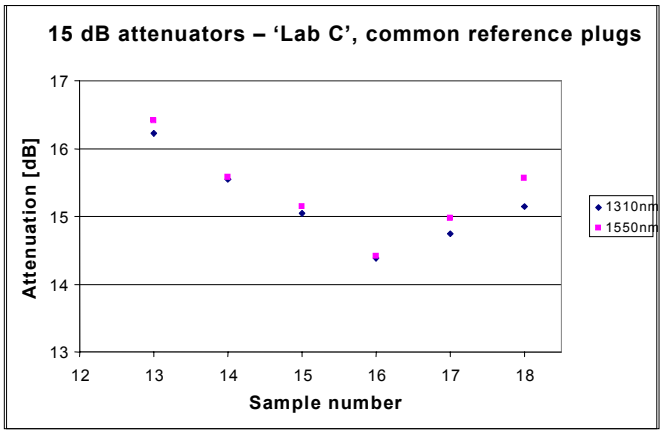
Figure B.5 – Laboratory C results – Spectral measurements



a) 1 dB attenuators – Lab. C – Common reference plugs



b) 5 dB attenuators – Lab. C – Common reference plugs



c) 15 dB attenuators – Lab. C – Common reference plugs

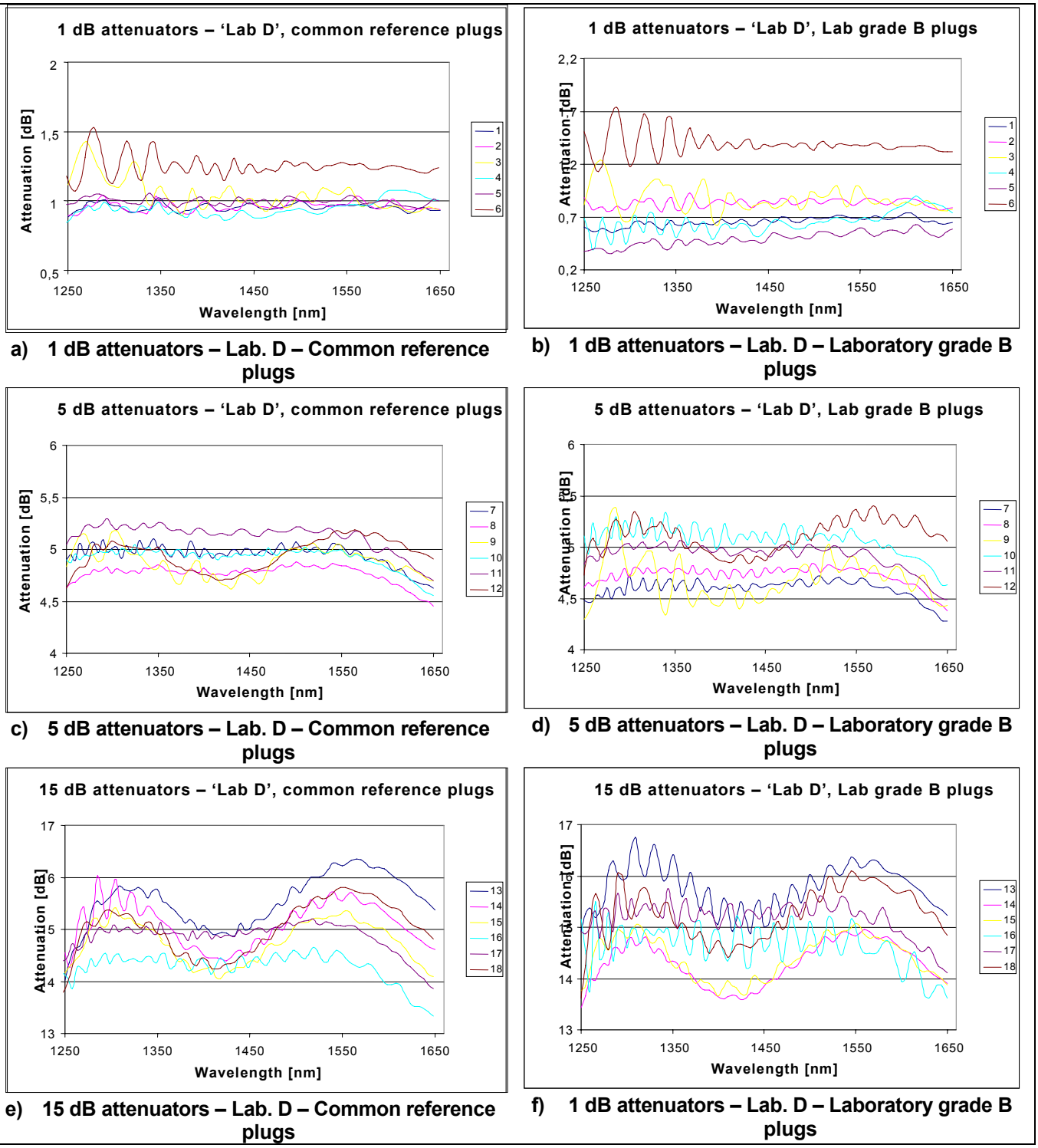
Figure B.6 – Laboratory C results – LED measurements

