Report on
the bilateral Comparison between
BIM (Bulgaria) and VSL (The Netherlands)
Final Report

Euramet Project 1073
EURAMET.PR-K6.2

Spectral regular transmittance

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Table of contents

1. Introduction

A bilateral comparison has been organized between VSL, The Netherlands and BIM-NMC, Bulgaria, in the field of spectral regular transmittance measurements. This comparison is registered as EURAMET project nr. 1073 and EURAMET.PR-K6.2 in the BIPM key comparison database.

The aim of the comparison is to demonstrate the improvement of calibration measurement capabilities of BIM-NMC, hereafter abbreviated, BIM, in this working field. If this comparison is successful, i.e. the results support the claimed improvement in uncertainties, the improved CMC's for BIM will be included in Appendix C of the CIPM mutual recognition arrangement (MRA).

The results of this comparison will be linked to comparison CCPR-K6.

This comparison is organized in the framework of Phare project BG 2005/017-353.02.02, Lot 1, and is in this framework financed by the EU. This project runs from March 2008 to the end of February 2009.

2. Participants and organisation of the comparison

2.1. List of participants

Participants:

Name:	VSL Dutch Metrology Institute
Acronym:	VSL
Address:	Thijsseweg 11 2629 JA, Delft
Country:	The Netherlands
Contact person:	Mr. Paul Dekker Tel.: +31 15 269 17 38 E-mail: pdekker@vsl.nl

Name:	Bulgarian Institute of Metrology
Acronym:	BIM
Address:	GD National Centre of Metrology Department "Optics, Acoustics & Vibrations" 2,"Prof. Peter Mutafchiev" str. 1784 Sofia
Country:	Bulgaria
Contact person:	Mrs. Angela Kunova Tel.: +359 2 974 31 61 E-mail: a.kunova@bim.government.bg

Comparison coordinator:
Mr E. Dierikx, VSL Dutch Metrology Institute, The Netherlands
Tel.: +31 15 269 16 88
E-mail: edierikx@vsl.nl

2.2. Comparison schedule

The travelling standards were circulated in a schedule A-B-A, as shown in the table below. The behaviour of the standards during the comparison was determined from the measurements of VSL.

Each participant was allowed approximately 4 weeks to perform the measurements. The schedule in the protocol was delayed. The actual schedule is given in the table below.

Participant	Measurements from	to
VSL1	17-10-2008	05-11-2008
BIM	12-11-2008	01-12-2008
VSL2	28-01-2009	30-01-2009

The transport of the travelling standards was arranged by door-to-door parcel service.

3. Travelling standard and measurement instructions

3.1. Description of the standards

The filter set to check the photometric scale is constituted by 4 neutral coloured glass filter plates 12.5 mm x 45 mm with nominal transmittance, at the wavelength of 546 nm, of approximately 92%, 56%, 10%, 1%. The filters are contained in a box specially designed for transportation.

Each filter is identified by a reference engraved in a corner outside the area used for measurement.
The main characteristics of the filters are summarised in the following table:

Nominal transmittance @ 546 nm in %	Type of glass	Nominal thickness mm	Reference
92	BK 7	4.0	23353-9N
56	NG 11	1.5	23370-5D
10	NG 5	3.9	24291-10%
1	NG 4	3.9	24699-1%

The manufacturing tolerances are for:

Size (12.5 x 45) mm (+0/-0.3) mm.
Flatness: better than 5 μm over a central diameter of 10 mm.
Parallelism: better than 0.02 mm.

3.2. Quantities to be measured and conditions of measurement

The measurand in this comparison is the spectral regular transmittance of the filters with nominal transmittance of: 92 %, 56 %, 10 % and 1 %. The spectral transmittance measurements should be performed at the wavelengths: 380, 400, 500, 546, 600, 635 and 700 nm.

The measurement should be performed in suitable laboratory accommodation maintained at an ambient temperature of (23 ± 2) °C.

3.3. Measurement instructions

Before measurement each filter should be inspected for damage or contamination.

The beam geometry must be a parallel beam or nearly parallel. The beam size probably will be different for the different instruments. The suitable size of the beam is 2 mm wide and 10 mm high.

The angle of incidence on the filter should be normal or near normal.

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.

