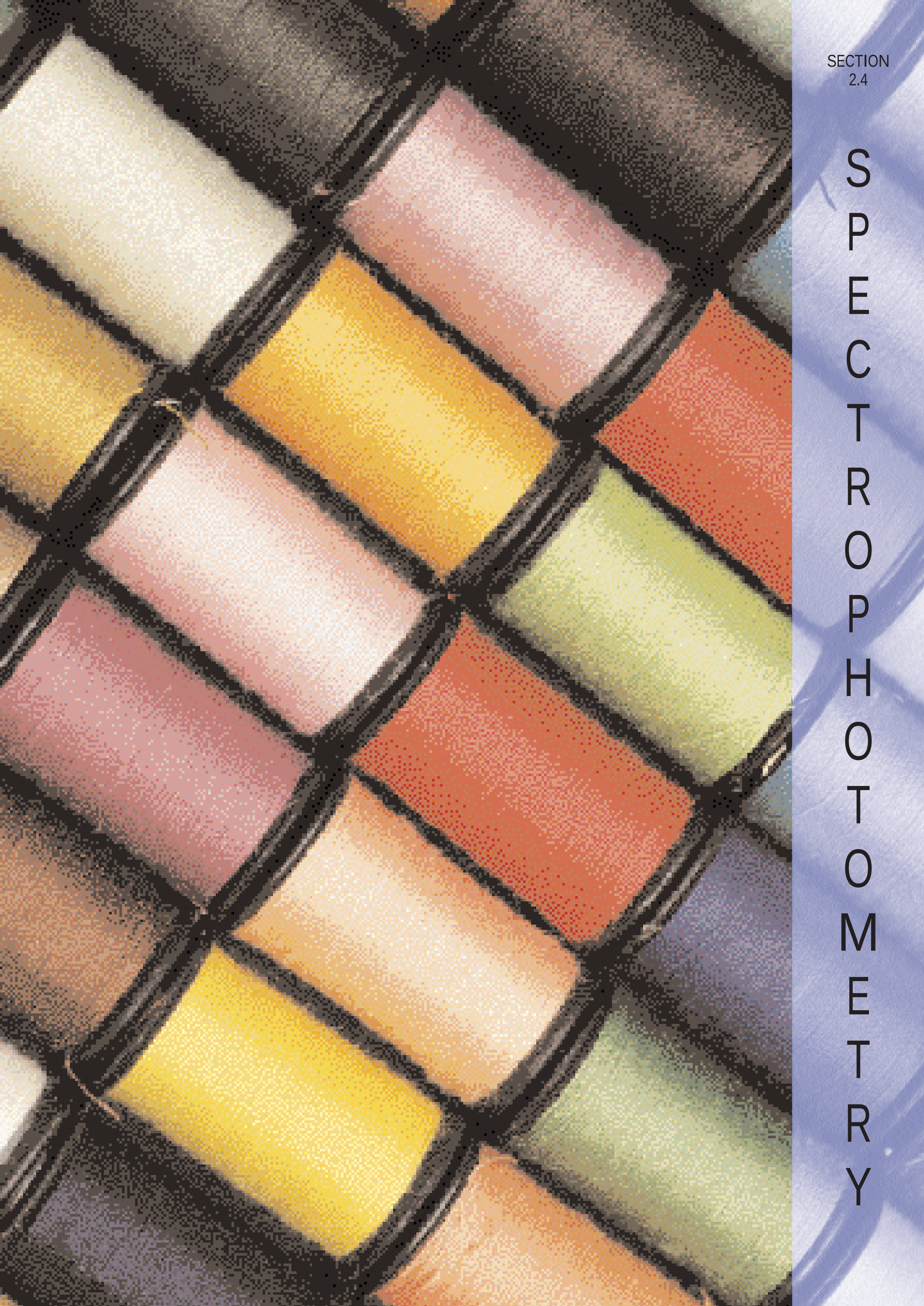

SECTION
2.4

# SPECTROPHOTOMETRY

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Absorbance**<br>***Filter*** | Poland<br>*GUM* | A | 0 - 3A | UV-VIS-NIR Spectrophotometer | 250 - 800 | | 1 | $3 \cdot 10^{-3}$ at 1A | GUM | GUM | |
| **Absorbance**<br>***Filter, Cuvettes*** | Sweden<br>*SP* | Bel(B) | 0 - 4 | Relative measurement, linearity | 200 - 2500 | | 0,1 - 20 | $10^{-2} \pm 0{,}002$B | SWEDAC | NPL | |
| **Absorbance**<br>***Filter, Matrix*** | Sweden<br>*SP* | Bel(B) | 0,0001 - 1<br>1 - 2<br>2 - 3 | Relative measurement, linearity | 200 - 800 | | 0,1 - 5 | 0,0001 - 0,008<br>0,008 - 0,015<br>0,015 - 0,03<br>(Absolute) | SWEDAC | NPL | |
| **Absorbance**<br>***Filter, Neutral Density*** | Hungary<br>*OMH* | A | 0 - 6A | Reference Spectrophotometer | 250 - 1600 | | 2 - 6 nm | $8 \cdot 10^{-4} - 8 \cdot 10^{-2}$ | OMH | OMH | Welding filter calibration according to EN 167 and EN 169 |
| **Absorbance**<br>***Filter, Neutral Density*** | Portugal<br>*CETO* | A | 0,05 - 3A | Scanning | 400 - 800 | | 1<br>20 | 0.001A<br>(Absolute) | IPQ | NPL | Glass filters, National intercomparison in progress |
| **Absorbance**<br>***Filter, Neutral Density*** | United Kingdom<br>*NPL* | A | 0 - 5.0A | Reference Spectro-photometer<br>Scanning Spectrophotometer | 200 - 2500 | | Usually 1 nm in uv-visible but can be selected by customer.<br>1 - 20 nm in near infrared | 0,0003 at 0,22A (Absolute)<br>0.0011 at 0,22A (Absolute) | NPL<br>UKAS | NPL | Best measurement capability is for Reference Spectrophotometer<br>Scanning Spectrophotometers used for UKAS calibrations |
| **Absorbance,**<br>***Filter, Neutral Density*** | United Kingdom<br>*Unicam* | A | 0 - 3 A | UV-Visible Spectrometer | 546 ± 0,3 | | 1 | 0,002 at 0 A<br>to<br>0,006 at 3 A<br>(Absolute) | UKAS | NPL or NIST | |
| **Absorbance,**<br>***Filter, Neutral Density*** | United Kingdom<br>*Unicam* | A | 0 - 3 A | UV-Visible Spectrometer | 546 ± 0,3 | | 2 | 0,003 at 0 A<br>to<br>0,006 at 3 A<br>(Absolute) | UKAS | NPL or NIST | Calibrations listed form part of the spectrometer parameter verification made available as the Calibration Validation Unit (CVU) for UV Series spectrometers |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Absorbance**<br>***Liquid*** | Sweden<br>*SP* | Bel(B) | 0 - 4 | Relative measurement, linearity | 200 - 2500 | | 0,1 - 20 | $1{,}5 \cdot 10^{-2} \pm 0{,}002B$ | SWEDAC | NPL | |
| **Absorbance**<br>***Material*** | United Kingdom<br>*NPL* | A | 0 - 5.0A | Reference Spectrophotometer<br>Scanning Spectrophotometer | 200 - 2500 | | Usually 1 nm in uv-visible but can be selected by customer.<br>1 - 20 nm in near infrared | 0,0003 at 0,22A (Absolute)<br>0.0011 at 0,22A (Absolute) | NPL<br>UKAS | NPL | Best measurement capability is for Reference Spectrophotometer<br>Scanning Spectrophotometers used for UKAS calibrations |
| **Absorbance**<br>***Sealed Cuvette*** | Sweden<br>*SP* | Bel(B) | 0,0001 - 1<br>1 - 2<br>2 - 4 | Relative measurement, linearity | 200 - 2500 | | 0,1 - 20 | 0,0001 - 0,008<br>0,008 - 0,015<br>0,015 - 0,04<br>(Absolute) | SWEDAC | NPL | |
| **Bandwidth**<br>***Standard*** | Portugal<br>*CETO* | nm | | Scanning | 200 - 3000 | | 0,05 | 0,1 nm | IPQ | NIST | |
| **Colour, Emitted**<br>***Electro Optic Display*** | Denmark<br>*Delta* | CIE<br>x, y, Y<br>u’, v’<br>L*a*b* | x, y : 0,0 - 0,9<br>Y : 0 - 100<br>u’, v’ : 0,0 - 0,7<br>L* : 0 -100<br>a*, b* : -200 to +200 | Colour data calculated from spectral radiance data measured on a spectroradiometer | 380 - 780 | | 5 | x, y : 0,003 | DANAK | NPL | |
| **Colour, Emitted**<br>***Electro Optic Display*** | Italy<br>*IEN* | x, y | | Spectrophotometer | | | | $4 \cdot 10^{-3}$ (Absolute) | IEN | IEN | |
| **Colour, Emitted**<br>***Electro Optic Display*** | United Kingdom<br>*NPL* | CIE<br>x, y, Y<br>u’, v’<br>L*a*b* | Y : 0 - 100%<br>x, y : 0 - 0,9<br>u’, v’ : 0 - 0,7<br>L* : 0 - 100<br>a*, b* -200 to +200 | Colour data calculated from spectral radiance data measured on a Spectroradiometer | 380 - 780 | | 5 | Y : $4 \cdot 10^{-2}$<br>x, y : 0,001<br>(Absolute) | NPL | NPL | Contrast can also be supplied |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Colour, Surface**<br>***Diffuse Reflector*** | Sweden<br>*SP* | CIE, x, y, z | 0,0001 - 1 | Spectral responsivity or by colour standards | VIS | | | White:<br>x, y : 0,0002<br>High chromaticities: x, y : 0,002<br>(Absolute) | SWEDAC | NPL | |
| **Colour, Surface**<br>***Flat Opaque Solid*** | Poland<br>*GUM* | X, Y, Z<br>x, y<br>L*, a*, b* | Y : 0 -100<br>x, y : 0 - 0,9 | Integrating sphere spectrophotometer, direct measurement, d/0 geometry | 400 - 700 | | 15 | Y : $3\cdot10^{-3}$<br>x, y : 0,001<br>(Absolute) | GUM | PTB | |
