Report on
the bilateral Comparison between
ZMDM (Serbia) and LNE-INM (France)

Euramet Project 766
EURAMET.PR-K6.1

Spectral regular transmittance

LNE-INM – October 2009
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1. Introduction

In 1952 the Comité Consultatif de Photométrie (CCP at that time) has carried out the first and up to now sole comparison of spectral regular transmittance on coloured glass filters with the Bureau International des Poids et Mesures acting as pilot laboratory. Since that time the organisation of the worldwide metrology has changed with the implementation of the Mutual Recognition Arrangement (MRA)[1] signed in October 1999 by thirty-eight Member States of the Metre Convention and representatives of two international organisations. Now the list of signatories of the Mutual Recognition Arrangement has 45 Members States, 20 Associates of the CGPM and 2 international organisations. A particular aspect of the MRA is the organisation of international comparisons of measurements, to be known as key comparisons. They are introduced, organised and processed according to guidelines which ensure the equivalence of values assigned to transfer standards by different National Metrological Institutes (NMIs).

At the 14th CCPR-meeting in June 1997, it was decided to carry out a Key Comparison of spectral regular transmittance. For the preparation of this comparison a working group with Helsinki University of Technology (HUT, at the present time MIKES), Measurement Standards Laboratory of New Zealand (MSL), National Institute of Standards and Technology (NIST), National Physical Laboratory (NPL), Physikalisch-Technische Bundesanstalt (PTB) and Bureau National de Métrologie (BNM-INM, at present time LNE-INM) was formed, with the LNE-INM acting as the central and reporting laboratory for the measurements to be done and co-operating closely with the BIPM.

To link laboratories which have not taken part in the CCPR key comparison it is possible to organise regional or bilateral comparisons. As ZMDM (Serbia) was not able to take part at the regional Euramet.PR-K6 comparison it was decided to organise a bilateral comparison with LNE-INM (France), pilot laboratory of the CCPR-K6 and the Euramet-PR-K6 comparisons.

This comparison was carried out under the Euramet framework, with the project number 766. The comparison has been registered at BIPM KCDB with the identifier Euramet.PR-K6.1.

2. Participants :

The participants are given in the following Table 1.

[1] Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes
Paris, 14 October 1999
Comité international des poids et mesures
Édité par le BIPM
Pavillon de Breteuil
F-92312 Sèvres Cedex, France
Imprimerie STEDI (Paris)
Achevé d'imprimer : septembre 1999

Table 1 – List of the participating laboratories to the bilateral comparison.[2]

Acronym	Laboratory Name	Country
BNM-INM → LNE-IMN	*Bureau National de Métrologie - Institut National de Métrologie* Laboratoire National de métrologie et d'Essais	France
ZMDM	Directorate of Measures and Precious Metals	Serbia

For laboratories having changed their name, the new name will be used in this report.
In some laboratories the contact person in charge of the comparison has also changed between the beginning and the end of the comparison. In some other cases it is the address of the contact person which has changed. Also the information given on that topic in the technical protocol (Annex A) has to be updated according to the information contained in the table below.

Table 2 – List updated in June 2009 of the contact persons for the participating laboratories to the Bilateral Euramet.PR-K6.1 comparison.

LNE-INM	**Dr Gaël Obein** LNE-INM/CNAM 61, rue du Landy 93210 La Plaine Saint-Denis France	Phone : +33 1 58 80 87 88 Fax : +33 1 58 80 89 00 E-mail : gael.obein@cnam.fr
ZMDM	**Dr Vladan Škerović** ZMDM Directorate of Measures and Precious Metals Mike Alasa 14 11 000 Beograd Republic of Serbia	Phone: + 38 1 11 2024446 Fax: +38 1 11 2181668 E-mail: vladanskerovic@dmdm.rs

3. Principle of the comparison

The comparison was organised exactly in the same way as the Euramet-K6 comparison :

* The aim of this bilateral comparison was restricted to check only the accuracy of the radiometric scale of the reference spectrophotometers of the participating laboritory's.
* The samples were provided by the pilot laboratory.
* The filters were coloured glass filters plates 50 × 50 mm^2.
* The nominal transmittances were approximately 92%, 56%, 10%, 1% and 0.1%.
* The wavelengths of measurement were 380, 400, 500, 600, 700, 800, 900 and 1000 nm.
* The recommended geometry was a parallel beam with a circular shape of 20 mm diameter or a square shape of 20 mm side.
* The angle of incidence was normal or near normal.
* The recommended bandwidth was 1 nm.

[2] When the laboratory name or the acronym has changed during the time of the key comparison, the first line, *written in italic*, is the name of the lab at the beginning of the comparison, the actual name is written under, in regular.

3.1. Description of the standards

The filter set to check the photometric scale is constituted by 5 neutral coloured glass filter plates 50 mm x 50 mm with nominal transmittance, at the wavelength of 546 nm, of approximately 92%, 56%, 10%, 1% and 0.1%. Each filter is identified by a reference engraved in a corner outside the area used for measurement. This reference has two parts. One is a letter indicating the type of glass (see table below) the other is the serial number of the filter. The main characteristics of the filters are summarised in the following Table 3:

Table 3 – Filter characteristics.

Nominal transmittance @ 546 nm in %	Type of glass	Nominal thickness mm	Reference
92	BK 7	4.0	A
56	NG 11	1.5	B
10	NG 5	3.9	C
1	NG 4	3.9	D
0.1	NG 3	3.1	E

The manufacturing tolerances are for :

Size : 50 x50 (+0/-0.3) mm

Flatness : better than 5 µm over a central diameter of 30 mm

Parallelism : better than 0.02 mm except for the filter of transmittance 92% (<0.1 mm)

For the CCPRK6 and Euromet.PR-K6 comparisons, 30 sets of filters have been used. We decided to use the set labelled 15 for this bilateral comparison.

3.2. Measurements before dispatching

At the pilot laboratory, measurements before dispatching the filters have been carried out on the reference spectrophotometer of the laboratory. The complete description of the experiment is detailed in the following paragraph.

3.3. LNE-INM experimental set-up

Facility

The LNE-INM reference spectrometer for transmission measurements is composed primarily of a source, a monochromator, an optical mount and a detector (Figure 1). The QTH lamp is used on the full spectral range from 380 to 1000 nm. The image of the filament is formed at the entrance slit of the monochromator with two lenses. Between the lenses, where the beam is collimated, non-fluorescent filters are used to suppress higher orders. These filters are colored filters from the SFK filter collection, from Schott. They are band pass filters with a half width at half the maximum ranging between 25 nm and 60 nm. To reduce the “in band” stray light, the aperture is adjusted to avoid having light outside the grating. The “out band” stray was checked using long pass, sharp cut-off, coloured glass filters at various wavelengths.

The wavelength is controlled by a high resolution Jobin Yvon single grating monochromator (THR). The focal distance of the spherical mirrors of the Czerny-Turner mount is 1500 mm and the numerical aperture is F/12. For the spectral range 380 nm to 700 nm, the grating is an holographic grating with 2000 groves per mm giving a band pass of 0.5 nm at the exit slit of the monochromator. For the spectral range 700 nm to 1000 nm, the grating is an engraved grating with 1200 groves per mm giving a band pass of 0.8 nm. The resolution obtained with the stepper motor is 0.002 nm with the holographic grating and better than 0.0035 nm between 800 and 1400 nm.

Two spherical mirrors are used to relay the light to the detector and avoid chromatic aberrations and back reflections. Between the mirrors, the light beam is collimated and goes through the filter to be measured. The beam spot on the filters was 20 mm diameter circle as recommended in the protocol. The filter holder is mounted on a translation stage, to allow the measurement of the reference beam (100%) and the black (0%).

The detector part is composed of an integrating sphere and a detector. The detector is associated with the grating. For the holographic grating, on the visible range, a photomultiplier S20 is used. For the ruled grating, on the IR range, a silicon photodiode is used.

All the optical mounts at the exit slit of the monochromator are housed in a temperature controlled black box. For the "before" measurements, the average temperature in the box was 22 ± 1 °C; for the "after" measurements the average temperature in the box was 22.5 ± 0.6 °C.

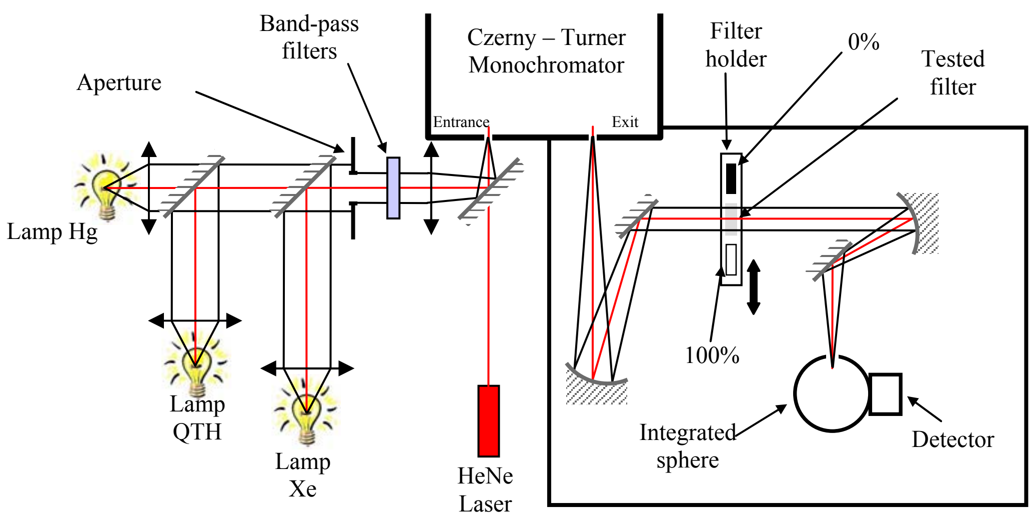


Figure 1 – Schematic drawing of the reference spectrometer.

Filter sets "D" and "E" have been measured using a step down method with an NG 5 filter in the reference beam. The transmittance of this filter was approximately 10%.

For each filter and each wavelength, a set of three successive measurements was taken and the mean value and the standard deviation were calculated. A second set of measurements identical to the first one was taken another day. If one of the standard deviations was larger than the expected value or the discrepancy between both measurements was too large, a third and eventually a fourth set of measurements was taken. The final result is the mean value of at least two sets of measurements.