3.4. Deviations from the protocol

There have been some deviations from the original schedule for this comparison when it was registered as EURAMET.PR-K6.2. The actual schedule is given in section 2.2 of this document.
There have also been several deviations from the technical protocol for CCPR-K6, to which the results of this bilateral comparison will be linked. These deviations are:

1) only 4 of the 5 neutral glass filters is included here; the nominally 0.1% filter is not included;
2) the comparison wavelength range is different; here the wavelength range is from 380 nm to 700 nm only whereas in CCPR-K6, the wavelength range was from 380 nm to 1000 nm;
3) some of the comparison wavelengths are different from CCPR-K6; here additional wavelengths of 546 nm and 635 nm are included;
4) the measurement beam size is different - BIM used a beam of 2 mm (wide) x 10 mm (high) and VSL used a circular beam of 4.4 mm in diameter. In CCPR-K6, the specified beam size was 20 mm diameter or 20 mm square;

4. Methods of measurement

4.1. Method of VSL

The measurements have been performed using a double grating monochromator in additive dispersion, Type: 2035, McPherson, f = 350.

For the measurements reported in this comparison, a Tungsten Halogen lamp was used.
The exit slit of the monochromator is imaged on the filters by three mirrors. The light transmitted through the filter is imaged with a flat mirror and a quartz lens on a silicon detector, Type S1337-1010BQ, Hamamatsu. The photocurrents of both detectors were measured using two Keithley 486 Picoammeters.

The transmittance of the filters was determined by measuring nearly monochromatic light with and without the filter in its path.

Before a transmittance measurement the monochromator was calibrated using the Cs Spectral lamp.

4.2. Method of BIM

The measurements have been performed with a commercial spectrophotometer VARIAN, CARY 5000.

This spectrophotometer has been calibrated with reference filters, which are traceable to PTB. The transfer filters were directly measured with the calibrated spectrophotometer.

5. Measurement results

5.1. Results of the participating institutes

Reported ambient conditions:

	Temperature °C	Uncertainty in temperature °C	Relative Humidity %	Uncertainty in Humidity %
BIM	22.9 ± 1.8	0.2	31 ± 6	2
VSL	23.0	0.5	45	10

The reported results from both participants are given in the tables on the following pages. Detailed uncertainty budgets are given in Annex D of this report.

Results at nominal 1 %

VSL1: 24699-1%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.0004191	1.5	0.0000006	7	0.0000029
400	0.0040380	1.5	0.0000032	8	0.0000100
500	0.0082563	1.5	0.0000029	10	0.0000058
546	0.0090514	1.5	0.0000047	9	0.0000072
600	0.0086601	1.5	0.0000072	7	0.0000089
635	0.0106904	1.5	0.0000066	7	0.0000092
700	0.0261178	1.5	0.0000108	7	0.0000188

VSL2: 24699-1%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.0004226	1.5	0.0000014	9	0.0000032
400	0.0040430	1.5	0.0000036	10	0.0000102
500	0.0082545	1.5	0.0000042	10	0.0000065
546	0.0090506	1.5	0.0000044	10	0.0000070
600	0.0086583	1.5	0.0000053	10	0.0000075
635	0.0106903	1.5	0.0000063	10	0.0000091
700	0.0261086	1.5	0.0000076	10	0.0000171

BIM: 24699-1%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1	
380	0.000430	1.0	0.000000	10	0.000004	*
400	0.004086	1.0	0.000002	10	0.000020	*
500	0.008220	1.0	0.000002	10	0.000040	
546	0.009005	1.0	0.000002	10	0.000040	
600	0.008611	1.0	0.000004	10	0.000040	
635	0.010637	1.0	0.000005	10	0.000050	
700	0.026044	1.0	0.000006	10	0.000100	

* Out of CMC range

Results at nominal 10 %

VSL1: 24291-10%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.025245	1.5	0.000018	9	0.000111
400	0.078496	1.5	0.000026	8	0.000066
500	0.096274	1.5	0.000028	7	0.000040
546	0.099931	1.5	0.000049	7	0.000058
600	0.092713	1.5	0.000034	6	0.000044
635	0.101850	1.5	0.000025	7	0.000032
700	0.153337	1.5	0.000046	7	0.000055

VSL2: 24291-10%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.025344	1.5	0.000017	10	0.000111
400	0.078576	1.5	0.000048	10	0.000077
500	0.096324	1.5	0.000041	10	0.000050
546	0.099992	1.5	0.000035	10	0.000046
600	0.092797	1.5	0.000037	10	0.000046
635	0.101899	1.5	0.000030	10	0.000036
700	0.153390	1.5	0.000051	10	0.000059