| **Colour, Surface**<br>***Flat Opaque Solid*** | United Kingdom<br>*CERAM* | XYZ<br>x, y<br>CIEL*a*b*<br>u' v' | 0 - 100 | Integrating sphere Spectrophotometer, by direct measurement | 380 - 780 | | 10<br>(Interpolated to 5 nm) | Pale grey:<br>Y : $4{,}5\cdot10^{-3}$<br>x, y : 0,0030<br>u', v' : 0,0003<br>L* : 0,30<br>a*, b* : 0,15<br><br>Deep grey:<br>Y : $2\cdot10^{-3}$<br>x, y : 0,0014<br>u', v' : 0,0010<br>L* : 0,45<br>a* : 0,15<br>b* : 0,30<br>(Absolute) | UKAS | NPL | Gloss or matt surface<br>Sample at least 30 mm diameter |
| **Colour, Surface**<br>***Flat Opaque Solid*** | United Kingdom<br>*CERAM* | XYZ<br>x, y,<br>CIEL*a*b* | CIEL*a*b* values<br>0 - 100 | 0°/45° Geometry. Colorimeter - by direct comparison with NPL Standards | 400 - 700 | | 4 broadband filters | Pale grey:<br>Y : $5\cdot10^{-3}$<br>x, y : 0,0003<br>L* : 0,35<br>a*, b* : 0,15<br><br>Deep grey:<br>Y : $1{,}5\cdot10^{-3}$<br>x, y : 0,0004<br>L* : 0,25<br>a*, b* : 0,15<br>(Absolute) | UKAS | NPL | Glossy surface only<br>Sample at least 50 mm diameter |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Colour, Surface *Material*** | Austria<br>*BEV* | CIE<br>x, y, Y | Y : 0 - 100%<br>x, y : 0 - 0,9 | Substitution to white standard geometry: 45°/0°, 0°/45° | 360 - 830 | | 0,5 - 10 | Reflectance:<br>$1 \cdot 10^{-2}$ | BEV | PTB | |
| **Colour, Surface *Material*** | Denmark<br>*Delta* | CIE<br>x, y, Y<br>u', v'<br>L*a*b* | x, y : 0,0 - 0,9<br>Y : 0 -100<br>u', v' : 0,0 - 0,7<br>L* : 0 - 100<br>a*, b* : -200 to +200 | Colour data calculated from spectral radiance data measured on a spectroradiometer, reference tiles | 380 - 780 | | 5 | x, y : 0,003 | DANAK | NPL | |
| **Colour, Surface *Material*** | France<br>*BNM-LCIE* | Y<br>x, y | Y : 0 - 100<br>x, y : 0 - 1 | Spectrophotometer and CIE method observer 1931 | | | | For Y = 95 : 4,3<br>x = 0,313 : 0,004<br>y = 0,329 : 0,004 (Absolute) | COFRAC | BNM | Uncertainties are for white standard |
| **Colour, Surface *Material*** | France<br>*BNM-LNE(1)* | Y<br>x, y<br>L a*b* | 0 - 100<br>0 - 1 | Calculation using CIE methods System XYZ 1931 | 400 - 750 | | 5 | Y : 0,8<br>x, y : 0,0007<br>L*a*b* : 0,5<br>(Absolute) | COFRAC | BNM | |
| **Colour, Surface *Material*** | Hungary<br>*OMH* | CIE<br>x, y, Y | | Reference spectrophotometer geometries : 8/d 45°/0° | 380 - 760 | | 3 | $\Delta E_{ab}$ = 0,1 - 0,5 | OMH | OMH | SRM set of 16 enamel colour standards, measured sample size < Ø 78 mm |
| **Colour, Surface *Material*** | Italy<br>*IEN* | x, y, Y | | Spectrophotometer Gonioreflectometer | | | | x, y : 0,002<br>(Absolute) | IEN | IEN | |
| **Colour, Surface *Material*** | Poland<br>*GUM* | X, Y, Z<br>x, y<br>L*a*b* | Y : 0 - 100<br>x, y : 0 - 0,9 | Colour data calculated from spectral reflectance data measured by spectrophotometer, 8/d geometry | 380 - 780 | | 5 | Y : $5 \cdot 10^{-3}$<br>x, y : 0,001<br>(Absolute) | GUM | NIST | |
| **Colour, Surface *Material*** | Spain<br>*AIDO* | CIE<br>CIELAB | | Spectrophotometer | 400 - 700 | | 10 | Reflectance:<br>$1 \cdot 10^{-2}$ | ENAC | NPL | Glossy<br>Matt |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Colour, Surface** **_Material_** | Spain<br>*IFA* | CIELAB | | Spectrophotometer | 380 - 780 | | 2 | 0,4 CIELAB units (Absolute) | IFA | IFA | Patch size |
| **Colour, Surface** **_Material_** | Sweden<br>*SP* | CIE x, y, z | $10^{-4}$ - $10^{0}$ | Spectral responsivity or by colour standards | 380 - 780 | | | White: $2\cdot10^{-4}$<br>High chromaticness: $2\cdot10^{-3}$ | SWEDAC | NPL | |
| **Colour, Surface** **_Material_** | United Kingdom<br>*NPL* | CIE<br>x, y, Y<br>u’, v’<br>L*a*b* | Y : 0 - 100%<br>x, y : 0 - 0,9<br>u’, v’ : 0 - 0,7<br>L* : 0 - 100<br>a*, b*<br>-200 to +200 | Against master standards traceable to perfect reflecting diffuser.<br>Geometries:<br>Spec. Inc. (8°/t)<br>Spec. Ex. (0°/d)<br>0°/45° | 320 - 780 | | 2 | Y : $4\cdot10^{-3}$ for pale grey,<br>$1\cdot10^{-3}$ for deep grey<br>x, y : 0,0002<br>u’, v’ : 0,0002<br>L* : 0,20<br>a*, b* : 0,10<br>(Absolute) | UKAS | NPL<br>PTB<br>NRC | Measurement of Set of 12 colour standards,<br>4 pairs of Metameric colour standards, Black, Grey and White tiles plus customer samples |
| **Colour, Surface** **_Material, Fluorescent_** | United Kingdom<br>*NPL* | CIE<br>x, y, Y,<br>u’, v’, L*,<br>a*, b* | Y : 0 - 300%<br>x, y : 0 - 0,9<br>u’, v’ : 0 - 0,7<br>L* : 0 - 160<br>a*, b* : -200 to +200 | Calibration on a reference Spectro-fluorimeter. Geometry 0°/45° | 320 - 780 | | 5 | Radiance Factor<br>$3\cdot10^{-2}$<br>x, y : 0,003<br>Y : $3\cdot10^{-2}$<br>u’, v’ : 0,002<br>L* : 1, 2 a*, b* : 1,5<br>(Absolute) | NPL | NPL | Measurements of set of 3 fluorescent colour standards, plus customers samples |
