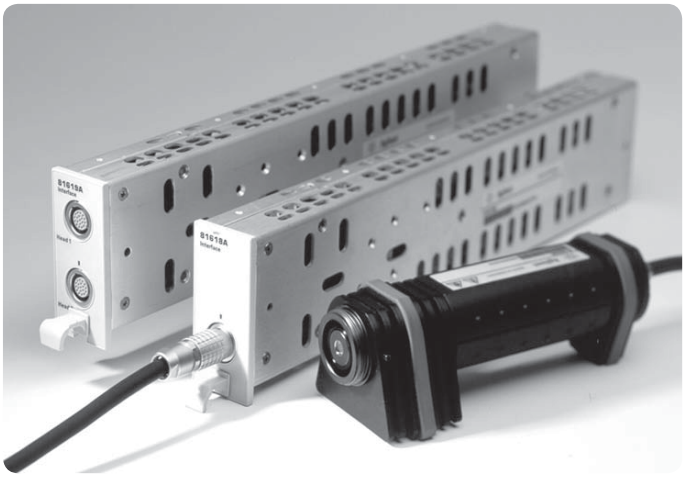
Agilent
Optical Power Meter Head Special Calibration

Data Sheet

January 2010

This document describes the calibration of Agilent's optical power meter heads (81623B, 81624B, 81626B) for standard products as well as the "special calibrations" C01, C02, C85, C86, and the calibration carried out at the German PTB, C05. The factory's Metrology Laboratory in Germany carries out these special calibrations on selected heads.



Agilent Technologies

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1. Agilent's Optical Power Meter Heads

Agilent Technologies offers a number of attractive solutions for optical power measurement.

All of them use the 816x mainframe family as the host for a number of plug-ins. These optical power meters feature firmware-corrected range discontinuities for best linearity, variable averaging time, data logging, min-max and stability applications.

The most versatile and accurate optical power meters come in the form of optical heads connected to interface modules, 81618A or 81619A.

The optical heads are temperature stabilized. The spectral responsivity data (Figure 1) is stored in the head, in steps of 2 nm.

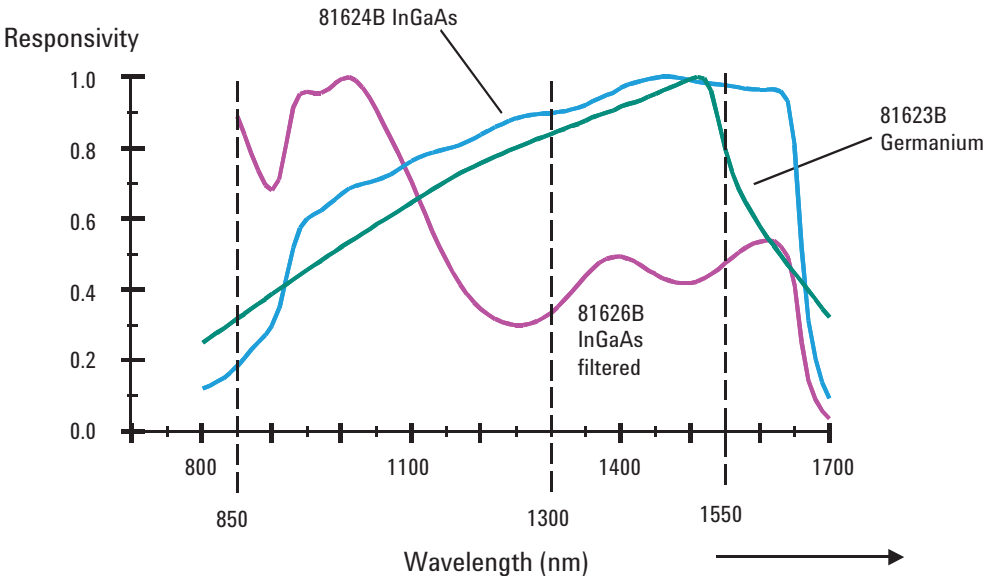

Figure 1. Spectral responsivity of different detector types (normalized)

Two detector types are available:

- Ge detectors offer excellent performance over a wavelength range from 800 nm to 1550 nm at low cost.
- InGaAs detectors have very low wavelength dependence at both 1300 nm and 1550 nm, combined with excellent sensitivity.