Typical uncertainties

The uncertainties are absolute uncertainties

Table 4 : Type A uncertainties

λ (nm)	Filter “A”	Filter “B”	Filter “C”	Filter “D”	Filter “E”
380	6,16E-05	4,11E-04	1,52E-04	1,04E-05	6,54E-07
400	6,15E-05	6,61E-05	2,96E-05	4,13E-06	1,60E-06
500	6,15E-05	6,60E-05	2,92E-05	6,28E-06	1,67E-06
600	6,15E-05	6,68E-05	4,23E-05	9,88E-06	2,41E-06
700	6,15E-05	7,02E-05	3,48E-05	1,73E-05	4,01E-06
800	6,84E-05	1,22E-04	1,15E-04	2,21E-05	9,52E-06
900	6,83E-05	1,21E-04	8,09E-05	2,28E-05	8,33E-06
1000	6,83E-05	8,72E-05	6,24E-05	1,71E-05	7,05E-06

Table 5 : Type B uncertainties

λ (nm)	Filter “A”	Filter “B”	Filter “C”	Filter “D”	Filter “E”
380	6,20E-05	4,12E-04	1,52E-04	1,10E-05	1,00E-06
400	6,20E-05	6,70E-05	3,00E-05	5,00E-06	2,00E-06
500	6,20E-05	6,70E-05	3,00E-05	7,00E-06	2,00E-06
600	6,20E-05	6,70E-05	4,30E-05	1,00E-05	3,00E-06
700	6,20E-05	7,10E-05	3,50E-05	1,80E-05	5,00E-06
800	6,90E-05	1,23E-04	1,15E-04	2,30E-05	1,00E-05
900	6,90E-05	1,22E-04	8,10E-05	2,30E-05	9,00E-06
1000	6,90E-05	8,80E-05	6,30E-05	1,80E-05	8,00E-06

3.4. Circulation of the filters

The filter set 15 was sent to ZMDM in October 2003. After a delay required for administrative formalities, the measurements at ZMDM were carried out in March 2004. The measurements at ZMDM were completed by April 2004. The “return” measurements at the pilot laboratory were completed at the end of June 2004. In order to check the stability of the filters, they were carried out exactly in the same way as the measurements before dispatching.

3.5. Stability of the filters

The stability of the filters during the comparison was checked by calculating the absolute deviation of the transmittance of the filter according to the equation :

$$\text{Deviation} = \text{transmittance after} - \text{transmittance before} \quad (1)$$

The uncertainties taken into account for this study are only the uncertainties determined by type A methods of the measurements carried out by LNE-INM. Because measurements have been done in exactly the same conditions in both cases, most of the uncertainties determined by type B methods cancelled out or have a negligible effect. The results for the filters used in the comparison are given in Figure 2 to Figure 6. Numerical values are reported in the table p.17.