| **Colour, Surface** **_Material, White_** | Finland<br>*KCL* | X, Y, Z | 1 - 120 | | | | | $5\cdot10^{-3}$ | FINAS | NRC | C/2° and D65/10° |
| **Colour, Surface** **_Material, White_** | Germany<br>*PTB* | X, Y, Z<br>x, y | | Weighted ordinate method - tristimulus method | | | | x, y : 0,0005<br>(Absolute) | PTB | PTB | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Colour, Surface**<br>***Standard, Ceramic Colour*** | United Kingdom<br>*CERAM* | XYZ<br>x, y<br>CIEL*a*b*<br>u' v' | 0 - 100 | Integrating sphere Spectrophotometer, by direct comparison with NPL standards | 380 - 780 | | 10 (Interpolated to 5 nm) | Pale grey:<br>Y : $4{,}5\cdot10^{-3}$<br>x, y : 0,0003<br>u', v' : 0,0003<br>L* : 0,30<br>a*, b* : 0,15<br><br>Deep grey:<br>Y : $1{,}5\cdot10^{-3}$<br>x, y : 0,0004<br>u', v' : 0,0003<br>L* : 0,25<br>a*, b* : 0,15<br>(Absolute) | UKAS | NPL | Gloss surface only<br>Sample at least 30 mm diameter.<br>0°/45° data available by calculation |
| **Colour, Surface**<br>***Standard, Colour*** | Portugal<br>*CETO* | CIE units | 360 - 830 nm | Scanning and CIE model | 360 - 830 | | 1 - 20 | 0,2 CIELAB<br>(Absolute) | IPQ | NPL | Intercomparison will be performed in 1997 under the SM&T |
| **Colour, Transmitted**<br>***Filter*** | Poland<br>*GUM* | X, Y, Z<br>x, y<br>L*, a*, b* | Y : 0 -100<br>x, y : 0 - 0,9 | Spectral transmittance measurement | 380 - 780 | | 1 | Y : $2\cdot10^{-3}$<br>x, y : 0,0005<br>(Absolute) | GUM | GUM | |
| **Colour, Transmitted**<br>***Filter*** | Sweden<br>*SP* | CIE x, y, z | $10^{-4}$ - $10^{0}$ | Spectral transmittance measurement | VIS | | | Low chromaticity:<br>$10^{-4}$<br>High chromaticity:<br>$10^{-3}$<br>(Absolute) | SWEDAC | | |
| **Colour, Transmitted**<br>***Material*** | France<br>*BNM-LNE(1)* | Y<br>x, y | 0 - 100<br>0 - 1 | Calculation using CIE methods<br>System XYZ 1931 | 400 - 750 | | 5 | Y : 0,5<br>x, y : 0,0007<br>(Absolute) | COFRAC | BNM | |
| **Colour, Transmitted**<br>***Material*** | Hungary<br>*OMH* | CIE<br>L*, u*, v*<br>L*, a*, b* | | Calculated from regular transmittance | 380 - 760 | | 3 | $\Delta E_{ab}$ = 0,1 - 0,5 | OMH | OMH | Measured sample size < 50·50 mm |
| **Colour, Transmitted**<br>***Material*** | Italy<br>*IEN* | x, y, Y | | Spectrophotometer | | | | x, y : 0,002<br>(Absolute) | IEN | IEN | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Colour, Transmitted**<br>***Material*** | Spain<br>*IFA* | CIELAB | | Spectrophotometer | 380 - 780 | | 1 | 0,2 CIELAB units (Absolute) | IFA | IFA | Patch size |
| **Colour, Transmitted**<br>***Material*** | United Kingdom<br>*NPL* | CIE<br>x, y, Y<br>u' v'<br>L*a*b* | Y, 0 - 100%<br>x, y, 0 - 0,9<br>u' v', 0 - 0,7<br>L*, 0 - 100<br>a*, b*, -200 to +200 | Calculated from regular transmittance | 380 - 780 | | 1 | Y : $4\cdot10^{-3}$<br>x, y : 0,0002<br>(Absolute) | UKAS | NPL | Range of red, yellow and blue colour standards, plus customer samples |
| **Colour, Transmitted**<br>***Material*** | United Kingdom<br>*Tintometer* | X, Y, Z<br>x, y<br>L*a*b* | Y, 0 - 100%<br>x, y, 0 - 0,9<br>L*, 0 - 100<br>a*, b*, -200 to +200 | Scanning Spectrophotometer | 380 - 780 | | | X, Y, Z : 0,4<br>x, y : 0,0004<br>L* : 0,2<br>a* : 0,08<br>b* : 0,11<br>(Absolute) | UKAS | NPL | |
| **Emissivity**<br>***Flat Metallic Surface*** | Sweden<br>*SP* | | 0,01 - 1 | Substitution to blackbody at 100 °C | 1 - 30 µm | | | $2\cdot10^{-2}$ - $4\cdot10^{-2}$ | SWEDAC | SP | Directional emissivity |
| **Emittance, Spectral**<br>***Material, Non Scattering*** | United Kingdom<br>*NPL* | ε% | $\varepsilon(\upsilon)$<br>0 - 100 | Spectrophotometer with regular reflectometer | 4000 cm$^{-1}$ - 180 cm$^{-1}$<br>(2,5 - 56 µm) | | 2 - 10 cm$^{-1}$ | $1\cdot10^{-3}$ (ε = 100%)<br>$3\cdot10^{-1}$ (ε = 1%) | NPL | NPL | Available: Aluminised mirrors, Uncoated glass |
| **Emittance, Spectral**<br>***Material, Scattering*** | United Kingdom<br>*NPL* | ε% | $\varepsilon(\upsilon)$<br>0 - 100 | Spectrophotometer with hemispherical reflectometer | 4000 cm$^{-1}$ - 180 cm$^{-1}$<br>(2,5 - 56 µm) | | | $4\cdot10^{-3}$ (ε = 100%)<br>$3{,}8\cdot10^{0}$ (ε = 1%) | NPL | NPL | Available: High, Medium & Low $\rho$ artefacts |
| **Emittance, Total**<br>***Flat Polished Surface*** | United Kingdom<br>*NPL* | $\varepsilon_T$ | 0 - 1 | Spectrophotometer with regular reflectometer | Planckian distribution<br>4000 cm$^{-1}$ - 180 cm$^{-1}$<br>(2,5 - 56 µm) | | 2 - 10 cm$^{-1}$ | $5\cdot10^{-4}$ (ε =1)<br>$2\cdot10^{-2}$ (ε = 0,1) | NPL | NPL | Available: Aluminised mirrors, Uncoated glass |