All Agilent optical heads have detectors of 5 mm diameter.

2. Calibration Chain, Traceability, Uncertainty

Agilent's traceability chain for spectral responsivity is shown in Figure 2.

Level 0: The calibration chain starts at the Physikalisch-Technische Bundesanstalt (PTB), the German national measurement institute. The PTB uses thermopile radiometers, because of their flat wavelength dependence and low reflectance.

Level 1: The PTB calibrates Agilent's reference standards in regular intervals as well as the option C05 power meters.

Agilent's reference standards are electrically calibrated pyroelectric radiometers (ECPRs). They exhibit similar characteristics to thermopile radiometers.

Level 2: Metrology Lab working standards.

Level 3: Working standards used:
- For special calibrations in the Agilent's Optical Metrology Laboratory,
- In production for the calibration of commercial power meters,
- As working standards for Agilent's service organization.

Level 3: Commercial power meters.
The working standards and Agilent's commercial power meters are based on Ge and InGaAs photodetectors.

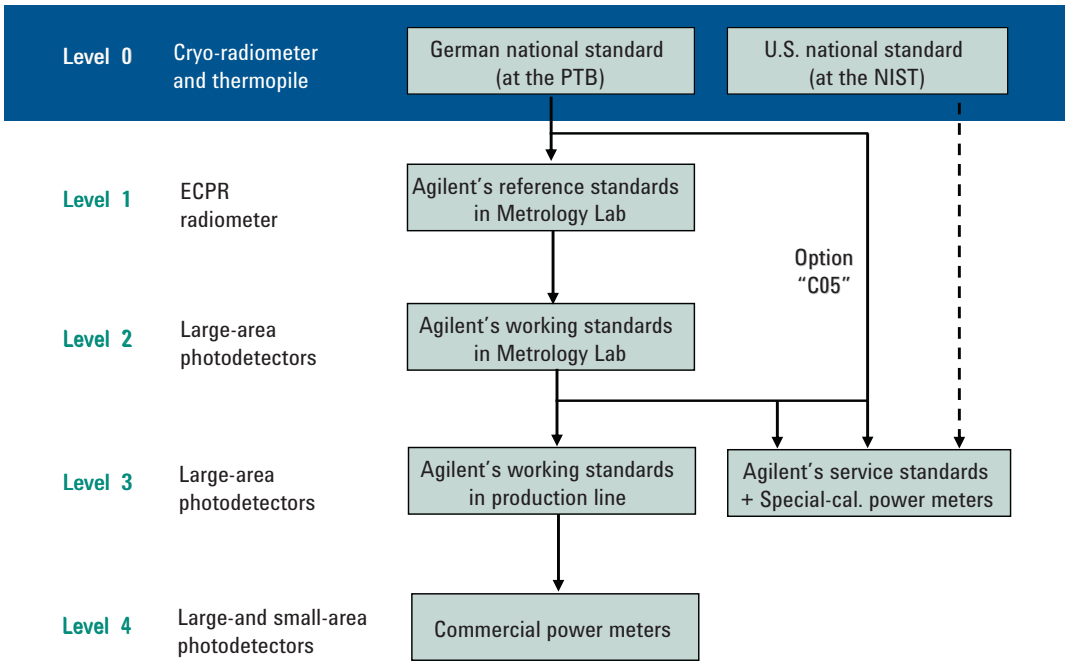

Figure 2. Agilent's traceability chain for optical power meters

Direct traceability to the PTB has been established and is maintained. International traceability is given because the PTB compares its scale with other national laboratories, such as NIST (USA), NPL (UK) and JMI (Japan), on a regular basis. Test results were published in Ref. [1] and [2].