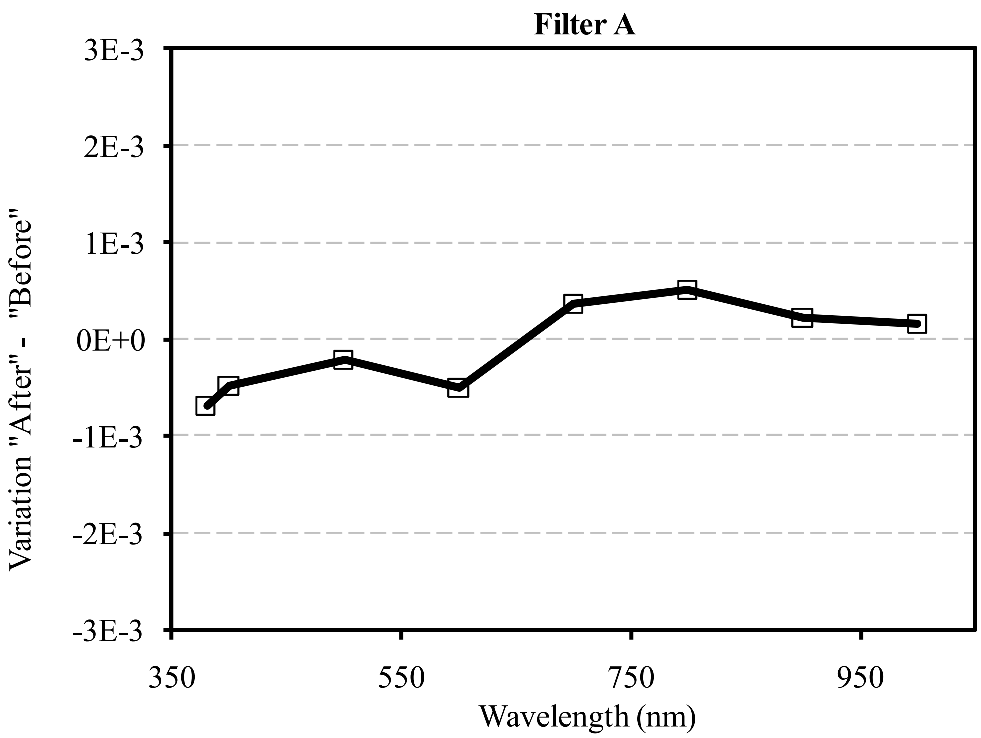


Figure 2 – Stability of type A filters during the comparison

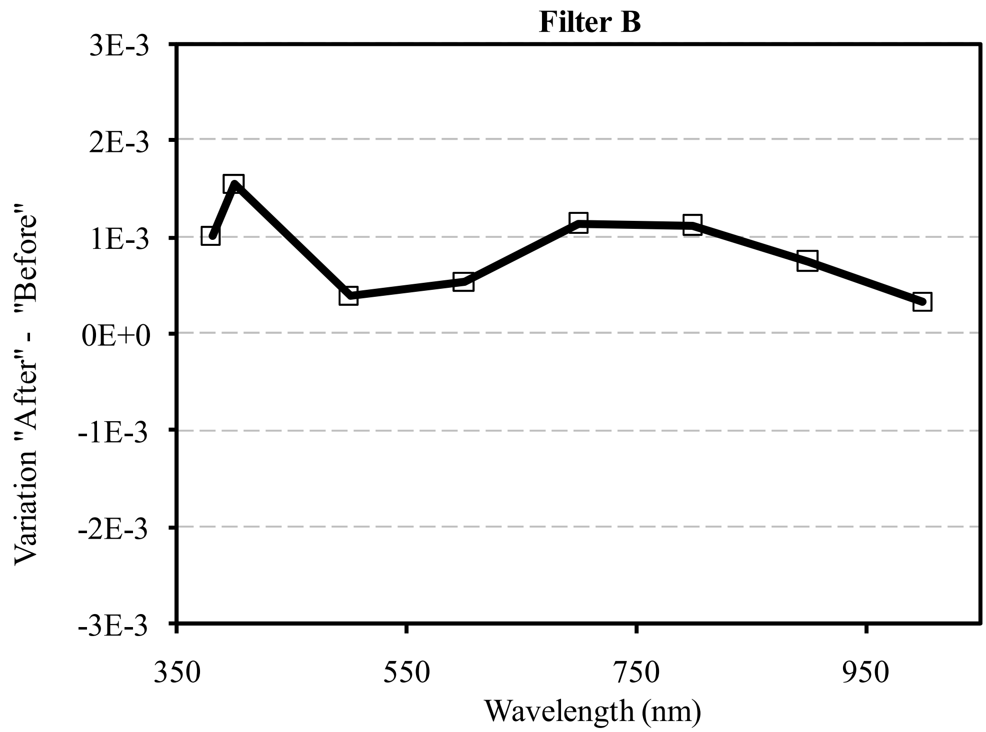


Figure 3 – Stability of type B filters during the comparison

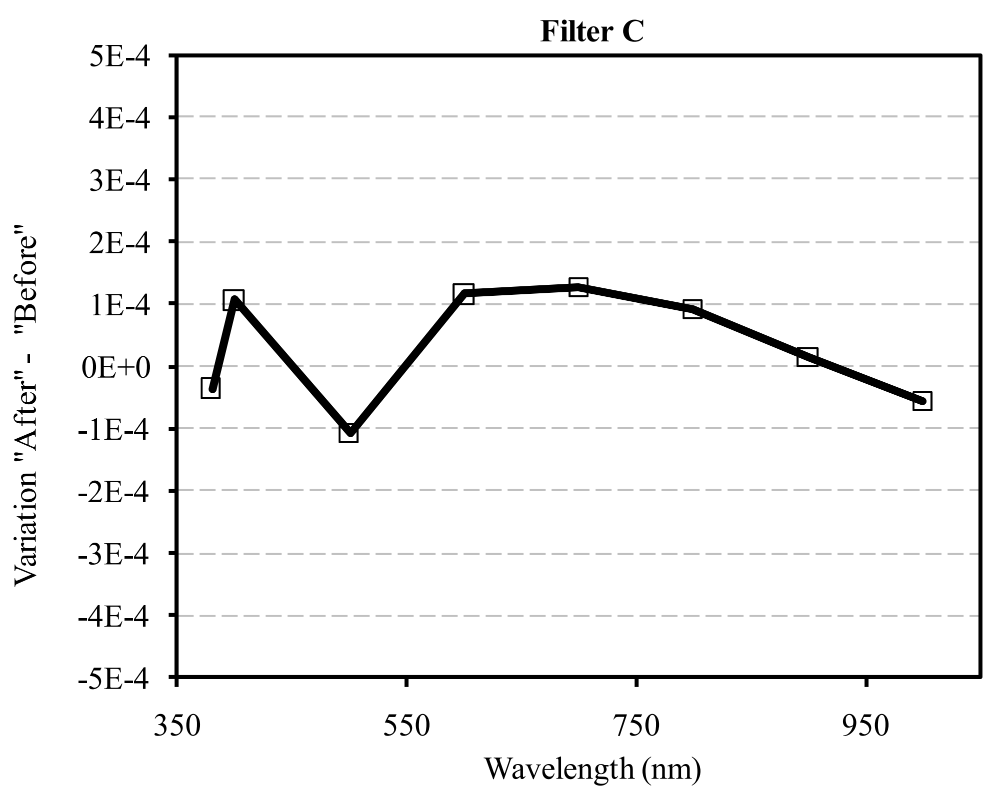


Figure 4 – Stability of type C filters during the comparison

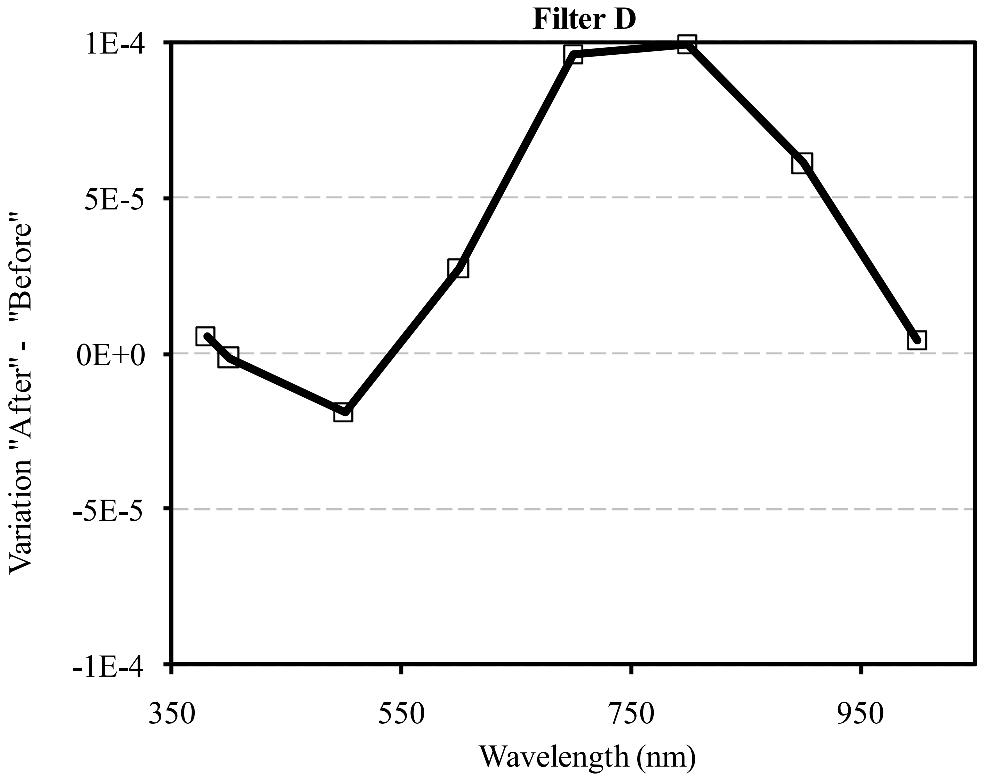


Figure 5 – Stability of type D filters during the comparison

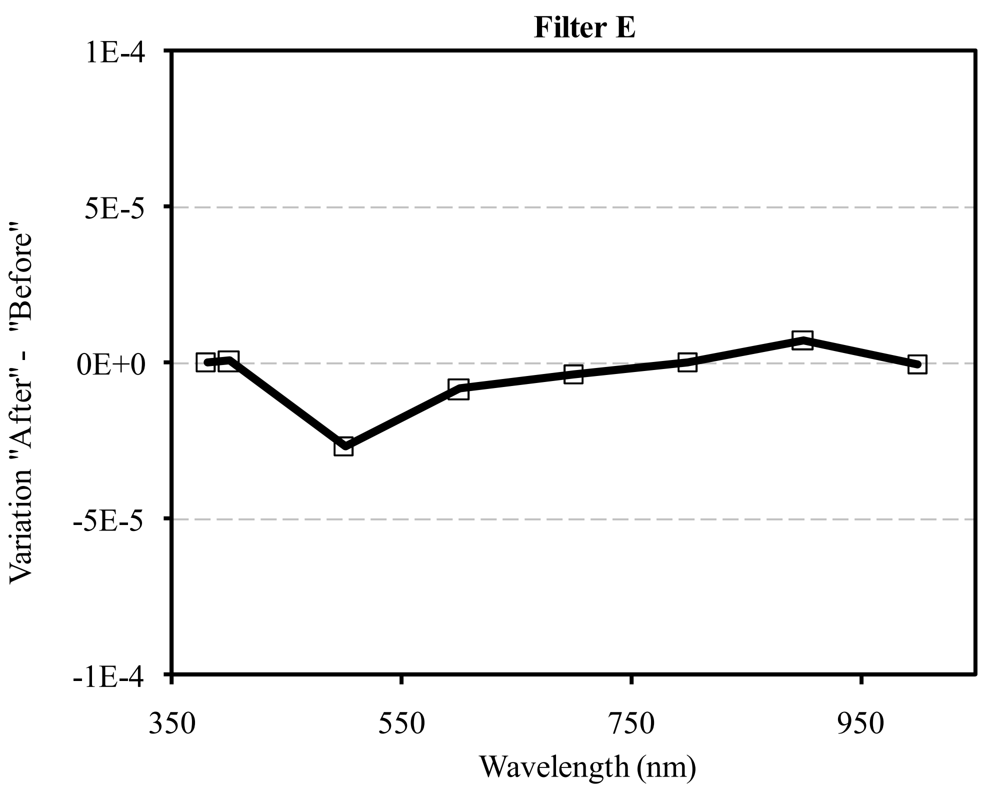


Figure 6 Stability of type E filters during the comparison

As it can be seen from the preceding graphs, the drift of the filters was not negligible. Moreover, for the coloured glass filters (filters B to D), the drift was wavelength dependent. As a consequence, the drift of the filters during the comparison has been included in the calculation of the total uncertainty.

3.6. LNE - INM transmittance value

The transmittance value adopted by the LNE-INM for the filter was the mean value of measurements before and after the circulation of the filters.

4. Facilities, measurement methods and conditions, and uncertainties from ZMDM

As requested by the protocol, ZMDM has returned its transmission measurements with a brief description of the experimental set up and a detailed uncertainties budget. This information is given below.

Make and type of the spectrophotometer

A single beam instrument with automated exchange of measured samples and compensation detector, based on double monochromator (Bentham DTM300V) and solid-state silicon detectors, is build up on the optical table (1 m × 1.5 m), in the Laboratory for photometry and radiometry of Bureau of Measures and Precious Metals (ZMDM). Functioning of the system is based on the concept of the virtual instrument. The scheme of spectrophotometric system is shown in Figure 7.

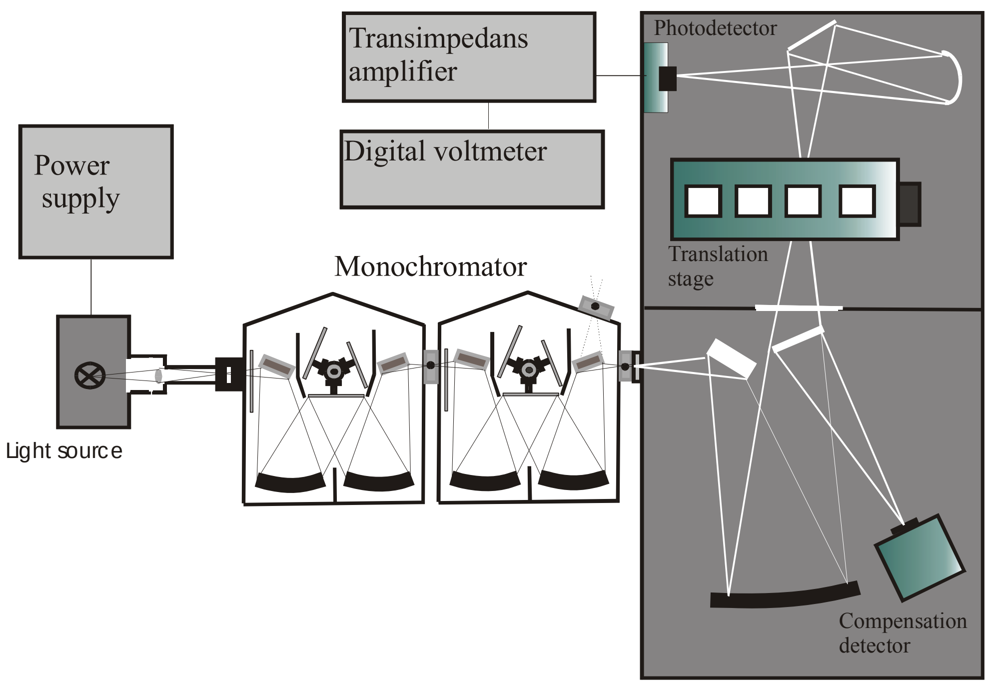


Figure 7 - Scheme of spectrophotometric system

The image of the halogen light source is projected on the entrance slit of the monochromator with quartz lens objective with appropriate *f*/# number, which is in this case *f*/5.5. In the plane of the exit slit of the monochromator, a 3 mm diameter, circular aperture is placed, so that, in the focal plane of the optical system, a regular circular spot is obtained. The all-mirror, off-axes (off-axes angle ≤ 6°) optical system consists of one plain mirror and one spherical mirror of large diameter

(152 mm, *f*/2 mirror relative aperture) projecting an image of the circular aperture at the focal plane with 1:1.1 ratio. The system is placed in a light-tight enclosure. A beam splitter is used to divert approximately 10 % of the radiant flux on to the compensation detector. Its role is to compensate for drift of the radiant flux between changes of measured samples and the reference in the light beam path. The stepping motor driven translation stage has linear resolution of 10 μm. The plane and one spherical mirrors refocus the spot from the measured sample on to the detector surface with a 1:1 ratio. Both detectors are silicon photodiodes Hammatsu S1337 1010BQ. Signals from photodiodes are measured through specially constructed transimpedance amplifier, with scanner and digital voltmeter. Automation based on the concept of virtual instrument provides a system functioning as a compact, user-friendly device, at the same time allowing independent access to all of its parts.

Method of characterisation of the spectrophotometer

Design of the optical system defines the light beam geometry, whose influence on measurements is manifested as beam-displacement errors, interreflection errors and obliquity errors.