| **Emittance, Total**<br>***Material, Scattering*** | United Kingdom<br>*NPL* | $\varepsilon_T$ | 0 - 1 | Spectrophotometer with hemispherical reflectometer | 4000 cm$^{-1}$ - 180 cm$^{-1}$<br>(2,5 - 56 µm) | | | $3\cdot10^{-3}$ (ε = 1)<br>$3\cdot10^{-1}$ (ε = 0,1) | NPL | NPL | Available: High, Medium & Low $\rho$ artefacts |
| **Fluorescence Quantum Efficiency**<br>***Material*** | Italy<br>*IEN* | | | Parametric fluorescence | | | | $2\cdot10^{-2}$ | IEN | IEN | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Gloss**<br>***Glossmeter*** | Czech Republic<br>*CMI LPM 814* | % gloss | 1 - 100 | Comparison | White light | | | $2 \cdot 10^{-2}$ | | NPL | 20°, 60°, 85°<br>ISO 2813 |
| **Gloss**<br>***Glossmeter*** | Netherlands<br>*NMi-VSL* | % gloss | 7 - 100 | Gloss standards | | | | $6 \cdot 10^{-2}$ | NMi-VSL | NRC | 20°; 60°; 85° |
| **Gloss**<br>***Glossmeter*** | United Kingdom<br>*NPL* | % gloss | 0 - 100 | Comparison against master calibrated on Reference Reflectometer | | | | $2{,}5 \cdot 10^{-2}$ | NPL | NPL | |
| **Gloss**<br>***Glossmeter, high gloss standards*** | Sweden<br>*SP* | GU<br>(gloss unit) | $8 \cdot 10^{1}$ - $1{,}1 \cdot 10^{-2}$ | ISO 2813<br>20°, 60°, 85° high gloss | 589 | | | 1 GU | SWEDAC | | |
| **Gloss**<br>***Material*** | Czech Republic<br>*CMI LPM 814* | % gloss | 1 - 100 | Gonio-reflectometer | White light | | | $2 \cdot 10^{-2}$ | | NPL | 20°, 60°, 85°<br>ISO 2813 |
| **Gloss**<br>***Material*** | France<br>*BNM-LNE(1)* | % gloss | 1 - 120 | Standard<br>NF T30-064 | | | | $1 \cdot 10^{-2}$ | COFRAC | BNM | 20°, 60°, 85° |
| **Gloss**<br>***Material*** | Hungary<br>*OMH* | % gloss | 0 - 100 | Gonio-reflectometer | 633 | | | $10^{-2}$<br>(at high gloss) | OMH | OMH | ISO 2813<br>20°, 60°, 85° |
| **Gloss**<br>***Material*** | Italy<br>*IEN* | % gloss | 1 - 100 | Gonio-reflectometer | | | | $1 \cdot 10^{-2}$ | IEN | IEN | |
| **Gloss**<br>***Material*** | Netherlands<br>*NMi-VSL* | % gloss | 7 - 100 | Gloss standards | | | | $6 \cdot 10^{-2}$ | NMi-VSL | NRC | 20°; 60°; 85° |
| **Gloss**<br>***Material*** | United Kingdom<br>*NPL* | % gloss | 0 - 100 | Gonio-reflectometer | white light | | | $1 \cdot 10^{-2}$ | NPL | NPL | |
| **Gloss**<br>***Silica, Black*** | United Kingdom<br>*NPL* | % gloss | 0 - 100 | Glossmeter<br>20°, 60°, 85° | | | | $1{,}5 \cdot 10^{-2}$ | NPL | NPL | Customer samples are measured on reference reflectometer |
| **Haze**<br>***Material*** | United Kingdom<br>*NPL* | % haze | 0 - 100 haze units | BS2782 part 5 Method 521A and ASTM D100 | white light, illuminants A or C | | | $1 \cdot 10^{-2}$ | NPL | NPL | |
| **Haze**<br>***Standard*** | Sweden<br>*SP* | % | $10^{-3}$ - $10^{0}$ | Substitution to haze standards | $V(\lambda)$ | | | $10^{-2}$ - $2 \cdot 10^{-2}$ | SWEDAC | | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **ISO Reflectance Factors $R_{457}$, $R_x$, $R_y$, $R_z$**<br>***Material, White*** | Finland<br>*KCL* | % | 1 - 100 | | | | | $5\cdot10^{-3}$ | FINAS | NRC | C/2° and D65/10° |
| **ISO Reflectance Factors $R_{457}$, $R_x$, $R_y$, $R_z$**<br>***Material, White*** | Finland<br>*UPM-Kymmene* | % | 80 - 100 | | | | | $5\cdot10^{-3}$ | FINAS | NRC | C/2° |
| **ISO Reflectance Factors $R_{457}$, $R_x$, $R_y$, $R_z$**<br>***Material, White*** | Germany<br>*PTB* | | | Standardised reflectometer | | | | $2\cdot10^{-3}$ | PTB | PTB | ISO 2469: 1994<br>ISO 2470: 1977<br>Procedures available from the PTB |
| **Optical Density**<br>***Material*** | Italy<br>*IEN* | log | < 3<br>< 5 | Gonio-reflectometer | | | | $1\cdot10^{-3}$<br>$5\cdot10^{-3}$ | IEN | IEN | |
| **Optical Density, Reflectance Factor**<br>***Material*** | Netherlands<br>*NMi-VSL* | $D_R$ | | Tile | | | | $1\cdot10^{-2}$ | NMi-VSL | NRC | 1,8; 0,1 $D_R$ |
| **Optical Density, Reflectance Factor**<br>***Reflectometer*** | Netherlands<br>*NMi-VSL* | $D_R$ | | Tile | | | | $1\cdot10^{-2}$ | NMi-VSL | NRC | 1,8; 0,1 $D_R$ |
| **Optical Density, Transmittance**<br>***Densitometer*** | Hungary<br>*OMH* | OD | 0,001 - 4 | Spectrophotometer | $V(\lambda)$ | | | $10^{-3}$ - $2\cdot10^{-2}$ | OMH | OMH | SRM : set of 3 filters for densitometer calibration |
| **Optical Density, Transmittance**<br>***Densitometer*** | Netherlands<br>*NMi-VSL* | $D_T$ | 0 - 3 | Film | $V(\lambda)$ | | | $5\cdot10^{-3}$ | NMi-VSL | NRC | |
| **Optical Density, Transmittance**<br>***Diffuse Film*** | Germany<br>*PTB* | $D_T$ | 0 - 1,6<br>1,6 - 3,2<br>3,2 - 4<br>4 - 6 | Reference densitometer according to<br>ISO 5 - 2<br>ISO 5 - 3 | $V(\lambda)$ | | | 0,003 (abs.)<br>0,0024 (rel.)<br>0,004 (rel.)<br>0,006 (rel.) | PTB | PTB | |