BIM: 24291-10%

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.02563	1.0	0.0000	10	0.00025
400	0.07889	1.0	0.00003	10	0.00025
500	0.09602	1.0	0.00001	10	0.00029
546	0.09968	1.0	0.00002	10	0.00030
600	0.09245	1.0	0.00002	10	0.00030
635	0.10153	1.0	0.00002	10	0.00030
700	0.15314	1.0	0.00002	10	0.00040

Results at nominal 56 %

VSL1: 23370-5D

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.34253	1.5	0.00008	6	0.00051
400	0.53525	1.5	0.00051	5	0.00052
500	0.55599	1.5	0.00029	7	0.00030
546	0.56634	1.5	0.00022	8	0.00024
600	0.54390	1.5	0.00047	6	0.00048
635	0.54100	1.5	0.00010	9	0.00014
700	0.56219	1.5	0.00026	6	0.00028

VSL2: 23370-5D

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.34333	1.5	0.00010	10	0.00051
400	0.53524	1.5	0.00017	10	0.00020
500	0.55596	1.5	0.00021	10	0.00023
546	0.56630	1.5	0.00011	10	0.00015
600	0.54411	1.5	0.00012	10	0.00016
635	0.54089	1.5	0.00019	10	0.00021
700	0.56189	1.5	0.00023	10	0.00025

BIM: 23370-5D

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.34477	1.0	0.00007	10	0.00070
400	0.53570	1.0	0.00004	10	0.00145
500	0.55557	1.0	0.00001	10	0.00145
546	0.56593	1.0	0.00003	10	0.00145
600	0.54370	1.0	0.00003	10	0.00146
635	0.54031	1.0	0.00003	10	0.00146
700	0.56166	1.0	0.00005	10	0.00146

Results at nominal 92 %

VSL1: 23353-9N

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.91208	1.5	0.00014	7	0.00022
400	0.91317	1.5	0.00024	6	0.00033
500	0.91601	1.5	0.00017	8	0.00024
546	0.91666	1.5	0.00017	6	0.00024
600	0.91749	1.5	0.00017	7	0.00024
635	0.91800	1.5	0.00009	6	0.00019
700	0.91845	1.5	0.00017	3	0.00023

VSL2: 23353-9N

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.91170	1.5	0.00040	10	0.00044
400	0.91295	1.5	0.00052	10	0.00057
500	0.91591	1.5	0.00045	10	0.00048
546	0.91683	1.5	0.00023	10	0.00029
600	0.91756	1.5	0.00033	10	0.00037
635	0.91783	1.5	0.00036	10	0.00040
700	0.91856	1.5	0.00028	10	0.00033

BIM: 23353-9N

Wavelength /nm	Spectral transmittance /1	Bandwidth /nm	Standard deviation /1	Number of runs /1	Total Uncertainty (k=1) /1
380	0.91284	1.0	0.00005	10	0.00146
400	0.91422	1.0	0.00004	10	0.00146
500	0.91715	1.0	0.00003	10	0.00146
546	0.91812	1.0	0.00005	10	0.00146
600	0.91894	1.0	0.00005	10	0.00146
635	0.91928	1.0	0.00006	10	0.00146
700	0.91996	1.0	0.00011	10	0.00146

5.2. Normalization of the results

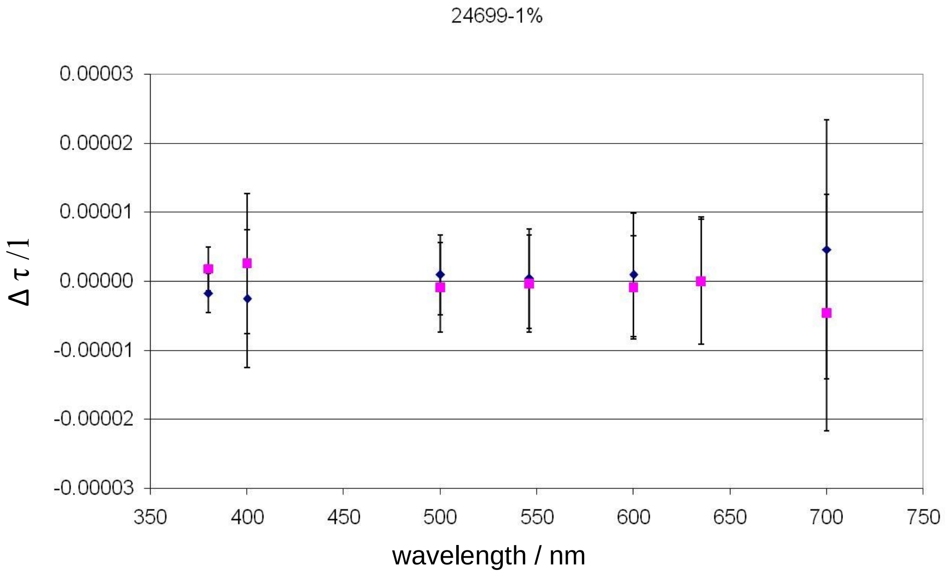
The behaviour of the filters during the course of the comparison was evaluated from the results of VSL.