In various round-robin comparisons among US participants, the Agilent optical power scale has regularly shown deviations of less than 1%, usually less than 0.5 %, from both the NIST scale and the average of the participants.

The method of characterizing and accumulating uncertainties is based on the IEC 61315 standard "Calibration of fiber-optic power meters" [3]. This takes into account the random and systematic uncertainties of all power meters and all transfer processes in the calibration chain according to GUM [5].

The special calibrations

- C01, C02 for 81623B, 81624B and 81626B
- C85, C86 for 81623B

  provide a significant improvement to this uncertainty.

These special calibrations are compliant to ISO/IEC 17025:2005.

3. Calibration Methods and Equipment

Three different types of systems for spectral responsivity calibration are installed at Agilent's factory:

- Systems based on white-light sources and monochromator filtering, located in Agilent's Optical Metrology Laboratory and in the production line. These systems are capable of calibrating over the full applicable wavelength range.
- Laser-based calibration systems in Agilent's service organization can calibrate at selected wavelength points.
- A system based on tunable laser sources and single mode fibers in selected wavelength ranges. This system is used for special calibration option C05.

The monochromator systems in the factory consist of an electronically stabilized halogen lamp and a double monochromator for the selection of the wavelength. The spectral width is approximately 4 nm. At the output of the monochromator, a lens system creates an almost parallel open beam with a numerical aperture < 0.1.

During calibration, the test meter is compared to the applicable higher-level standard indicated in the traceability chain. This is done by sequential stimulation of both meters with the monochromator output. During the entire procedure, an optic-electronic feedback system ensures the stability of the lamp output.

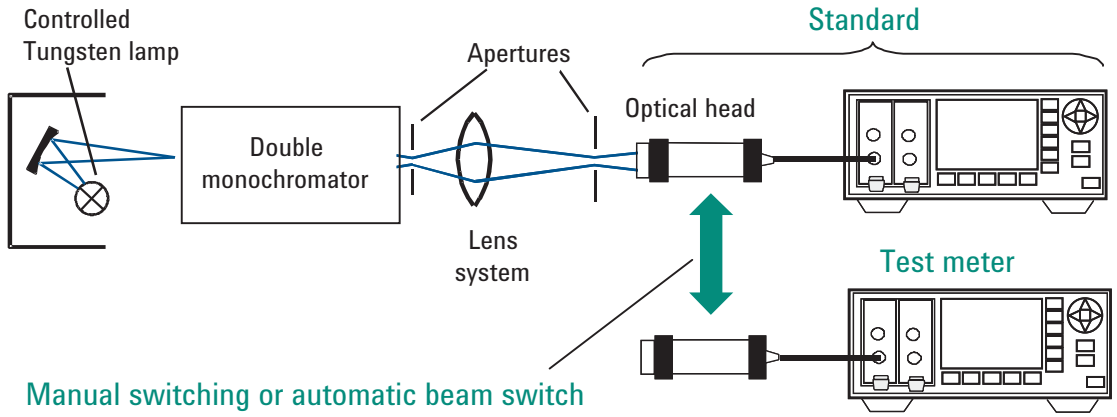

Figure 3. Spectral responsivity calibration at Agilent Technologies

Customers' power heads are (re-) adjusted for zero deviation by writing appropriate correction factors into the non-volatile memory of the optical heads.

4. Special Calibrations C01/C02, C85/C86

Calibration package

Agilent's optical heads 81623B, 81624B and 81626B are highly precise tools to measure optical power. The accuracy can be further increased by an additional head selection and special calibration. The result is a head that is calibrated with lower measurement uncertainty and having tighter specifications.

The special calibrated optical power meters are most attractive for high accuracy calibration purposes. The factory's Metrology Lab offers special calibrations, both for new power meters and power meters sent back for recalibration.

For order instructions see Chapter 6.

These options include the following package of measurements:

- Responsivity versus wavelength
- Linearity over the specified measurement range
- Spatial homogeneity over the detector's active area
- Certificate of calibration with a detailed measurement report

The calibration methods are described and comply with ISO/IEC 17025:2005 and ANSI/NCSL Z540-1. They are traceable to PTB (Germany).