| **Optical Density, Transmittance**<br>***Filter, Grey*** | Sweden<br>*SP* | OD | 0 - 6 | Relative measurement | 0,4 - 10,6 µm | <1W | Laser lines | $1\cdot10^{-2}$<br>± 0,002 OD | SWEDAC | | Laser lines<br>Ar, HeNe, $CO_2$ |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Optical Density, Transmittance** ***Grey Scale for Densitometer*** | Sweden *SP* | OD | 0 - 4 | Relative measurement on opal glass | V(λ) | | | $1 \cdot 10^{-2}$<br>± 0,002 OD | SWEDAC | | |
| **Radiance Factor** ***Material*** | Denmark *DELTA* | % | 0,5 - 100 | Spectrometer reflection standard Geometry: $0^\circ/45^\circ$ | | | | $2 \cdot 10^{-2}$ | DANAK | PTB | CIE standards are used |
| **Radiance Factor** ***Material*** | Italy *IEN* | % | | Gonioreflectometer | | | | $1 \cdot 10^{-3}$ | IEN | IEN | |
| **Radiance Factor** ***Material*** | Poland *GUM* | % | 0,5 - 100 | Integrating sphere spectrophotometer, d/0 geometry | 400 - 700 | | 15 | $3 \cdot 10^{-3}$ | GUM | PTB | |
| **Radiance Factor** ***Material*** | Spain *IFA* | % | 0,01 - 100 | Spectrophotometer Geometry: $0^\circ/45^\circ$ | 320 - 730 | | 1 | $\rho < 1 = 3 \cdot 10^{2}$<br>$1 < \rho < 10 = 5 \cdot 10^{-3}$<br>$10 < \rho < 100 = 2{,}5 \cdot 10^{-3}$ | IFA | IFA | Patch size |
| **Radiance Factor** ***Material*** | United Kingdom *NPL* | % | 0 - 100 | Gonioreflectometer<br>Calibration against master traceable to perfect reflecting diffuser. Geometry: $0^\circ/45^\circ$ | 350 - 1600<br>200 - 2500 | | approx. 20 interference filters<br>Usually 2 nm in UV-visible.<br>2 - 20 nm in near infrared | $1{,}2 \cdot 10^{-2}$<br>$6{,}5 \cdot 10^{-3}$ | NPL<br>UKAS | NPL<br>NPL<br>PTB | Incident angles: 0° to 85°<br>Viewing angles: 5° to 85°<br>White, Grey and Black ceramic tiles, White, Grey and Black PTFE (NIR), Ceramic colour standards. Customer samples are also measured. |
| **Radiance Factor** ***Material, Diffuse*** | Sweden *SP* | % | $10^{-4}$ - $10^{0}$ | Substitution to radiance factor standards Geometry: $45^\circ/0^\circ$ | V(λ) | | | $10^{-1}$ - $2 \cdot 10^{-2}$ | SWEDAC | NPL | |
| **Radiance Factor** ***Material, White*** | Germany *PTB* | % | 1 - 100 | Gonioreflectometer Geometry: $0^\circ/45^\circ$, $45^\circ/0^\circ$ | 360 - 830 | | | $3 \cdot 10^{-3}$ | PTB | PTB | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Radiance Factor**<br>***Material, White*** | Hungary<br>*OMH* | % | 0,01 - 100 | Reference spectrophotometer in geometry 45°/0° | 380 - 760 | | 2 | $7\cdot10^{-3}$ | OMH | OMH | SRM: PTFE and white enamel colour standards, measured sample size < Ø 78 mm |
| **Reflectance, Diffuse**<br>***Flat Opaque Solid*** | United Kingdom<br>*CERAM* | % | 0 - 100 | Integrating sphere Spectrophotometer, by direct measurement | 380 - 780 | | 10 (Interpolated to 5 nm) | Pale Grey:<br>$1\cdot10^{-2}$<br>Deep Grey:<br>$4{,}4\cdot10^{-2}$ | UKAS | NPL | Gloss or matt surface. Sample at least 30 mm diameter |
| **Reflectance, Diffuse**<br>***Material*** | Austria<br>*BEV* | % | 0,01 - 100 | Substitution to white standard. Geometry: 45°/0°, 0°/45° | 250 - 900 | | 0,5 - 10 | $1\cdot10^{-2}$ | BEV | PTB | |
| **Reflectance, Diffuse**<br>***Material*** | Denmark<br>*DELTA* | % | 0,5 - 100 | Integrating sphere geometries:<br>8°/t<br>8°/d | | | | $2\cdot10^{-2}$<br>$1{,}5\cdot10^{-2}$ | DANAK | PTB<br>NPL | CIE standards are used |
| **Reflectance, Diffuse**<br>***Material*** | France<br>*BNM-LNE(1)* | % | 0,5 - 100 | Calibrated Spectrophotometer geometry: 8°/d | 360 - 860 | | 1 - 5 | $(0{,}3 + 0{,}4.\rho)\cdot10^{-2}$ | COFRAC | BNM | |
| **Reflectance, Diffuse**<br>***Material*** | Hungary<br>*OMH* | % | 0,01 - 100 | Spectrophotometer with integrating sphere geometrries 8°/t, 8°/d | 380 - 760 | | 2 | $5\cdot10^{-3}$ - $5\cdot10^{-2}$ | OMH | OMH | SRM: PTFE and white enamel colour standards, measured sample size < Ø 78 mm |
| **Reflectance, Diffuse**<br>***Material*** | Italy<br>*IEN* | % | 0,03 - 100 | Sphere | | | | $1\cdot10^{-2}$ | IEN | IEN | |
| **Reflectance, Diffuse**<br>***Material*** | Poland<br>*GUM* | % | 0,5 - 100 | Spectrophotometer with integrating sphere, 8/d geometry | 250 - 800<br>800 - 2500 | | 2<br>1 - 20 | $5\cdot10^{-3}$<br>$2\cdot10^{-2}$ | GUM | NIST | |
| **Reflectance, Diffuse**<br>***Material*** | Portugal<br>*CETO* | % | 1 - 90 | Integrating sphere | 200 - 2000 | | 0,5 - 20 | $1\cdot10^{-2}$ | IPQ | NIST | Reflectance factor 0°/45° is possible |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Reflectance, Diffuse *Material*** | Spain<br>*IFA* | % | 0,01 - 100 | Spectrophotometer geometry 0°/d | 380 - 780 | | 2 | $\rho < 1 = 3{\cdot}10^{2}$<br>$1 < \rho < 10 = 5{\cdot}10^{-3}$<br>$10 < \rho < 100 = 2{,}5{\cdot}10^{-3}$ | IFA | IFA | Patch size |