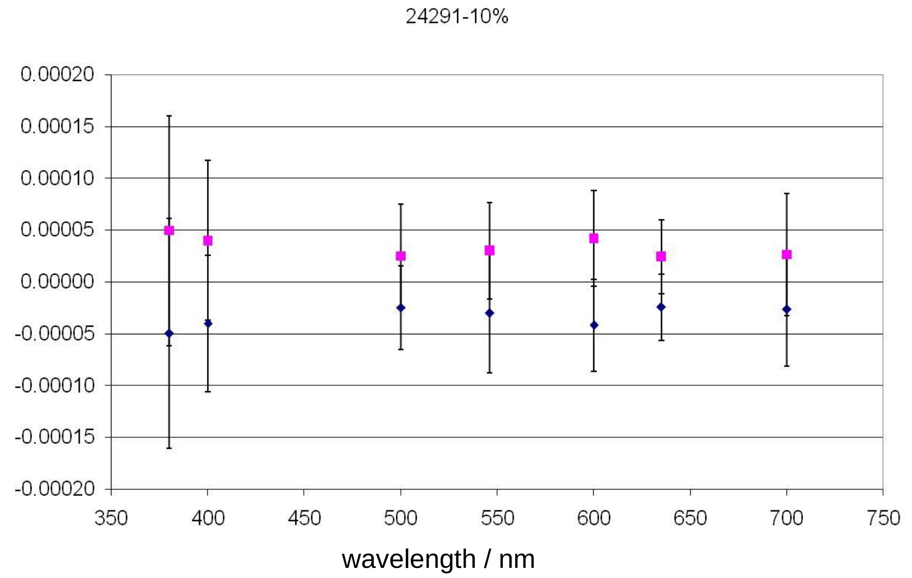
In the figures below, the difference is shown of the first measurement of VSL (*VSL*1: blue marker) and the second measurement of VSL (*VSL*2: pink marker) with respect to the average of *VSL*1 and *VSL*2.

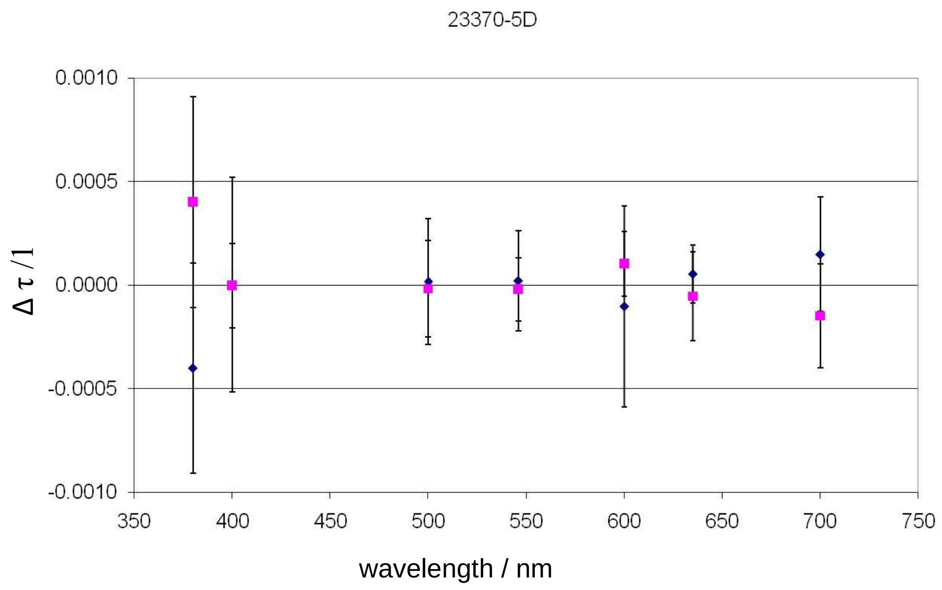
On the x-axis is the wavelength in nm.On the y-axis is the difference of *VSL*1 and *VSL*2 with respect to the average of the two measurements. The values on the y-axis are absolute values (relative to 1).