Beam-displacement errors occur in spectrophotometers with focused light beam, because inserting the sample, of a thickness *t*, in the focused light beam shortens the effective distance (due to different refractive index, *n*) between spot image in the focal plane and refocusing optics by an amount $t(1-1/n)$ so that the final spot image is shifted towards the detector. A different part of the detector surface is irradiated before and after the sample is inserted, which again causes error due to surface nonuniformity of detector responsivity. In the particular case of light beam geometry, sample thickness 4 mm, and refractive index of 1.5, and, on the basis of the detector surface nonuniformity data (0.5 % in the worst case), measurement uncertainty component due to beam-displacement is in the worst case 0.4×10^{-4}.

Obliquity errors are divided according to their source, at a path-length error and Fresnel-reflectance error. In our case where the sample is inserted normal to the incident light beam, Fresnel-reflectance error is equal to zero, and path-length error may be corrected by approximate formula $\Delta T = -(T/3n^2)\left(\ln\frac{T}{1-2r}\right)\theta_0^2$, where *T* is measured value of transmittance, *n* is refractive index, *r* is defined by $r=(1-n)^2/(1+n)^2$, and θ_0 is a cone half angle of the incident light beam. For measurement geometry *f*/6 (θ_0 = 0.08 rad), and transmittance level of 10 %, this correction amount is 2.0×10^{-4}, and it is separately calculated for each transmittance value. The uncertainty of making this correction is due to deviation of beam geometry from the calculated one (*f*/6), and it is in the worst-case $\leq 0.6\times10^{-4}$.

Interreflection error is evaluated by the method of transmittance measurements on tilted samples in polarized light (K. D. Mielenz, R. Mavrodineanu, *Reflection Correction For High-Accuracy Transmittance Measurements on Filter Glasses*, JOURNAL OF RESEARCH of the National Bureau of Standards – A. Physics and Chemistry, Vol. 77A, No. 6, November-December 1973). No interreflection errors were found with this experimental procedure (all possible deviations of the measurement results that effect from interreflections, was less than dispersion of measurement results, apropos repeatability of measurements). The same conclusion can be applied for **Polarization error** witch is a consequence of positioning the sample towards the optical axes.

Nonlinearity of the detector (u_L) is determined by the double aperture method (K. D. Mielenz, K. Eckerle, *Spectrophotometer linearity testing using the double-aperture method*, Applied Optics, Vol. 11, 1972), and it is found to be below 5×10^{-4} transmittance levels, which is in full agreement with results obtained by other metrological laboratories for photodiodes of the same type. This is found to be sufficiently small so that applying the correction was not needed. Uncertainty component due to nonlinearities is evaluated as $u_{\tau L} = \tau(1-\tau)u_L$, which in the worst case for $u_L = 0.05\%$ and τ = 10 %, amounts 4.5×10^{-4}. This uncertainty component is separately calculated for each transmittance value.

Wavelength accuracy has negligible effect on the total measurement uncertainty, because measurements are made on neutral density filters, which are spectrally nonselective, with sufficiently small bandwidths (4 nm), and wavelength accuracy of monochromator is 0.1 nm, and 0.2 nm at 800 nm. Reproducibility of the wavelength scale is better than 0.015 nm. The uncertainty component in transmittance measurements is obtained by the product of the wavelength scale uncertainty and variation of the transmittance with wavelength, and is evaluated at 0.3×10^{-4} for VIS-NIR spectral ranges, with distinction for 380 nm and 400 nm where it amounts 1×10^{-4}.

Stray light is reduced by using the double monochromator at the level ≤ 10^{-8}.
Some initial verification measurements are performed on the three NIST 930e (National Institute of Standards and Technology) calibrated glass filters of nominal transmittances of 10 %, 20 % and 30 %, on five wavelengths. Average relative difference between NIST certified data and data obtained by measurement with spectrophotometric system amount 0.128 %.

Description of measuring technique
All measurements are preformed with the spectrophotometric system shown in Figure 7, with a circular aperture placed on the optical bench, before the translation stage with measurement sample, to define relative aperture ***f*/6**, so as the size of the beam at the plane of the measured sample.
Translation stage was put behind the circular aperture in such way, that the size of the beam at the plane of the measured sample is approximately **1.5 cm** in diameter.
Measurements were repeated with sample positioned at the focus plane of the system and spot size of **3 mm** in diameter. Differences in the results related to previous case, was in the range of the dispersion of measurement results.
All measurements were preformed with **4 nm** bandwidth and **1.3 nm** bandwidth. The monochromator has variable slits and resolution of 0.15 nm. Because of the double monochromator and silicon detector combination, the signal is relatively small for smaller bandwidths which results in much larger dispersion of measurement results (system was originally constructed for measurement of detector spectral responsivity with spot size of 3 mm and bandwidth of 4 nm). This was the reason because the results of measurements with 1.3 nm bandwidth are given only where significant (greater than measurement uncertainty) difference occurs between these results and results for 4nm bandwidths.
Measurement procedure was automatic exchange of measured sample in the path of the light beam. Each time the signals from main and compensation detectors were measured simultaneously, **ten** times each detector. Average value of those readings was taken into account. At every wavelength measurements were performed for the sample and the reference (air), and before each of that, the measurement of dark current was made and correction applied.

Reproducibility of measurements was determined up on the sample of **30** independent measurements of each sample for every wavelength. All measurements were preformed during two months.

During the whole measurement procedure **temperature** in the laboratory was in the range of (22±2) °C, and it couldn't be controlled better, so that the influence of these temperature changes is encountered in reproducibility of measurements. Nevertheless, the uncertainty component due to temperature stability of the filters of 0.1% is encountered in the uncertainty budget.
Due to its optical design the system was liable to some astigmatism influence, which results in nonuniformity of the beam cross-section. This means that some influence of the nonuniformity of the filters may also be encountered, although, it wasn't done here. Detailed analysis wasn't carried out here, but some measurements were made, and it was found that nonuniformity of the filters is in the range of 0.05 % to 0.1 %.

Description of calibration laboratory conditions
During the whole measurement procedure **temperature** in the laboratory was in the range of (22±2) °C.

Humidity in laboratory was 50 % ± 15 %.
No cleaning of the filters was performed.

Uncertainties

Uncertainties

The uncertainties are absolute uncertainties

Table 6 : Type A uncertainties

λ(nm)	Filter "A"	Filter "B"	Filter "C"	Filter "D"	Filter "E"
380	0,000497	0,001003	0,000267	0,000062	
400	0,000425	0,000568	0,000322	0,000149	
500	0,000197	0,000127	0,000072	0,000013	0,000008
600	0,000178	0,000127	0,000053	0,000015	0,000009
700	0,000202	0,000768	0,000107	0,000029	0,000010
800	0,000337	0,000246	0,000084	0,000031	0,000033
900	0,000505	0,000208	0,000057	0,000022	0,000068
1000	0,000373	0,000153	0,000026	0,000019	0,000018

Table 7 : Type B uncertainties

λ(nm)	Filter "A"	Filter "B"	Filter "C"	Filter "D"	Filter "E"
380	0,001086	0,000475	0,000025	0,000000	
400	0,001089	0,000715	0,000112	0,000006	
500	0,001092	0,000733	0,000109	0,000010	0,000001
600	0,001094	0,000719	0,000091	0,000010	0,000001
700	0,001095	0,000752	0,000190	0,000031	0,000006
800	0,001096	0,000681	0,0001790	0,000039	0,000011
900	0,001096	0,000590	0,000123	0,000027	0,000010
1000	0,001097	0,000531	0,000091	0,000020	0,000008

Table 8 : Total uncertainties

λ(nm)	Filter "A"	Filter "B"	Filter "C"	Filter "D"	Filter "E"
380	0,001195	0,001110	0,000268	0,000062	
400	0,001169	0,000914	0,000341	0,000149	
500	0,001110	0,000744	0,000131	0,000016	0,000008
600	0,001108	0,000730	0,000106	0,000018	0,000009
700	0,001113	0,001075	0,000218	0,000042	0,000012
800	0,001146	0,000724	0,000198	0,000049	0,000035
900	0,001207	0,000626	0,000135	0,000035	0,000069
1000	0,001158	0,000553	0,000095	0,000027	0,000020

5. Results

Notations

τ_X Spectral transmission of the filter type *X* (*X* varies from A to E).

$u(\tau_X)$ Total absolute uncertainty (k=1) of τ_X reported by the NMI.

$\tau^{P}_{X,r}$ Spectral transmission of the filter type *X* (*X* varies from A to E), measured by the Pilot. *r* is the round. r = 1 to 2, where r=1 is the measurement before dispatching. r=2 is the measurement after dispatching.

$u(\tau^{P}_{X,r})$ Total absolute uncertainty (k=1) of $\tau^{P}_{X,r}$ reported by the Pilot.

$u(\tau^{PR}_{X,r})$ Reproducibility (type A) of Pilot measurements for $\tau^{P}_{X,r}$.

Pilot Measurements

The adopted value for the pilot lab transmission measurements is the average of round 1 and round 2

$$\tau_X^P = \frac{1}{2}\left(\tau_{X,1}^P + \tau_{X,2}^P\right) \tag{2}$$

Additional uncertainties

The additional uncertainties arise from artefacts due to transportation or different measurement conditions between Pilot and participant that affect comparison results. No problem was identified during the procedure that could suggest incorporating an additional uncertainty.

Drift uncertainty

As it was shown in §3.5, p.7, the stability of the filters during the comparison can be accessed by the difference between transmittance measurements before and after the dispatching. We plotted this difference for all the filters (see Figure 2 to Figure 6, p.7-9). We assume that the drift is quite smooth and reasonably taken into account by the mean value of the measurement "before" and "after" at the pilot laboratory.
After discussion within the participants of the CCPR-K6 comparison, it was accepted that the uncertainty $u_{\mathrm{drift},\ X}$, associated to possible drift of the filter X is estimated to be within the difference "before" – "after" with a rectangular probability distribution.

$$u_{driftX} = \frac{1}{2\sqrt{3}}\left|\tau_{X,1}^P - \tau_{X,2}^P\right| \tag{3}$$

Determination of the delta

For each filter X, the difference between NMI measurement and the Pilot lab measurement (as the average of the two rounds) is given by:

$$\Delta_X = \tau_X - \tau_X^P \tag{4}$$

and its uncertainty by

$$u(\Delta_X) = \sqrt{u^2(\tau_X) + u^2(\tau_X^{\mathrm{P}}) + u_{\mathrm{drift},X}^2}$$

Δ_X, $u(\Delta_X)$ and $u_{drift,X}$ are reported in table page 17.