Table B.3 – PDL measurements from Laboratory C

	Lab. C – PDL measurements, common reference plugs																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1 310 nm	0,02	0,02	0,08	0,07	0,04	0,13	0,03	0,02	0,23	0,01	0,03	0,23	0,26	0,29	0,11	0,10	0,05	0,31
1 550 nm	0,01	0,01	0,02	0,01	0,01	0,01	0,02	0,02	0,03	0,02	0,03	0,01	0,10	0,07	0,02	0,03	0,02	0,02

B.4 Laboratory D results

Figure B.7 shows the spectral insertion loss measurements results. Figure B.8 shows LED insertion loss measurements results. Table B.4 lists PDL measurements at 1 310 nm and 1 550 nm.



a) 1 dB attenuators – Lab. D – Common reference plugs

b) 1 dB attenuators – Lab. D – Laboratory grade B plugs

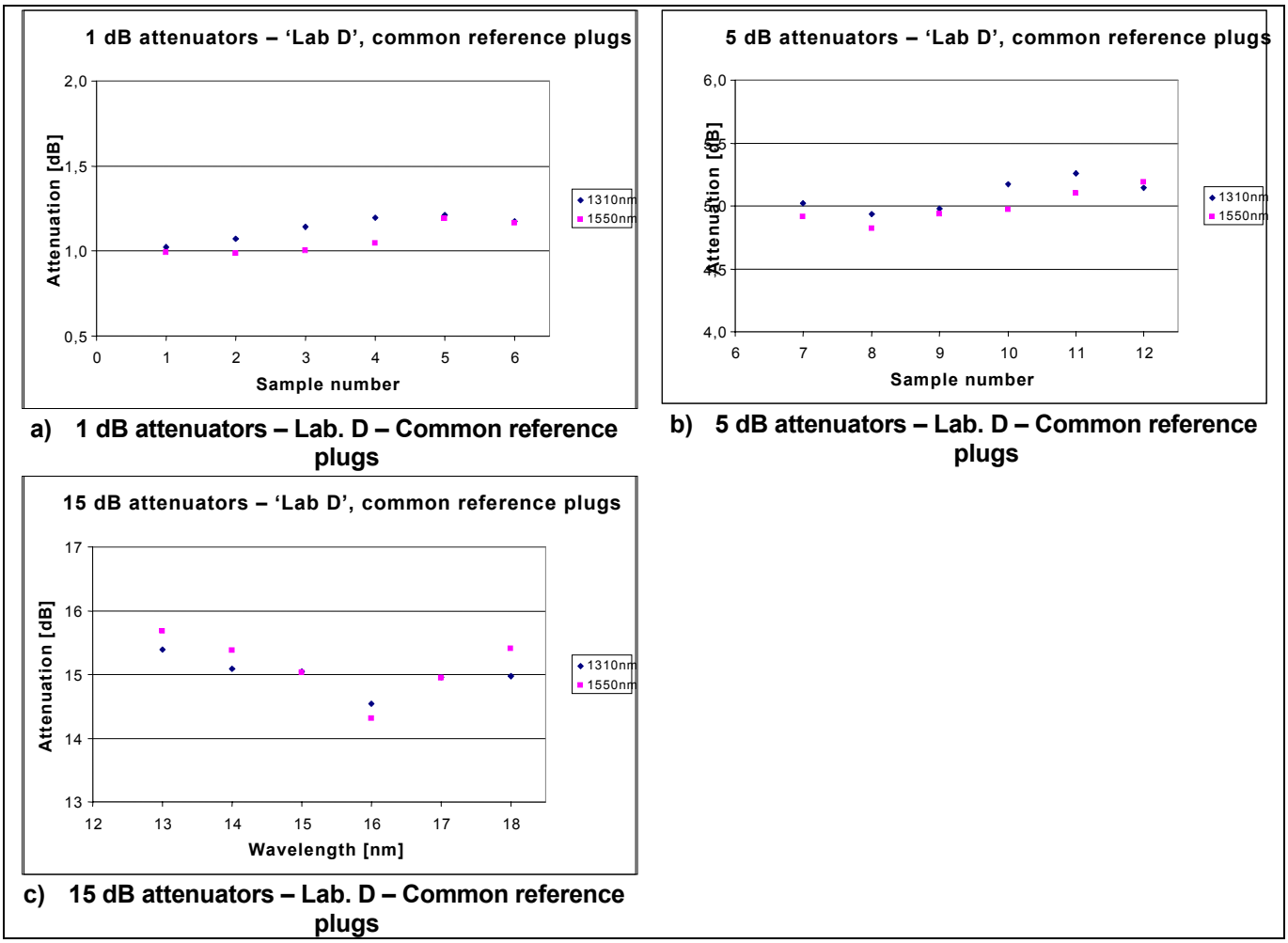
c) 5 dB attenuators – Lab. D – Common reference plugs