| **Reflectance, Diffuse *Material*** | Sweden<br>*SP* | % | $10^{-2}$ - $10^{-0}$ | Substitution to reflectance standards geometry 8°/t | 300 - 2500 | | 0,1 - 20 | $2{\cdot}10^{-2}$ - $1{\cdot}10^{-2}$ | SWEDAC | NPL | |
| **Reflectance, Diffuse *Material*** | Switzerland<br>*OFMET* | % | 0,1 - 100 | Various methods | 350 - 1100 | | 3 | $2{\cdot}10^{-3}$ - $2{\cdot}10^{-2}$ | OFMET | OFMET | Various geometries |
| **Reflectance, Diffuse *Material*** | United Kingdom<br>*NPL* | % | 0 - 100 | Gonioreflectometer | 350 - 1600 | | Approx. 20 interference filters | $8{\cdot}10^{-3}$ | NPL | NPL | |
| | | | | Integrating sphere: Calibration against master traceable to perfect reflecting diffuser. Geometry: 8°/d, 8°/t | 200 - 2500 | | Usually 2 nm in UV-visible.<br>2 - 20 nm in near infrared | $3{,}5{\cdot}10^{-3}$ | UKAS | NPL<br>PTB<br>NRC | White, Grey and Black ceramic tiles, White, Grey and Black PTFE (NIR), Ceramic colour standards. Customer samples are also measured. |
| **Reflectance, Diffuse *Material, Black*** | Italy<br>*IEN* | % | 0,03 - 100 | Sphere | | | | $2{\cdot}10^{-3}$ | IEN | IEN | |
| **Reflectance, Diffuse *Material, White*** | Finland<br>*KCL* | % | 1 - 100 | Reflectance standard<br>geometry: d/0°<br>geometry: d/8° | 400 - 700<br>360 - 740 | | | $5{\cdot}10^{-3}$ | FINAS | NRC | |
| **Reflectance, Diffuse *Material, White*** | Finland<br>*UPM-Kymmene* | % | 80 - 100 | Reflectance standard geometry: d/0° | 400 - 700 | | 20 | $5{\cdot}10^{-3}$ | FINAS | NRC | |
| **Reflectance, Diffuse *Material, White*** | Germany<br>*PTB* | % | 1 - 100 | Absolute sphere reflectometer geometry: d/0°, d/6° | 300 - 1100 | | | $2{\cdot}10^{-3}$ | PTB | PTB | |
| **Reflectance, Diffuse *Material, White*** | Hungary<br>*OMH* | % | | Absolute sphere reflectometer in geometry d/0° | 380 - 760* | | 5 - 15 | $7{\cdot}10^{-3}$ | OMH | OMH | *Measured with interference filters, interpolated |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Reflectance, Diffuse** ***Material, White*** | Italy<br>*IEN* | % | 0,03 - 100 | Sphere | | | | $2 \cdot 10^{-3}$ | IEN | IEN | |
| **Reflectance, Diffuse** ***Standard, Ceramic Colour*** | United Kingdom<br>*CERAM* | % | 0 - 100 | Integrating sphere Spectrophotometer, by direct comparison with NPL standards | 380 - 780 | | 10 (Interpolated to 5 nm) | Pale Grey: $6 \cdot 10^{-3}$<br>Deep Grey: $1{,}2 \cdot 10^{-2}$ | UKAS | NPL | Gloss surface only. Sample at least 30 mm diameter. 0°/45° data available by calculation |
| **Reflectance, Hemispherical** ***Material, Scattering*** | United Kingdom<br>*NPL* | % | $\rho(\upsilon)$<br>0 - 100 | Spectrophotometer with hemispherical reflectometer | 4000 - 180 $\text{cm}^{-1}$ (2,5 - 56 µm) | | | $4 \cdot 10^{-1}$ ($\rho$ = 1%)<br>$3{,}8 \cdot 10^{-2}$ ($\rho$ = 100%) | NPL | NPL | Available: High, Medium & Low $\rho$ artefacts |
| **Reflectance, Regular** ***Material*** | Finland<br>*HUT* | % | 5 - 100<br>1 - 100 | Reference spectrometer | 250 - 380<br>380 - 1000 | | 3<br>1 - 3 | $5 \cdot 10^{-3}$ - $5 \cdot 10^{-2}$<br>$3 \cdot 10^{-3}$ - $3 \cdot 10^{-2}$ | HUT | HUT | Measurement angle 5° - 85° |
| **Reflectance, Regular** ***Material*** | Italy<br>*IEN* | % | 0,001 - 100 | Gonioreflectometer | | | | $7 \cdot 10^{-3}$ | IEN | IEN | |
| **Reflectance, Regular** ***Material*** | Portugal<br>*CETO* | % | 0,1 - 90 | | 200 - 2000 | | 0,5 - 20 | $1 \cdot 10^{-2}$ | IPQ | NIST | 8° incidence |
| **Reflectance, Regular** ***Material*** | Spain<br>*IFA* | % | 0,01 - 100 | Spectrophotometer | 200 - 2000<br>> 2000 | | 1<br>3 - 10 | $\rho < 1 = 2 \cdot 10^{-2}$<br>$1 < \rho < 10 = 3{,}5 \cdot 10^{-3}$<br>$10 < \rho < 100 = 1 \cdot 10^{-3}$ | IFA | IFA | Patch size |
| **Reflectance, Regular** ***Material*** | Switzerland<br>*OFMET* | % | 0,1 - 100 | Various methods | 350 - 1100 | | 3 | $2 \cdot 10^{-3}$ - $2 \cdot 10^{-2}$ | OFMET | OFMET | Various geometries |
| **Reflectance, Regular** ***Material*** | United Kingdom<br>*NPL* | % | 0,3 - 100 | Gonioreflectometer<br>VW accessory on scanning Spectrophotometer | 320 - 1600<br>200 - 2500 | | 1 - 20 | $1 \cdot 5 \cdot 10^{-3}$<br>$3 \cdot 10^{-3}$ | NPL | NPL | Angle 5° to 85°<br>Angle 7° |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Reflectance, Regular**<br>***Material, Non Scattering*** | United Kingdom<br>*NPL* | % | ρ(υ)<br>0 - 100 | Spectrophotometer with regular Reflectometer | 4000 - 180 cm$^{-1}$<br>(2,5 - 56 µm) | | 2 - 10 cm$^{-1}$ | $1\cdot10^{-1}$ (ρ = 1%)<br>$3\cdot10^{-3}$<br>(ρ = 100%) | NPL | NPL | Available: Aluminised mirrors, Uncoated glass |