5.2. Key Comparison Reference Value (KCRV)

The KCRV is given by the CCPR-K6 comparison. The results are reported in the following tables
The final KCRV is detailed in Table 9 and Table 10

Table 9 : Δ_{KCRV} for the five filters:

λ (nm)	Filter "A"	Filter "B"	Filter "C"	Filter "D"	Filter "E"
380	4,357E-04	1,540E-03	1,211E-04	-1,599E-06	1,049E-06
400	3,701E-04	1,093E-03	-3,117E-05	-1,185E-05	-6,444E-09
500	3,234E-04	9,756E-04	1,156E-04	8,555E-06	2,954E-06
600	3,075E-04	7,611E-04	1,777E-04	4,101E-05	8,210E-06
700	4,225E-04	3,424E-04	9,633E-05	3,374E-05	7,620E-06
800	6.383E-04	2,010E-04	1,455E-05	6,546E-06	1,543E-05
900	5,228E-04	7,263E-05	8,838E-06	-4,104E-06	-2,187E-06
1000	4,211E-04	1,051E-04	-1,840E-06	-3,835E-06	-9,511E-06

Table 10 : $u(\Delta_{KCRV})$ for the five filters:

λ (nm)	Filter "A"	Filter "B"	Filter "C"	Filter "D"	Filter "E"
380	1,058E-04	1,637E-04	3,114E-05	3,689E-06	2,379E-06
400	8,210E-05	1,187E-04	2,835E-05	4,792E-06	1,209E-06
500	6,338E-05	1,139E-04	2,193E-05	4,187E-06	1,125E-06
600	6,302E-05	6,358E-05	1,765E-05	4,668E-06	1,484E-06
700	6,926E-05	5,251E-05	2,987E-05	1,090E-05	4,124E-06
800	4,380E-05	5,879E-05	2,755E-05	8,918E-06	3,869E-06
900	6,047E-05	5,819E-05	1,978E-05	6,348E-06	3,015E-06
1000	6,443E-05	6,384E-05	1,555E-05	5,411E-06	2,903E-06

Uncertainties are absolute uncertainties

6. Degrees of equivalence (DoE)

Knowing the Δ_{KCRV} , the unilateral DoE is given by:

$$DoE_X = \Delta_X - \Delta_{\mathrm{KCRV,X}} \qquad (5)$$

$$u_{DoE,X} = k\sqrt{u^2(\Delta_X) + u^2(\Delta_{\mathrm{KCRV}})} \text{ ; k=2} \qquad (6)$$

Results are reported in the following table.
A graphical representation of the unilateral degrees of equivalence with k=2 is proposed in the following pages.

Filter A	λ (nm)	Drift	T pilot	unc (T pilot)	unc (T pr)	u(T add)	T nmi	unc (T nmi)	Delta	unc (delta)	KCRV	Unc(KCRV)	DoE	unc (DoE)
	380	-6,95E-04	9,14E-01	2,18E-04	2,09E-04	2,01E-04	9,12E-01	1,20E-03	-1,33E-03	1,23E-03	4,36E-04	1,06E-04	-1,77E-03	2,47E-03
	400	-4,88E-04	9,15E-01	2,55E-04	2,46E-04	1,41E-04	9,14E-01	1,17E-03	-7,79E-04	1,20E-03	3,70E-04	8,21E-05	-1,15E-03	2,41E-03
	500	-2,15E-04	9,17E-01	1,33E-04	1,18E-04	6,21E-05	9,17E-01	1,11E-03	-4,58E-04	1,12E-03	3,23E-04	6,34E-05	-7,81E-04	2,24E-03
	600	-5,15E-04	9,19E-01	1,46E-04	1,31E-04	1,49E-04	9,18E-01	1,11E-03	-4,87E-04	1,13E-03	3,07E-04	6,30E-05	-7,95E-04	2,26E-03
	700	3,68E-04	9,20E-01	1,32E-04	1,15E-04	1,06E-04	9,20E-01	1,11E-03	3,62E-05	1,13E-03	4,23E-04	6,93E-05	-3,86E-04	2,26E-03
	800	5,10E-04	9,20E-01	1,49E-04	1,18E-04	1,47E-04	9,20E-01	1,15E-03	2,45E-04	1,16E-03	6,38E-04	4,38E-05	-3,93E-04	2,33E-03
	900	2,28E-04	9,21E-01	7,41E-05	2,86E-05	6,59E-05	9,21E-01	1,21E-03	1,89E-04	1,21E-03	5,23E-04	6,05E-05	-3,34E-04	2,43E-03
	1000	1,60E-04	9,21E-01	7,26E-05	2,37E-05	4,62E-05	9,21E-01	1,16E-03	4,50E-05	1,16E-03	4,21E-04	6,44E-05	-3,76E-04	2,33E-03

Filter B	λ (nm)	Drift	T pilot	unc (T pilot)	unc (T pr)	u(drift)	T nmi	unc (T nmi)	Delta	unc (delta)	KCRV	Unc(KCRV)	DoE	unc (DoE)
	380	1,01E-03	4,01E-01	4,37E-04	1,43E-04	2,92E-04	4,08E-01	1,11E-03	6,94E-03	1,23E-03	1,54E-03	1,64E-04	5,40E-03	2,48E-03
	400	1,54E-03	6,02E-01	1,82E-04	1,67E-04	4,46E-04	6,02E-01	9,14E-04	5,13E-04	1,03E-03	1,09E-03	1,19E-04	-5,80E-04	2,08E-03
	500	3,95E-04	6,16E-01	1,20E-04	9,96E-05	1,14E-04	6,15E-01	7,44E-04	-3,87E-04	7,62E-04	9,76E-04	1,14E-04	-1,36E-03	1,54E-03
	600	5,37E-04	6,04E-01	1,03E-04	7,77E-05	1,55E-04	6,04E-01	7,30E-04	1,01E-04	7,53E-04	7,61E-04	6,36E-05	-6,60E-04	1,51E-03
	700	1,15E-03	6,32E-01	9,78E-05	6,58E-05	3,31E-04	6,33E-01	1,08E-03	8,54E-04	1,13E-03	3,42E-04	5,25E-05	5,12E-04	2,26E-03
	800	1,13E-03	5,71E-01	1,26E-04	2,55E-05	3,25E-04	5,72E-01	7,24E-04	1,05E-03	8,04E-04	2,01E-04	5,88E-05	8,46E-04	1,61E-03
	900	7,55E-04	4,95E-01	1,22E-04	1,35E-05	2,18E-04	4,96E-01	6,26E-04	7,52E-04	6,74E-04	7,26E-05	5,82E-05	6,80E-04	1,35E-03
	1000	3,40E-04	4,46E-01	8,85E-05	1,46E-05	9,81E-05	4,46E-01	5,53E-04	1,25E-04	5,69E-04	1,05E-04	6,38E-05	1,99E-05	1,14E-03

Filter C	λ (nm)	Drift	T pilot	unc (T pilot)	unc (T pr)	u(drift)	T nmi	unc (T nmi)	Delta	unc (delta)	KCRV	Unc(KCRV)	DoE	unc (DoE)
	380	-3,53E-05	2,12E-02	1,59E-04	4,42E-05	1,02E-05	2,22E-02	2,68E-04	9,66E-04	3,12E-04	1,21E-04	3,11E-05	8,45E-04	6,27E-04
	400	1,05E-04	9,49E-02	8,20E-05	7,53E-05	3,02E-05	9,49E-02	3,41E-04	-5,63E-05	3,52E-04	-3,12E-05	2,83E-05	-2,51E-05	7,06E-04
	500	-1,06E-04	9,16E-02	4,00E-05	2,72E-05	3,07E-05	9,20E-02	1,31E-04	3,82E-04	1,40E-04	1,16E-04	2,19E-05	2,67E-04	2,84E-04
	600	1,15E-04	7,67E-02	4,72E-05	2,10E-05	3,31E-05	7,68E-02	1,06E-04	4,73E-05	1,21E-04	1,78E-04	1,77E-05	-1,30E-04	2,44E-04
	700	1,25E-04	1,61E-01	5,35E-05	3,94E-05	3,61E-05	1,61E-01	2,18E-04	5,71E-04	2,27E-04	9,63E-05	2,99E-05	4,75E-04	4,59E-04
	800	9,00E-05	1,50E-01	1,15E-04	6,10E-06	2,60E-05	1,51E-01	1,98E-04	8,77E-04	2,30E-04	1,46E-05	2,76E-05	8,62E-04	4,64E-04
	900	1,50E-05	1,03E-01	8,09E-05	2,05E-06	4,33E-06	1,03E-01	1,35E-04	6,56E-04	1,57E-04	8,84E-06	1,98E-05	6,47E-04	3,17E-04
	1000	-5,60E-05	7,63E-02	6,25E-05	2,25E-06	1,62E-05	7,66E-02	9,48E-05	3,39E-04	1,15E-04	-1,84E-06	1,55E-05	3,41E-04	2,31E-04