Special recalibrations are carried out by the factory's Metrology Lab. Please note that standard point-type recalibrations are handled by the Agilent service centers.

Measurement parameters and result

Calibration C01 and C02 for 81623B, 81624B and 81626B

Spectral responsivity	
Wavelength	
81623B	750 nm to 1800 nm
81624B	800 nm to 1700 nm
81626B	850 nm to 1650 nm
Step width	10 nm
Power level (nominal)	10 µW (–20 dBm)
Beam geometry	Collimated beam ∅ 3 mm
Measurement uncertainty	
81623B	±1.7% (1000 nm to 1650 nm)
81624B	±1.5% (970 nm to 1630 nm)
81626B	±2.5% (950 nm to 1630 nm)
Certificate	Includes deviations data: on receipt and after adjustment

Non-linearity	
Wavelength	
81623B, 81624B	1300 nm and 1550 nm
81626B	1550 nm
Measurement range	
81623B	1 nW to 10 mW (–60 dBm to +10 dBm)
81624B	100 pW to 10 mW (–70 dBm to +10 dBm)
81626B	20 nW to 500 mW (–50 dBm to +27 dBm), only at 1550 nm
Reference power level (nominal)	10 µW (–20 dBm)
Step size	3 dB
Beam geometry	Divergent beam from SM fiber with NA = 0.1
Measurement uncertainty	
81623B	±0.30%
81624B	±0.30%
81626B	±0.30% up to +10 dBm, ±0.50% up to +20 dBm, ±0.70% up to +27 dBm
Test limit	
81623B	±0.40%
81624B	±0.30%
81626B	±0.50% up to +10 dBm, ±1.8% at 20 dBm[1], ±6.8% at 27 dBm[1]
Certificate	Includes data of measured nonlinearities and uncertainties

Sensor homogeneity	
Wavelength	1300 nm and 1550 nm
Power Level	10 µW (–20 dBm)
Scanning Range	5 mm x 5 mm
Step size	0.25 mm
Beam geometry	Focused beam, ∅ 0.5 mm
Measurement uncertainty	±0.25%
Test limit	1.75% p-p for spot center within a concentric circle of ∅ 3.5 mm
Certificate	Includes data of spatial responsivity relative to the center of the detector, and three-dimensional plots of the relative responsivity.

1. Using adapter Agilent 81000AF

Calibration C85 and C86 for 81623B

Spectral responsivity	
Wavelength	750 nm to 1800 nm
Step width	10 nm
Power level	10 µW (–20 dBm)
Beam geometry	Collimated beam ∅ 3 mm
Measurement uncertainty	±2.5% (800 nm to 1000 nm) ±2.2% (1000 nm to 1650 nm)
Certificate	Includes deviations data: on receipt and after adjustment

Non-linearity	
Wavelength	850 nm and 1300 nm
Measurement range	18 nW to 1.8 mW (–47 dBm to + 3 dBm)
Reference power level	10 µW (–20 dBm)
Step size	3 dB
Beam geometry	Collimated beam ∅ 3 mm for 850 nm Divergent beam from SM fiber with NA = 0.1 for 1300 nm
Measurement uncertainty	±0.30%
Test limit	±0.40%
Certificate	Includes data of measured nonlinearities and uncertainties

Sensor homogeneity	
Wavelength	850 nm and 1300 nm
Power Level	10 µW (–20 dBm)
Scanning Range	5 mm x 5 mm
Step size	0.25 mm
Beam geometry	Focused beam, ∅ 0.5 mm
Measurement uncertainty	±0.25%
Test limit	1300 nm: 1.75% p-p for spot center within a concentric circle of ∅ 3.5 mm 850 nm: 4.5% p-p for spot center within a concentric circle of ∅ 3.5 mm
Certificate	Includes data of spatial responsivity relative to the center of the detector, and three-dimensional plots of the relative responsivity.