d) 5 dB attenuators – Lab. D – Laboratory grade B plugs

e) 15 dB attenuators – Lab. D – Common reference plugs

f) 1 dB attenuators – Lab. D – Laboratory grade B plugs

Figure B.7 – Laboratory D results – Spectral measurements



a) 1 dB attenuators – Lab. D – Common reference plugs

b) 5 dB attenuators – Lab. D – Common reference plugs

c) 15 dB attenuators – Lab. D – Common reference plugs

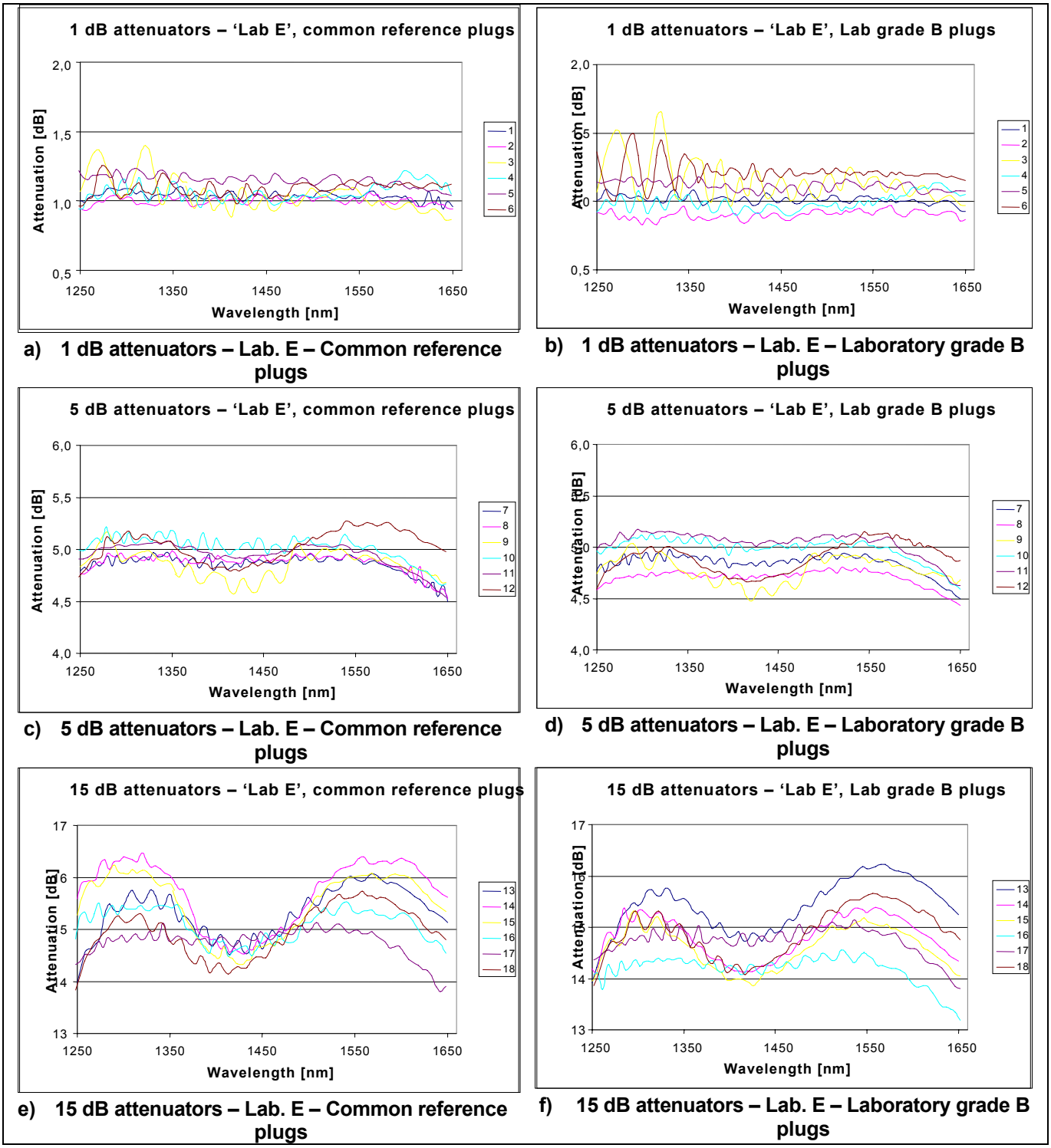
Figure B.8 – Laboratory D results – LED measurements

Table B.4 – PDL measurements from Laboratory D

	Lab. D – PDL measurements, common reference plugs																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 310 nm	0,01	0,01	0,17	0,06	0,04	0,07	0,04	0,01	0,12	0,01	0,02	0,05	0,24	0,21	0,08	0,02	0,03	0,03
1 550 nm	0,01	0,01	0,01	0,02	0,01	0,02	0,02	0,01	0,02	0,01	0,02	0,01	0,02	0,02	0,01	0,03	0,04	0,00

B.5 Laboratory E results

Figure B.9 shows the spectral insertion loss measurements results. Figure B.10 shows LED insertion loss measurements results. Table B.5 lists PDL measurements at 1 310 nm and 1 550 nm.