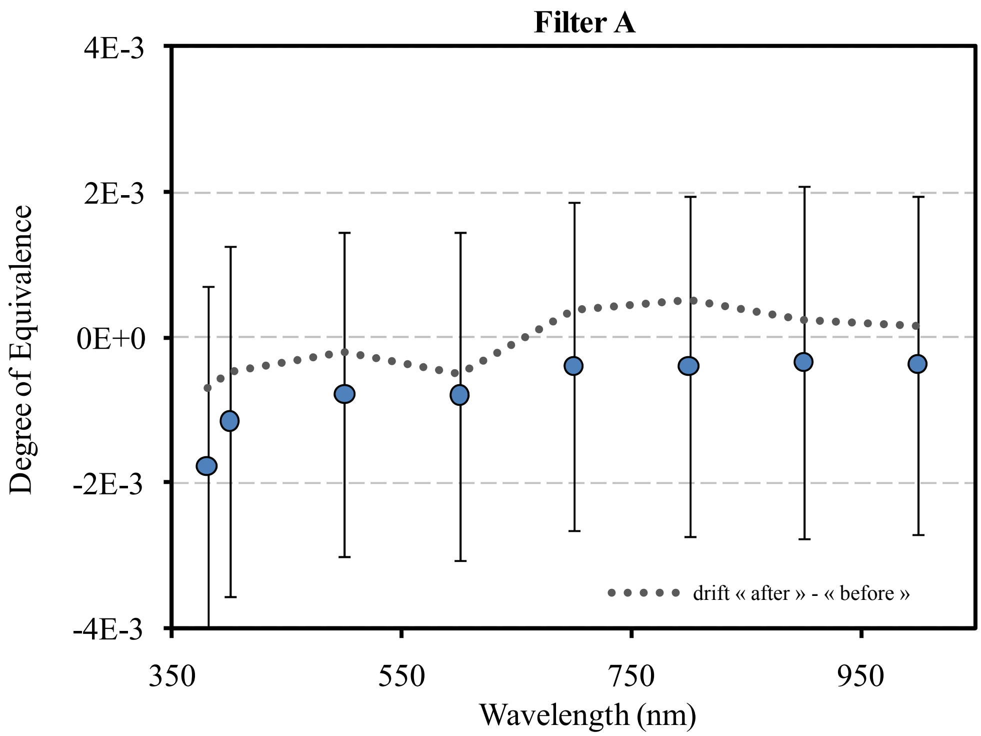
Filter D	λ (nm)	Drift	T pilot	unc (T pilot)	unc (T pr)	u(drift)	T nmi	unc (T nmi)	Delta	unc (delta)	KCRV	Unc(KCRV)	DoE	unc (DoE)
	380	5,25E-06	3,49E-04	1,49E-05	9,05E-06	1,52E-06	3,52E-04	6,17E-05	2,65E-06	6,35E-05	-1,60E-06	3,69E-06	4,24E-06	1,27E-04
	400	-1,50E-06	5,14E-03	9,00E-06	7,89E-06	4,32E-07	5,17E-03	1,49E-04	2,47E-05	1,49E-04	-1,18E-05	4,79E-06	3,65E-05	2,99E-04
	500	-1,90E-05	8,37E-03	1,43E-05	1,26E-05	5,49E-06	8,43E-03	1,62E-05	6,49E-05	2,23E-05	8,55E-06	4,19E-06	5,63E-05	4,54E-05
	600	2,71E-05	8,27E-03	1,63E-05	1,30E-05	7,83E-06	8,29E-03	1,77E-05	2,76E-05	2,53E-05	4,10E-05	4,67E-06	-1,35E-05	5,15E-05
	700	9,59E-05	2,64E-02	4,19E-05	3,79E-05	2,77E-05	2,66E-02	4,24E-05	1,70E-04	6,57E-05	3,37E-05	1,09E-05	1,36E-04	1,33E-04
	800	9,90E-05	3,21E-02	2,24E-05	3,44E-06	2,86E-05	3,23E-02	4,92E-05	2,25E-04	6,11E-05	6,55E-06	8,92E-06	2,18E-04	1,24E-04
	900	6,09E-05	2,24E-02	2,28E-05	1,36E-06	1,76E-05	2,26E-02	3,51E-05	2,03E-04	4,54E-05	-4,10E-06	6,35E-06	2,07E-04	9,17E-05
	1000	4,16E-06	1,66E-02	1,72E-05	1,91E-06	1,20E-06	1,67E-02	2,72E-05	1,06E-04	3,22E-05	-3,83E-06	5,41E-06	1,10E-04	6,53E-05

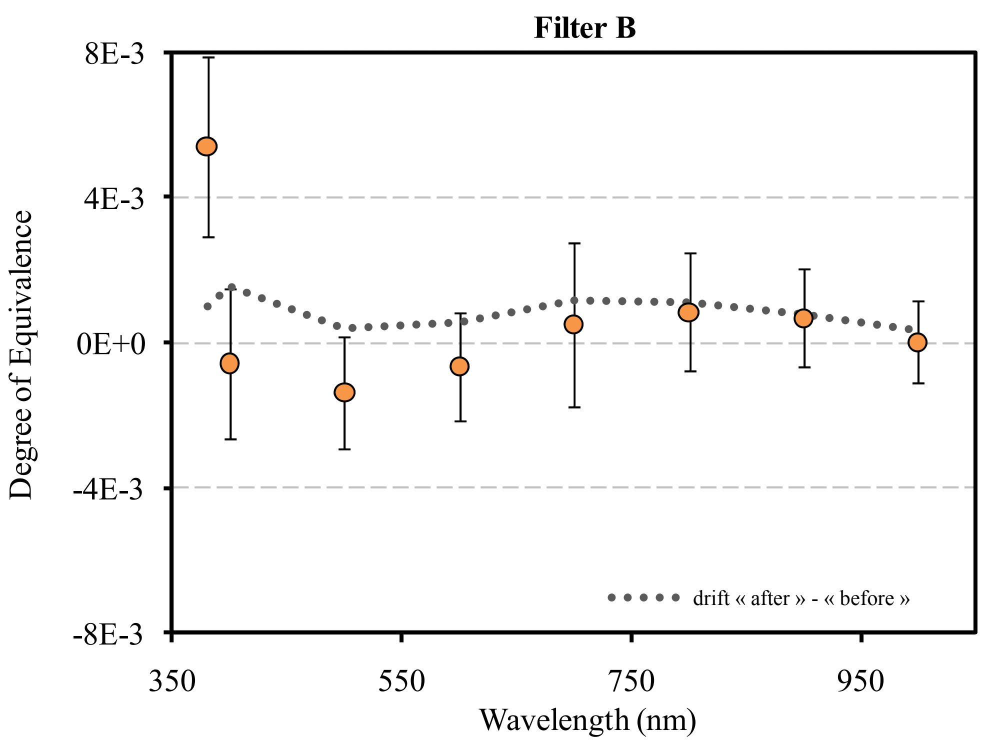
Filter E	λ (nm)	Drift	T pilot	unc (T pilot)	unc (T pr)	u(drift)	T nmi	unc (T nmi)	Delta	unc (delta)	KCRV	Unc(KCRV)	DoE	unc (DoE)
	380	1,27E-07	1,17E-05	7,11E-07	2,75E-07	3,67E-08								
	400	3,57E-07	3,19E-04	3,64E-06	3,01E-06	1,03E-07								
	500	-2,67E-05	8,90E-04	9,43E-06	9,17E-06	7,70E-06	9,05E-04	7,89E-06	1,50E-05	1,45E-05	2,95E-06	1,13E-06	1,20E-05	2,91E-05
	600	-8,60E-06	9,56E-04	7,27E-06	6,57E-06	2,48E-06	9,58E-04	8,60E-06	2,06E-06	1,15E-05	8,21E-06	1,48E-06	-6,15E-06	2,33E-05
	700	-3,72E-06	4,88E-03	5,69E-06	3,87E-06	1,07E-06	4,92E-03	1,15E-05	3,86E-05	1,29E-05	7,62E-06	4,12E-06	3,09E-05	2,70E-05
	800	5,30E-09	9,40E-03	1,06E-05	3,62E-06	1,53E-09	9,47E-03	3,46E-05	7,01E-05	3,62E-05	1,54E-05	3,87E-06	5,46E-05	7,28E-05
	900	6,89E-06	8,19E-03	8,42E-06	1,06E-06	1,99E-06	8,23E-03	6,89E-05	4,05E-05	6,94E-05	-2,19E-06	3,01E-06	4,27E-05	1,39E-04
	1000	-7,73E-07	6,91E-03	7,09E-06	6,46E-07	2,23E-07	6,97E-03	1,96E-05	5,62E-05	2,08E-05	-9,51E-06	2,90E-06	6,57E-05	4,21E-05