Optical Head Special Calibration 81623B Option C01, C02, C85 and C86

Product specifications

All optical heads have to be operated with the single (Agilent 81618A) or dual (Agilent 81619A) Interface Modules.

	Agilent 81623B	Agilent 81623B Calibration Option C85/C86	Agilent 81623B Calibration Option C01/C02
Sensor element	Ge, ∅ 5 mm		
Wavelength range	750 nm to 1800 nm		
Power range	–80 dBm to +10 dBm		
Applicable fiber type Open beam	Standard SM and MM max 100 µm core size, NA ≤ 0.3 Parallel beam max ∅ 4 mm		
Uncertainty at reference conditions [1]	±2.2% (1000 nm to 1650 nm) ±3.0% typ. (800 nm to 1000 nm)	±2.2% (1000 nm to 1650 nm) ±2.5% (800 nm to 1000 nm)	±1.7% (1000 nm to 1650 nm) ±3.0% typ. (800 nm to 1000 nm)
Total uncertainty [2, 9]	±3.5% ± 100 pW (1000 nm to 1650 nm) ±4.0% typ. ± 250 pW (800 nm to 1000 nm)	±3.5% ± 100 pW (1000 nm to 1650 nm) ±3.7% ±250 pW (800 nm to 1000 nm)	±3.0% ± 100 pW (1000 nm to 1650 nm) ±4.0% typ. ± 250 pW (800 nm to 1000 nm)
Relative uncertainty: • due to polarization[3] • spectral ripple (due to interference)[4]	< ±0.01 dB[10] (typ. < ±0.005 dB) < ±0.006 dB (typ. < ±0.003 dB)		
Linearity (power):[5] at 23 °C ±5 °C at operating temp. range	(CW –60 dBm to +10 dBm)[9] < ±0.025 dB < ±0.05 dB		
Return loss[7]	> 50 dB, typ. > 55 dB[8]		> 56 dB
Noise (peak to peak)[6]	< 100 pW (1200 nm to 1630 nm) < 400 pW (800 nm to 1200 nm)		
Averaging time (minimal)	100 µs		
Analog output	included		
Dimensions	57 mm x 66 mm x 156 mm		
Weight	0.5 kg		
Recommended recalibration period	2 years		
Operating temperature	0 °C to 40 °C		
Humidity	Non-condensing		
Warm-up time	40 min		

1. Reference conditions:
   - Power level 10 µW (–20 dBm), continuous wave (CW)
   - Parallel beam, 3 mm spot diameter on the center of the detector.
   - Ambient temperature 23 °C ± 5 °C
   - On day of calibration (add ± 0.3% for aging over one year, add ± 0.6% over two years)
   - Spectral width of source < 10 nm (FWHM)
   - Wavelength setting at power sensor corresponding to source wavelength ± 0.4 nm

2. Operating Conditions:
   - Parallel beam, 3mm spot diameter on the center of the detector or connectorized fiber with NA ≤ 0.2 (straight connector, options C01 / C02 also with angled connector ≤ 8°)
   - For NA > 0.2 add 1%
   - Averaging time 1s
   - Within one year after calibration, add 0.3 % for second year.
   - Spectral width of source < 10 nm (FWHM)
   - Wavelength setting at power sensor corresponding to source wavelength ± 0.4 nm

3. All states of polarization at constant wavelength (1550 nm ± 30 nm) and straight connector, T = 23 °C ±5 °C.
   For angled connector (8°) add 0.01 dB typ.