| **Reflectance, Regular**<br>***Mirror*** | Germany<br>*PTB* | % | 0 - 100 | Direct comparison | 220 nm - 20 µm | | 0,1 - 16 | $5\cdot10^{-3}$ - $2\cdot10^{-2}$ | PTB | PTB | Specular<br>7° - 80° |
| **Reflectance, Regular**<br>***Mirror*** | Sweden<br>*SP* | % | $10^{-1}$ - $10^{0}$<br>$10^{-2}$ - $10^{0}$<br>$10^{-1}$ - $10^{0}$ | Relative measurement | 200 - 300<br>0,3 - 2 µm<br>2 - 30 µm | | 1 - 100 | $2\cdot10^{-2}$ - $1\cdot10^{-2}$ | SWEDAC | NPL | |
| **Reflectance, Regular**<br>***Mirror, Photodiode*** | Hungary<br>*OMH* | % | 0,1 - 100 | VW accessory on spectrophotometer | 300 - 1100 | | 2 | $4\cdot10^{-3}$ - $1\cdot10^{-2}$ | OMH | OMH | |
| **Reflectance, Regular**<br>***Optical Component*** | Germany<br>*PTB* | % | | Trap | 40 - 400 | < 50 µW | 1 - 4 | $2\cdot10^{-3}$ | PTB | PTB | Synchrotron Radiation (BESSY) |
| **Reflectance, Regular**<br>***Standard*** | Italy<br>*IEN* | % | | Gonioreflectometer | | | | $1\cdot10^{-3}$ | IEN | IEN | |
| **Transmittance**<br>***Filters*** | Sweden<br>*SP* | | $10^{-3}$ - $10^{-2}$<br>$10^{-2}$ - $10^{0}$ | Relative measurement, linearity | 300 - 2500 | See range | 0,1 - 20 nm | $2\cdot10^{-2}$ - $10^{-2}$<br>$10^{-2}$ | SWEDAC | | |
| **Transmittance, Diffuse**<br>***Filter*** | Sweden<br>*SP* | % | 0,1 - 100 | Relative measurement, linearity | 300 - 2500 | | 0,1 - 20 | $2\cdot10^{-2}$ - $1\cdot10^{-2}$ | SWEDAC | SP | |
| **Transmittance, Diffuse**<br>***Material*** | Italy<br>*IEN* | % | | Sphere | | | | $1\cdot10^{-2}$ | IEN | IEN | |
| **Transmittance, Diffuse**<br>***Material*** | Portugal<br>*CETO* | % | 1 - 90 | Integrating sphere | | | 0,5 - 20 | $2\cdot10^{-2}$ | IPQ | NIST | |
| **Transmittance, Diffuse**<br>***Material*** | United Kingdom<br>*NPL* | % | 0 - 100 | Calibration on a spectrophotometer with an integrating sphere accessory | 200 - 2500 | | Usually 2 nm in uv-visible.<br>2 - 20 nm in near infrared | $1\cdot10^{-2}$ | NPL | NPL | Can measure to BS EN 578 : 1994 and BS 7914 : 1998 |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Transmittance, Regular *Filter*** | Czech Republic<br>*CMI LPM 814* | % | 0 - 100 | Monochromator and trap diode array | 360 - 700<br>360 - 1000 | | | $2\cdot10^{-3}$<br>$3\cdot10^{-3}$ | | CMI | |
| **Transmittance, Regular *Filter*** | Germany<br>*PTB* | % | | Trap | 40 - 400 | < 50 µW | 1 - 4 | $2\cdot10^{-3}$ | PTB | PTB | Synchrotron Radiation (BESSY) |
| **Transmittance, Regular *Filter*** | Germany<br>*PTB* | % | $> 10^{-10}$ | Direct/cascading | 220 nm - 20 µm | | 0,1 - 16 | $5\cdot10^{-3} - 2\cdot10^{-2}$ | PTB | PTB | |
| **Transmittance, Regular *Filter*** | Hungary<br>*OMH* | % | 10 -100<br>1 - 10<br>0,1 - 1<br>0,01 - 0,1 | Reference spectrophotometer direct/cascading | 350 - 800<br>240 -1700 | | 1 - 3 | $8\cdot10^{-4}$<br>$2\cdot10^{-3}$<br>$4\cdot10^{-3}$<br>$1{,}5\cdot10^{-2}$<br>$1\cdot10^{-3} - 2\cdot10^{-2}$ | OMH | OMH | SRM: set of 6-8 glass filters for spectrophotomter calibration |
| **Transmittance, Regular *Filter*** | Netherlands<br>*NMi-VSL* | % | 0,01 - 100 | | 250 - 1050 | | 2,5 | $5\cdot10^{-3}$ | NMi-VSL | NMi-VSL | Monochromator |
| **Transmittance, Regular *Filter*** | Poland<br>*GUM* | % | 0,1 - 100 | Spectrophotometer | 250 - 800<br>800 - 2500 | | 1<br>1 - 20 | $3\cdot10^{-3}$<br>$6\cdot10^{-3}$ | GUM | GUM | |
| **Transmittance, Regular *Filter*** | Slovakia<br>*SMU-272* | % | 0,001 - 100 | Spectrophotometer | 250 - 2000 | | 0,1 - 5 | $10^{-3}$ ($\tau$)<br>0,1 nm | SMU | SMU | Set of spectral lamps, monochromators |
| **Transmittance, Regular *Filter*** | Spain<br>*AIDO* | % | 0 - 100 | Spectrophotometer | 380 - 780 | | 0,1 - 5 | $1\cdot10^{-3}$ | ENAC | NIST | ISO 13666<br>EN 1836 |
| **Transmittance, Regular *Filter*** | Sweden<br>*SP* | % | $10^{-4} - 10^{-2}$<br>$10^{-2} - 10^{0}$<br>$10^{-2} - 10^{0}$ | Relative measurement, linearity | 200 nm - 2,5 µm<br>2,5 - 30 µm | | 0,5 - 20 | $3\cdot10^{-2} - 5\cdot10^{-3}$<br>$5\cdot10^{-3}$<br>$3\cdot10^{-2} - 2\cdot10^{-2}$ | SWEDAC | NPL | |
| **Transmittance, Regular *Filter*** | Switzerland<br>*OFMET* | | 0,01 - 100 | Direct beam linear detector | 350 - 1100 | | 3 | $1\cdot10^{-3}$ -<br>$1\cdot10^{-2}$ | OFMET | OFMET | |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Transmittance, Regular *Filter*** | United Kingdom<br>*NPL* | τ% | 73 | Spectrophotometer | 3990 cm$^{-1}$ | | | $2{,}3\cdot10^{-3}$ | NPL | NPL | Schott NG11 Optical Glass Filters |
| | | | 36 | | 3031 cm$^{-1}$ | | | $3{,}0\cdot10^{-3}$ | | | |
| | | | 17 | | 2598 cm$^{-1}$ | | | $4{,}6\cdot10^{-3}$ | | | |
| | | | 14 | | 3512 cm$^{-1}$ | | | $4{,}6\cdot10^{-3}$ | | | |
| | | | 10 | | 2473 cm$^{-1}$ | | | $6{,}4\cdot10^{-3}$ | | | |
| | | | 6 | | 2739 cm$^{-1}$ | | | $8{,}6\cdot10^{-3}$ | | | |