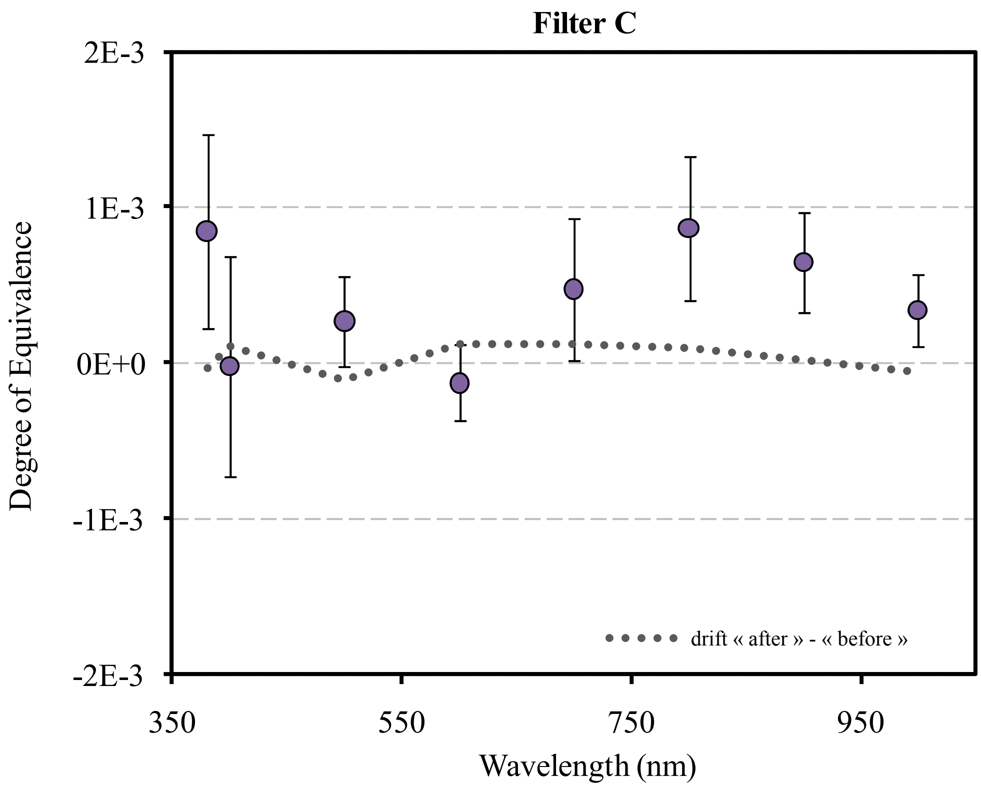
Unilateral DoE of ZMDM

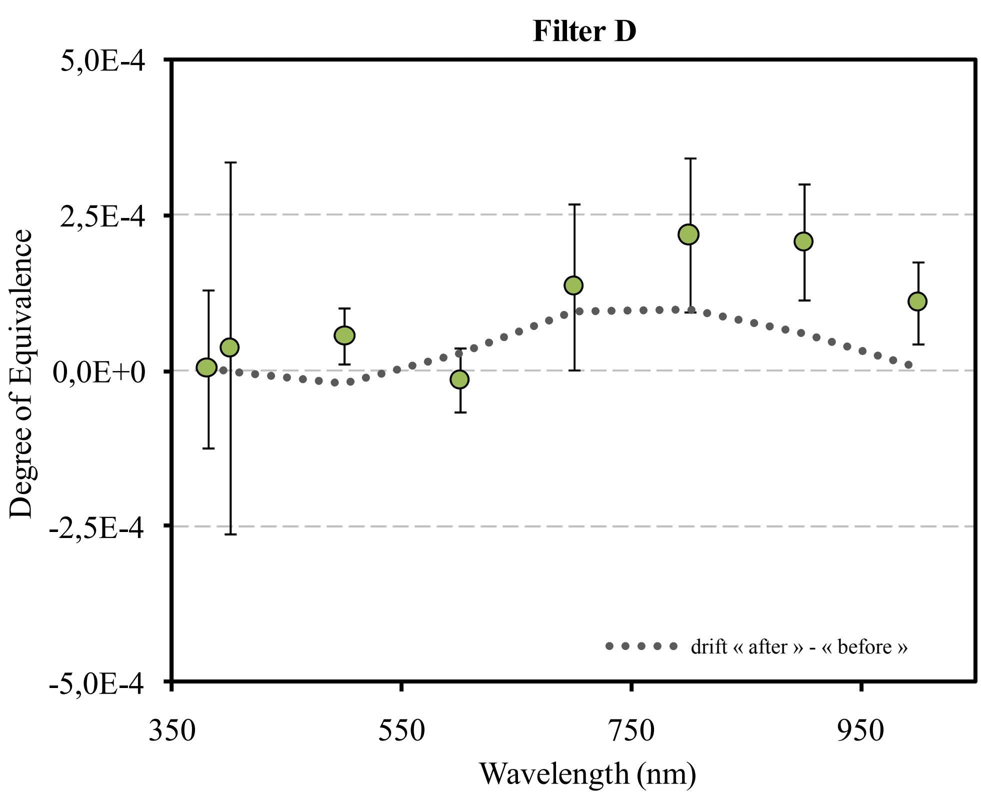
Values reported here are absolute

Uncertainties are calculated with k=2






Filter C
2E-3
1E-3
0E+0
-1E-3
-2E-3
Degree of Equivalence
drift « after » - « before »
350
550
750
950
Wavelength (nm)


Filter D
5,0E-4
2,5E-4
0,0E+0
-2,5E-4
-5,0E-4
Degree of Equivalence
drift « after » - « before »
350
550
750
950
Wavelength (nm)

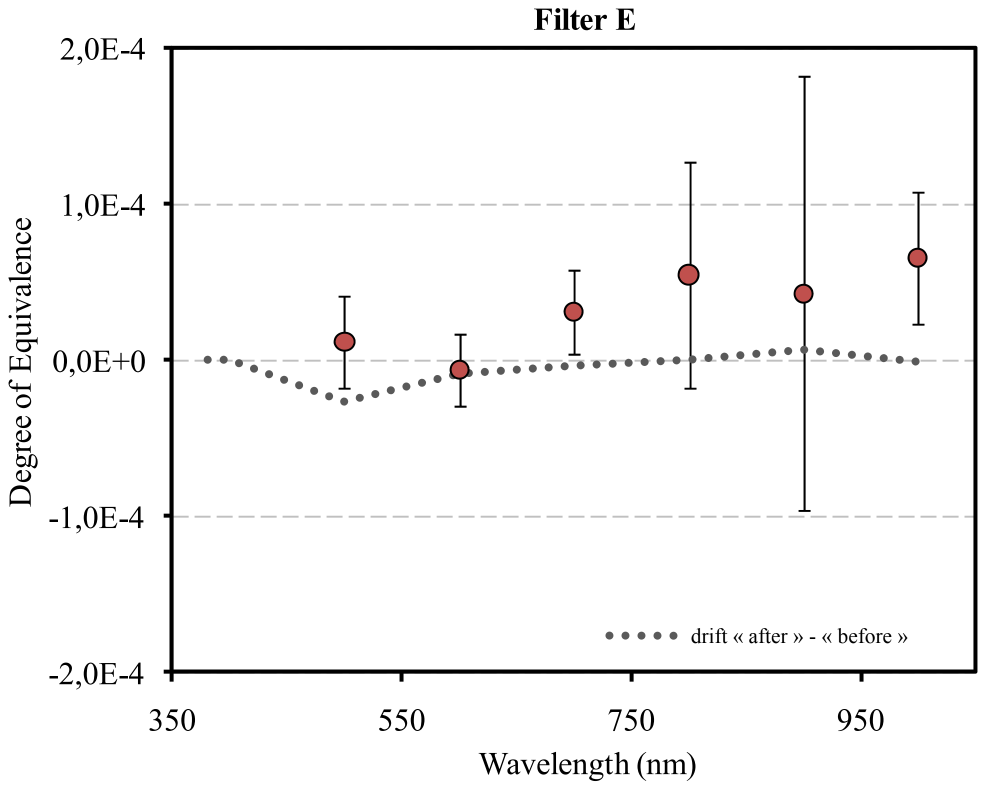


Figure 8 – DoE between ZMDM and the KCRV

7. Conclusion

The present Draft-B presents the degree of equivalence of the ZMDM to the reference values of the CCPR-K6 comparison.

The comments are open on this proposal.

ANNEX A

EUROMET-766 Bilateral Key Comparison

Spectral Regular Transmittance

Technical Protocol

1. Introduction

1.1 The metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organised by the Consultative Committees of the CIPM working closely with the Regional Metrology Organisations (RMOs).

1.2 In order to link to the CIPM key comparisons the laboratories which are not participating in the key comparison organised by the Consultative Committee of the CIPM it has been decided to organise the same comparisons within the Regional Metrology Organisations.

1.3 At its meeting in March 1997, the Consultative Committee for Photometry and radiometry, CCPR, identified several key comparisons in the field of optical radiation metrology. In particular, it decided that a key comparison of spectral regular transmittance shall be carried out, with the BNM-INM (France) acting as pilot laboratory.

1.4 The EUROMET project 538 “ Comparison of spectral regular transmittance” in charge of doing the link between the European laboratories and the CCPR key comparison has been started in April 1999 with the BNM-INM (France) acting as pilot laboratory. It was decided to use exactly the same technical protocol as for the CCPR key comparison. The Bureau of Measures and Precious Metals (ZMDM) was at that time unable to join this comparison. In order to established the metrological equivalence of this laboratory, a bilateral key comparison was organised in the EUROMET project 766 with also the BNM-INM acting as pilot laboratory and the exactly the same technical protocol as for CCPR and EUROMET key comparison was used.

1.5 This technical protocol has been drawn up by a small working group comprising the Institut National de Metrologie, France (BNM-INM), the Helsinki University of Technology, Finland (HUT), the Measurement Standard Laboratory, New Zealand (MSL), the National Institute of Standard and Technology, USA (NIST), the National Physical Laboratory, UK (NPL), and the Physikalisch-Technische Bundesanstalt, Germany (PTB).

1.6 The procedures outlined in this document cover the technical procedure to be followed during measurement of the transfer standard filters. The procedure, which followed the guidelines established by the BIPM[3], is based on current best practise in the use of standard

[3] T.J. Quinn, « Guidelines for key comparison carried out by Consultative Committees », BIPM, Paris, 1 March 1999

filters and takes account of the experience gained from the previous comparisons organised in this field[4].

Organisation

1.1 Participants

1.1.1 The information related to the two participants are given in the table below.

1.1.2 The participants must be able to demonstrate independent traceability to the realisation of the quantity, or make clear the route of traceability to the quantity via another named laboratory.

1.1.3 By their declared intention to participate in this key comparison, the laboratories accept the general instructions and the technical protocols written down in this document and commit themselves to follow the procedures strictly.

1.1.4 Once the protocol and list of participants has been agreed, no change to the protocol or list of participants may be made without prior agreement of all participants.

1.2 Participants' details

BNM-INM	**Mr Jean Bastie** BNM-INM/CNAM 292 rue Saint Martin 75003 Paris France	**Phone : 33 1 40 27 20 25** Fax : 33 1 42 71 37 36 E-mail : bastie@cnam.fr
ZMDM	Mr. Predrag Vukadin Bureau of Measures and Precious Metals Mike Alasa 14 11000 Beograd Serbia	Phone : + 381-11-32 82 736 Fax : + 381-11-21 81 668 E-mail : vukadin@szmdm.sv.gov.yu

1.3 Form of comparison

1.3.1 The comparison will principally be carried out through the calibration group of transfer standard filters.

1.3.2 A full description of the transfer standard filters is given in section 3 of this protocol.

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[4] K.L. Eckerle, J. Bastie, J. Zwinkels, V. Sapritsky, A. Ulyanov, « Comparison of regular transmittance scales of four national standardizing laboratories », Color research and application, volume 18, number 1, February 1993.

J.F. Verrill, « Intercomparison of spectrophotometric measurements of regular transmittance », Report contract N°. MAT1-CT940021, November 1996.

Etc…….

1.3.3 The artefacts (filters) will initially be calibrated by the pilot laboratory. They will then distributed to the participant who will perform the calibration. They will be returned to the pilot laboratory to carry out a repeat calibration to check the stability.

1.3.4 BNM-INM will act as the pilot laboratory. All results are to be communicated directly to the pilot laboratory as soon as possible and certainly within 6 weeks of completion of the measurements by a laboratory.

1.3.5 The laboratory has 3 months for calibration and transportation.

1.3.6 If for some reasons, the measurement facility is not ready or customs clearance takes too much time, the participant laboratory must contact the pilot laboratory immediately.