4. Conditions:
   - Wavelength 1550 nm ±30 nm, fixed state of polarization
   - Temperature 23 °C ±5°C
   - Linewidth of source ≥ 100 MHz
   - Angled connector 8°

5. Does not include noise; for wavelength < 1000 nm applies for – 50 dBm to +10 dBm

6. Averaging time 1 s, T = 23 °C ± 5 °C, ΔT ±1 °C, observation time 300 s

7. Conditions: Wavelengths 1550 nm ± 30 nm.
   Standard single mode fiber, angled connector min 8°

8. With D-shape adapter 81001xx return loss > 60 dB typical

9. For input power > 2 mW add ± 0.004 dB/mW (not for C01 / C02); zeroing required

10. Specification valid for optical heads with S/N starting with "DE413..."
    (shipping began April 1, 2001)

Optical Head Special Calibration 81624B, 81626B Option C01 and C02

Product specifications

All optical heads have to be operated with the single (Agilent 81618A) or dual (Agilent 81619A) Interface Modules

	Agilent 81624B	Agilent 81624B Calibration Option C01/C02	Agilent 81626B	Agilent 81626B Calibration Option C01/C02
Sensor element	InGaAs, ∅ 5 mm		InGaAs, ∅ 5mm	
Wavelength range	800 nm to 1700 nm		850 nm to 1650 nm	
Power range	–90 dBm to +10 dBm		–70 to +27 dBm (1250 nm to 1650 nm) –70 to +23 dBm (850 nm to 1650 nm)	
Applicable fiber type Open beam	Standard SM and MM max 100 µm core size, NA ≤ 0.3 Parallel beam max ∅ 4 mm		Standard SM and MM max 100 µm core size, NA ≤ 0.3 Parallel beam max ∅ 4 mm	
Uncertainty at reference conditions[1]	±2.2% (1000 nm to 1630 nm)	±1.5% (970 nm to 1630 nm)	±3.0% (950 nm to 1630 nm)	±2.5% (950 nm to 1630 nm)
Total uncertainty[2]	±3.5% ± 5 pW (1000 nm to 1630 nm)	±2.8% ± 5 pW (970 nm to 1630 nm)	±5.0% ± 500 pW[8] (950 nm to 1630 nm)	4.5% ±500 pW[8] (950 to 1250 nm max 23 dBm) (1250 to 1630 nm max 27 dBm)
Relative uncertainty:[7] • due to polarization[3] • spectral ripple (due to interference)[4]	≤ ±0.005 dB (typ. ±0.002 dB) ≤ ±0.005 dB (typ < ±0.002 dB)		≤ ±0.005 dB (typ. ±0.002 dB) ≤ ±0.005 dB (typ. < ±0.002 dB)	
Linearity (power):[5] at 23 °C ± 5 °C at operat. temp. range	CW –70 dBm to +10 dBm, 1000 nm to 1630 nm < ±0.02 dB < ±0.05 dB		CW –50 dBm to +27 dBm, 950 nm to 1630 nm < ±0.04 dB[8] < ±0.15 dB[8]	
Return loss	typ. 60 dB[7]		> 45 dB	> 47 dB
Noise (peak to peak)[6]	< 5 pW		< 500 pW	
Averaging time (min.)	100 µs		100 µs	
Analog output	Included		Included	
Dimensions	57 mm x 66 mm x 156 mm		57 mm x 66 mm x 156 mm	
Weight	0.5 kg		0.5 kg	
Recommended recalibration period	2 years		2 years	
Operating temperature	0 °C to 40 °C		0 °C to +35 °C[9]	
Humidity	Non-condensing		Non-condensing	
Warm-up time	40 min		40 min	

1. Reference conditions:
   - Power level 10 µW (–20 dBm), continuous wave (CW)
   - Parallel beam, 3 mm spot diameter on the center of the detector
   - Ambient temperature 23 °C ±5 °C
   - On day of calibration (add ±0.3% for aging over one year, add ±0.6% over two years)
   - Spectral width of source ≤ 10 nm (FWHM)
   - Wavelength setting at power sensor corresponding to source wavelength ±0.4 nm

2. Operating Conditions:
   - Parallel beam, 3mm spot diameter on the center of the detector or connectorized fiber with NA ≤ 0.2 (straight connector, Options C01/C02 also with angled connector ≤ 8°)
   - For NA > 0.2 add 1%.
   - Averaging time 1s
   - Within one year after calibration, add 0.3% for second year
   - Zeroing required

3. All states of polarization at constant wavelength (1550 nm ±30 nm), straight connector, T = 23 °C ±5 °C.
   For angled connector (8°) add 0.01 dB typ.