| | | | 0,01 | | 2010 cm$^{-1}$ | | | $1\cdot10^{0}$ | | | |
| **Transmittance, Regular *Filter, IR*** | Spain<br>*AIDO* | % | 0 - 100 | Spectrophotometer | 780 - 2000 | | 0,1 - 5 | $1\cdot10^{-3}$ | ENAC | NIST | ISO 13666<br>EN 1836 |
| **Transmittance, Regular *Filter, Neutral Density*** | United Kingdom<br>*NPL* | % | 0,001 - 100 | Reference Spectro-photometer | 200 - 2500 | | Usually 1 nm in uv-visible but can be selected by customer.<br>1 - 20 nm in near infrared | $4\cdot10^{-4}$ at 60% T | NPL | NPL | Best measurement capability is for Reference Spectrophotometer. |
| | | | | Scanning Spectrophotometer | | | | $2{,}5\cdot10^{-3}$ at 60% T | UKAS | | Scanning Spectro-photometers used for UKAS calibrations |
| **Transmittance, Regular *Filter, Stray Light*** | Sweden<br>*SP* | % | 0,001 - 1 | Relative measurement | 200 - 800 | | 1 - 5 | $1\cdot10^{-4}$ | SWEDAC | SP | |
| **Transmittance, Regular *Material*** | Austria<br>*BEV* | % | 0,01 - 100 | Spectrophotometer | 250 - 900 | | 0,5 - 10 | $3\cdot10^{-3}$ | BEV | BEV | |
| **Transmittance, Regular *Material*** | Finland<br>*HUT* | % | 0,05 - 100 | Reference spectrometer | 250 - 380 | | 1 - 3 | $1\cdot10^{-3}$ - $1\cdot10^{-2}$ | HUT | HUT | |
| | | | 0,01 - 100 | | 380 - 920 | | 0,3 - 3 | $5\cdot10^{-4}$ - $5\cdot10^{-3}$ | | | |
| | | | 0,05 - 100 | | 920 - 1700 | | 1 - 6 | $1\cdot10^{-3}$ - $1\cdot10^{-2}$ | | | |
| **Transmittance, Regular *Material*** | France<br>*BNM-INM* | % | 0,01 - 100 | Reference spectrophotometer | 250 - 2500 | | 0,5 - 2 | $2\cdot10^{-4}$ - $1\cdot10^{-3}$ | BNM | BNM | |
| **Transmittance, Regular *Material*** | France<br>*LNE(1)* | % | 0,01 - 100 | Calibrated spectrophotometer | 250 - 2500 | | 1 - 5 | $0{,}04\cdot10^{-2}$ - $1{,}0\cdot10^{-2}$<br>(Absolute) | COFRAC | BNM | |
| **Transmittance, Regular *Material*** | Italy<br>*IEN* | % | 0,01 - 100 | Sphere gonioreflectometer | 300 - 800 | | | $2\cdot10^{-3}$ | IEN | IEN | |
| **Transmittance, Regular *Material*** | Portugal<br>*CETO* | % | 0,1 - 90 | Scanning | 200 - 3000 | | 0,5 - 20 | $1\cdot10^{-3}$ | IPQ | NPL | Uncertainty for 200 to 800 nm |

| Type of Calibration & Artefact | Country & Name of Lab | Units | Measurement Range | Measurement Method | Range of Measurement Parameters | | | Best Measurement Capability (Relative) | Accreditation Body/NMI | Traceability Route | Further Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wavelength (nm) | Power Level | Bandwidth (nm) | | | | |
| **Transmittance, Regular**<br>***Material*** | Spain<br>*IFA* | % | 0,01 - 100 | Spectrophotometer | 200 - 800<br>800 - 2000<br>> 2000 | | 0,2 - 1<br>1<br>3 - 10 | $\tau < 1 = 2\cdot10^{-2}$<br>$I < \tau < 10 = 3,5\cdot10^{-3}$<br>$10 < \tau < 100 = 1\cdot10^{-3}$ | IFA | IFA | Patch size |
| **Transmittance, Regular**<br>***Material*** | United Kingdom<br>*NPL* | % | 0,001 - 100 | Reference Spectrophotometer<br>Scanning Spectrophotometer | 200 - 2500 | | Usually 1 nm in uv-visible but can be selected by customer.<br>1 - 20 nm in near infrared | $4\cdot10^{-4}$ at 60% T<br>$2,5\cdot10^{-3}$ at 60% T | NPL<br>UKAS | NPL | Best measurement capability is for Reference Spectrophotometer<br>Scanning Spectrophotometers used for UKAS calibrations |
| **Transmittance, Regular**<br>***Material*** | United Kingdom<br>*NPL* | % | $\tau(\upsilon)$<br>0 - 100 | Spectrophotometer | 4000 - 180 cm$^{-1}$<br>2,5 - 56 µm | | 2 - 10 cm$^{-1}$ | $5\cdot10^{-2}$ ($\tau$ = 1%)<br>$2\cdot10^{-3}$ ($\tau$ = 100%) | NPL | NPL | |
| **Transmittance, Regular**<br>***Material*** | United Kingdom<br>*Tintometer* | % | 0 - 100 | Scanning Spectrophotometer | 380 - 780 | | | 0,04 T + 0,26% (Absolute) | UKAS | NPL | |
| **Transmittance, UV**<br>***Filter*** | Spain<br>*AIDO* | % | 0 - 100 | Spectrophotometer | 280 - 380 | | 0,1 - 5 | $1\cdot10^{-3}$ | ENAC | NIST | ISO 13666<br>EN 1836 |
| **Transmittance, Visual**<br>***Filter*** | Switzerland<br>*OFMET* | % | 0,01 - 100 | | $V(\lambda)$ | | | $1\cdot10^{-3} - 1\cdot10^{-2}$ | OFMET | OFMET | Various geometries. Colour and Neutral Filters |
| **Wavelength**<br>***Filter, Bandpass, Line*** | Sweden<br>*SP* | nm | 200 - 800 | Substitution to wavelength standards | 200 - 800 | | 0,5 - 5 | $10^{-3}$ | SWEDAC | NPL | |
| **Wavelength**<br>***Filter, Glass*** | Hungary<br>*OMH* | nm | 240 - 800 | Reference spectrophotometer | 240 - 800 | | 0,5 - 1 | 0,1 - 0,2 nm | OMH | OMH | Absorption peak and inflexion point method<br>SRM: didymium filter |
| **Wavelength**<br>***Filter, Glass, Rare Earth*** | Austria<br>*BEV* | nm | 250 - 900 | Spectrometer | 250 - 900 | | 0,2 - 2 | 0,3 nm in range 250 -600 nm<br>0,5 nm in range 600 - 900 nm | BEV | BEV | |