1.3.7 Timetable

Activity	**Date**
start of the EUROMET project 766	April 2003
Participants filters received	October 2003
Filters returned to BNM	January 2004
End of measurements	June 2004
Draft A comparison report	after EUROMET.PR-K6
Draft B report submitted to EUROMET	after EUROMET.PR-K6

1.4 Handling the artefacts

1.4.1 The standard filters should be examined immediately upon receipt at final destination. The condition of the filters and associated packaging should be noted and communicated to the pilot laboratory. Please use the fax form or e-mail form in appendix A4 and A5.

1.4.2 The standard filters should only be handles by authorised persons and stored in a such way as to prevent damage.

1.4.3 No cleaning of any filter should be normally done. Dust could be removed with a very soft brush or with a stream of dry nitrogen or dry CO_2. In case of accidental pollution cleaning will be made with alcohol and special optical paper. Cleaning must be indicated in the measurement report and documented using the appropriate form in appendix A.2. If a filter appears damaged a replacement will be available from the pilot laboratory.

1.4.4 After the measurements, the filters should be repackaged in their original transit cases or any other appropriate case for transportation. Ensure that the content of the package is complete before shipment. A copy of the provisional results should be included in the package.

1.5 Transport of artefacts

1.5.1 It is of outmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by unauthorised persons.

1.5.2 Artefact should be marked as “fragile”.

1.5.3 The artefacts should be accompanied by a suitable customs carnet (where appropriate) or documentation identifying the items uniquely.

1.5.4 Transportation is each laboratory’s responsibility and cost. Each participating laboratory covers the costs for its own measurements, transportation and any customs charges as well as for any damages that may have occurred within its country. The overall costs for the organisation of the comparison are covered by the pilot laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during transportation.

2. Description of the standards

2.1 The filter set to check the photometric scale is constituted by 5 neutral coloured glass filter plates 50 mm x 50 mm with nominal transmittance, at the wavelength of 546 nm, of approximately 92%, 56%, 10%, 1% and 0.1%. The filters are contained in a wood box specially design for transportation.

2.2 Each filter is identified by a reference engraved in a corner outside the area used for measurement. This reference has two parts. One is a letter indicating the type of glass (see table below) the other is the serial number of the filter.

2.3 The main characteristics of the filters are summarised in the following table :

Nominal transmittance %	Type of glass	Nominal thickness mm	Reference
92	BK 7	4.0	A
56	NG 11	1.5	B
10	NG 5	3.9	C
1	NG 4	3.9	D
0.1	NG 3	3.1	E

2.4 The manufacturing tolerances are for :

Size : 50 x50 (+0/-0.3) mm
Flatness : better than 5 µm over a central diameter of 30 mm
Parallelism : better than 0.02 mm except for the filter of transmittance 92% (<0.1 mm)

3. Measurement instructions

3.1 Traceability

Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90)

3.2 Measurand

3.2.1 The measurand is the spectral transmittance of the filters. The measurement should be performed in suitable laboratory accommodation maintained at a temperature of 23±2°C. The exact temperature of the laboratory during the time of the measurements should be reported.

4.2.2 The filter transmittance has to be measured independently several times. The exact number of measurements should be that normally used by the participating laboratory to obtain the appropriate accuracy of their specific measurement facility. The exact number of measurements used should be stated in the measurement report but only the mean or final declared value of the set required to be included.

3.3 Measurement instructions

3.3.1 Before measurement each filter should be inspected for damage or contamination. Any damage or cleaning should be documented using the appropriate form in appendix A5.

3.3.2 The spectral transmittance measurement of the filters should be performed at the following wavelength : 380, 400, 500, 600, 700, 800, 900 and 1000 nm.

3.3.3 The beam geometry must be a parallel beam where possible. For instruments that do not use a parallel beam the departure from parallel should be stated. The beam size probably will be different for the different instruments. 20mm diameter or 20mm square might be considered an ideal compromise between the conflicting requirements of flux and uniformity.

3.3.4 The angle of incidence on the filter should be normal or near normal and should be stated in the report.

3.3.5 The bandwidth used for the measurement should be stated in the report. 1 nm might be considered the norm for this wavelength range. However, there is no need for an agreed value of bandwidth because of the spectral neutrality of the filters.

3.3.6 Any information obtained relating to the use or any results obtained by a participant during the course of the comparison shall be sent only to the pilot laboratory who will be responsible for co-ordinating how the information should be disseminated to other participants. No communication whatsoever regarding any details of the comparison other than the general conditions described in this protocol shall occur between any of the participants or any party external to the comparison without the written consent of the pilot laboratory. The pilot laboratory will in turn seek permission of all the participants. This is to ensure that no bias from whatever accidental means can occur.

4. Measurement uncertainty

4.1 Measurement uncertainty shall be estimated according to the ISO Guide to the expression of uncertainty in measurement. In order to achieve optimum comparability, a list containing the principal influence parameters for calibration of spectral transmittance is given below. An example table which should be completed by participants is included as appendix A3. The participating laboratories are encouraged to follow this breakdown as closely as possible, and adapt it to their instruments and procedures. Other additional parameters may be felt

4.2 Type A

4.2.1 Repeatability of measurements.
The repeatability of measurements can be determined in calculating the standard deviation of a set of measurements without realignment or repositioning of the filter. It characterises mainly the noise and the stability of the experimental set-up.

4.2.2 Reproducibility of measurements.
The reproducibility of measurements can be determined in calculating the standard deviation of a set of measurement with realignment and repositioning of the filter between each individual measurement. It characterise the whole process of the measurement. It is this value which has to be taken into account for the uncertainty evaluated according the type A method.

4.3 Type B

4.3.1 Main uncertainty components.
The 3 main components of uncertainty usually determined by type B method are :

- The non linearity of the detector over the dynamic range of the detector used for the measurements
- The uncertainty of the wavelength setting of the monochromator
- The stray light.

The uncertainties related to these effects have to be clearly stated in the uncertainty budget provided with the results of the comparison.

4.3.2 Other uncertainty components.
The other uncertainty components which can be put in the uncertainty budget if necessary are :

- The beam displacement effect and the defocusing effect due to introduction of the filter in the beam.
- The inter-reflection between the filter and the various optical and mechanical components of the experimental set-up.
- The obliquity effect due to the residual non parallelism of the beam, a non parallel beam or the imperfect alignment of the filter.
- The effect of the polarisation of the light
- The drift of the detector and/or of the sources during the measurements.
- Any other uncertainty components specific to the apparatus used for the measurements as explained in § 5.1.

5. Reporting of results

5.1 On completion of the measurements by the participating laboratory the provisional results of these measurements should be sent to the pilot laboratory with the filters.

5.2 The Final results should be communicated to the pilot laboratory at the latest within six weeks.

5.3 In completing the description of the participants measurement facility, appendix A.2, it would be useful for a schematic diagram of the facility to be included.

5.4 The measurement report forms in appendix A.1, A.2, A.3 of this document will be sent by e-mail to all participating laboratories. It would be appreciated if the report form (in particular the results sheet) could be completed by computer and sent back electronically to the co-ordinator. **In any case, the signed report must also be sent in paper form by mail.** In of any differences, the paper forms are considered to be the definitive version.

5.5 Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare a first draft report on the comparison. This will be circulated to the participants for comments, additions and corrections. Subsequently, the procedure outlined in the BIPM and EUROMET Guidelines will be followed.

A.1 Measurement results

The attached measurement summary should be completed for each filter. For clarity and consistency the following list describes what should be entered under the appropriate heading in the table.

Wavelength The assigned centre wavelength of the measured spectral transmittance.

Spectral transmittance The value of the spectral transmittance of the filter as measured by the participating laboratory.

Bandwidth The spectral bandwidth of the instrument used for the measurement defined as the Full Width at Half the Maximum.

Standard Deviation The standard deviation of the number of measurements made to obtain the assigned transmittance of the filter.

Number of runs The number of independent measurements made to obtain the specified standard deviation.

Uncertainty The total uncertainty of the measurement of spectral transmittance including both Type A and B for a coverage factor of k=1.

Table of measurement results

Reference of he filter : **Ambient temperature :**

Wavelength nm	Spectral transmittance	Bandwidth nm	Standard deviation	Number of runs	Uncertainty
380					
400					
500					
600					
700					
800					
900					
1000					

Laboratory :

Date : **Signature :**

A.2 Description of the measurement facility.

This form should be used as a guide. It is anticipated that many of the questions will require more information than the space allocated, please use separate sheets of paper as appropriate.

Make and type of the spectrophotometer
…………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………….
Method of characterisation of the spectrophotometer
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………….
Description of measuring technique (please include a diagram if appropriate)
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………………..
Description of calibration laboratory conditions : e.g. temperature, humidity, cleaning of the filter if it has be done due to accidental pollution etc
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………

Laboratory :

Date : **Signature :**

A.3 Uncertainty of measurement

Parameter	Type A	Type B	Uncertainty in spectral transmittance
Repeatability	U_1		
Non linearity		U_2	
Wavelength setting		U_3	
Beam displacement		U_4	
Inter-reflection		U_5	
Obliquity effect		U_6	
Polarisation		U_7	
Drift		U_8	
Others		U_9	
RMS total			

The table is a suggested layout for the presentation of uncertainties for the calibration of each filter. However, it should be noted that since the uncertainties are wavelength dependant this table can only present a range for the various parameters. The summary table associated with the results (appendix A.1.) will of course take account of the wavelength dependent parameters. The RMS total refers to the usual expression i.e. square root of the sum of the squares of all the individual uncertainty terms.

Laboratory :

Date : **Signature :**

A.4 Receipt confirmation

To : Jean Bastie
BNM-INM / CNAM
292 rue Saint Martin
75003 Paris
France

Fax : + 33 1 42 71 37 36
E-mail : bastie@cnam.fr

From : *(participating laboratory)*

We confirmed having received the standards of the BIPM Key comparison “regular spectral transmittance”.

Date : **Signature :**

A.5 Inspection of the transfer standards

Has the filter transportation package been opened during transit ? e.g; Customs…..Y / N

If yes please give details……………

Is there any damage to the transportation package ?…….Y / N

If yes please give details………………..

Are there any visible signs of damage to the filters ?……Y / N

If yes please give details…………………..

Laboratory :

Date : **Signature :**

Fin du Document