4. Conditions:
   - Wavelength 1550 nm ±30 nm, fixed state of polarization
   - Temperature 23 °C ±5 °C
   - Linewidth of source ≥ 100 MHz
   - Angled connector 8°

5. Does not include noise; zeroing required

6. Averaging time 1s, T = 23 °C ±5 °C, ΔT ±1 °C, observation time 300 s. Wavelength range 1200 nm to 1630 nm

7. Conditions:
   - Wavelengths 1550 nm ±30 nm
   - Standard single mode fiber, angled connector min 8°
   - With D-shape adapter 81001xx return loss > 60 dB typical

8. For input power > +10 mW:
   - Add typ. ±0.0016 dB/mW, or in case of Options C01/C02 for wavelength ≤ 1550 nm add ±0.0006 dB/mW (guaranteed) using adaptor Agilent 81000AF.
   - In case of decreasing power, allow time for stabilization of the reading (about 5 s per dB change).
   - In case of decreasing power by more than 50 dB, allow recovery time of 3 minutes.

9. Max 30 °C above +20 dBm input power

5. Special Calibration C05 at the German PTB

For 81624B optical heads, the special calibration C05 is available, which comprises a C01 selection/calibration and a calibration of the responsivity directly at the German national measurement institute “Physikalisch Technische Bundesanstalt” PTB.

The responsivity calibration is based on tunable laser sources around 1310 nm and 1550 nm. The optical power is transferred to the power meter via single mode fiber. This calibration is done against a standard traced to the PTB primary standard.

The C05 comes with a C01 calibration report and a calibration certificate from the PTB in English language, listing the relative responsivity deviation at the calibration wavelengths.

Calibration C05

Wavelength	1300, 1310,1320 nm and 1540, 1550, 1560 nm
Power Level	10 µW (–20 dBm)
Beam geometry	Single mode fiber on head connector adaptor Agilent 81000*A
Measurement uncertainty	±0.8%
Certificate	PTB certificate in English language, listing the relative responsivity deviation at the calibration wavelengths

6. Logistics

First calibration

Special calibrations of new 81623B, 81624B and 81626B optical heads are ordered as an additional Option C01.

For example: 81624B #C01.

The PTB calibration of new 81624B optical head is ordered as option C05.

For example: 81624B #C05.

Recalibration

Agilent recommends a recalibration every 2 years. The Agilent 8163A/B main instrument and the 81618A or 81619A head interface modules can be expected to have no influence on the calibration result, due to the exclusive use of digital signal processing. Only the optical head must be returned to the factory.

Note: Agilent's heads for special calibration C01 and C85 are selected for enhanced measurement quality. During recalibration, an optical head not ordered previously with this option might fail the tighter limits of the special calibration.

Ordering instructions

- Recalibration for 81623B: 81623C2 or 81623C86,
- Recalibration for 81624B: 81624C2,
- Recalibration for 81626B: 81626C2.

Any Agilent Service Center will do the handling and shipping.

For price information about the special calibrations and special recalibrations of Agilent's optical heads, please contact any Agilent sales or service office.

References

[1] R.L. Gallawa et al., *A limited international intercomparison of responsivity scales at fiber optic wavelengths,* J. of Research of the National Institute of Standards and Technology, Vol. 96,. No. 2, March-April 91, 225-230

[2] J.L. Gardner et al. *International intercomparison of detector responsivity at 1300 and 1550 nm,* Applied Optics, Vol. 31, No. 34, Dec. 1992, 7226-7231

[3] *Calibration of Fibre-Optic Power Meters,* IEC standard 61315

[4] *Setting Up a Calibration System for Fiber-Optic Power Meters? A Recommendation.* Agilent Solution Note 153-2 (ask Agilent for a copy).

[5] *Guide to the expression of uncertainty in measurement (GUM),* ISO/IEC et al. (1995)

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