a) 1 dB attenuators – Lab. E – Common reference plugs

b) 1 dB attenuators – Lab. E – Laboratory grade B plugs

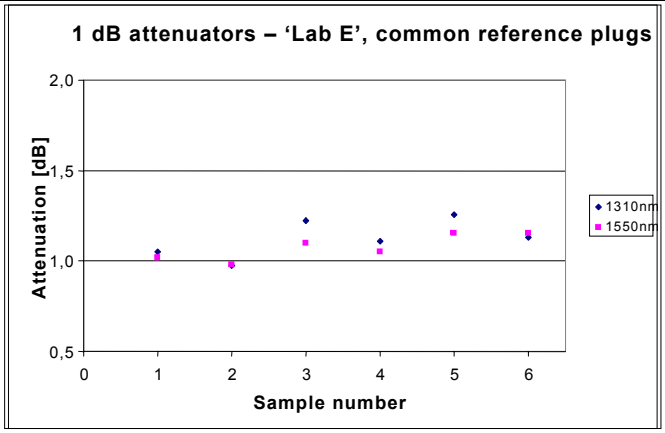
c) 5 dB attenuators – Lab. E – Common reference plugs

d) 5 dB attenuators – Lab. E – Laboratory grade B plugs

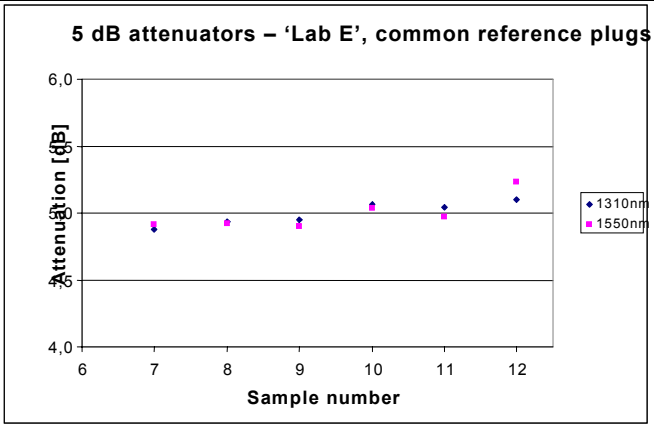
e) 15 dB attenuators – Lab. E – Common reference plugs

f) 15 dB attenuators – Lab. E – Laboratory grade B plugs

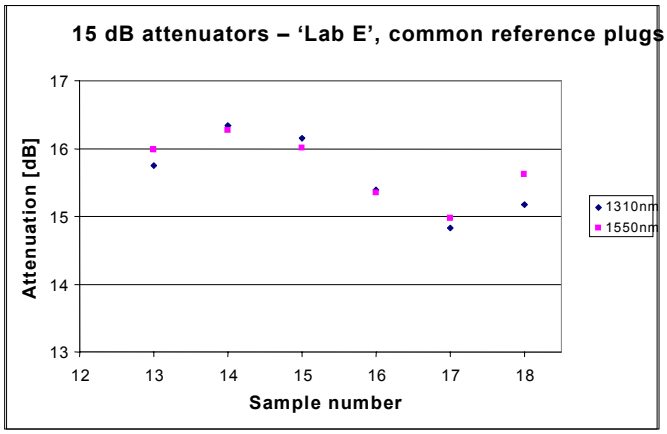
Figure B.9 – Laboratory E results – Spectral measurements



a) 1 dB attenuators – Lab. E – Common reference plugs



b) 5 dB attenuators – Lab. E – Common reference plugs



c) 15 dB attenuators – Lab. E – Common reference plugs

Figure B.10 – Laboratory E results – LED measurements

Table B.5 – PDL measurements from Laboratory E

	Lab. E – PDL measurements, common reference plugs																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 310 nm	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,01	0,02	0,01	0,06	0,04	0,01	0,05	0,03	0,01
1 550 nm	0,01	0,01	0,09	0,05	0,01	0,04	0,01	0,02	0,08	0,02	0,01	0,04	0,15	0,24	0,05	0,05	0,06	0,12

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