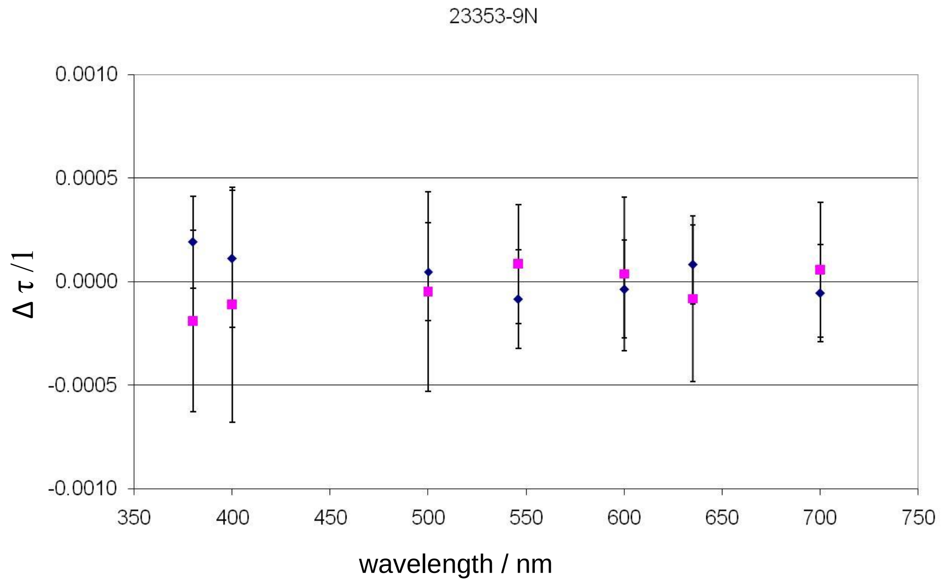
The uncertainty bars indicate the standard uncertainties $u(VSL1)$ and $u(VSL2)$ ($k = 1$)

From these graphs we conclude that only in the 24291-10% filter there seems to be a small systematic change. For the other filters, there is no clear systematic change or drift in the values.






23370-5D
0.0010
0.0005
0.0000
-0.0005
-0.0010
Δ τ / 1
350
400
450
500
550
600
650
700
750
wavelength / nm


23353-9N
0.0010
0.0005
0.0000
-0.0005
-0.0010
Δ τ / 1
350
400
450
500
550
600
650
700
750
wavelength / nm

5.3. Calculation of the reference value and its uncertainty

In this bilateral comparison, VSL is the linking laboratory to the CCPR-K6 comparison. Therefore, the reference value in this comparison is derived from the VSL results.
The reference value *RV* is calculated as the mathematical mean of *VSL*1 and *VSL*2:

$$RV = \frac{VSL1 + VSL2}{2}$$

The uncertainty in the reference value $u(RV)$ is given by:

$$u(RV) = \sqrt{\left(\frac{u_{A\_VSL1}}{2}\right)^2 + \left(\frac{u_{A\_VSL2}}{2}\right)^2 + \left(u_{B\_VSL}\right)^2 + \left(\sigma(VSL1, VSL2)\right)^2}$$

where:
$u_{\mathrm{A\_VSL1}}$ and $u_{\mathrm{A\_VSL2}}$ are the type A uncertainties from *VSL*1 and *VSL*2 respectively.
u_{B_VSL} is the type B uncertainty from VSL which is assumed to be correlated for *VSL*1 and *VSL*2.
$\sigma(VSL1,VSL2)$ is the standard deviation of the *VSL*1 and *VSL*2 result to account for the difference and may be the drift of the filters between the two sets of measurements.
The RV's and corresponding uncertainties are given in the table in section 5.4.

5.4. Degree of Equivalence

The degree of equivalence (D_{ij}) between BIM and VSL is found from the difference between the BIM result and the *RV* as calculated in section 5.3.

$$D_{ij} = BIM - RV$$

The uncertainty in D_{ij} is given by:

$$u(D_{ij}) = \sqrt{\left(u(BIM)\right)^2 + \left(u(RV)\right)^2}$$

where it is assumed that there is no significant correlation between the results of BIM and the results of VSL. The values are given in the table below. Graphs are given in Annex A of this report.

Filter ID	Wavelength	RV	$u(RV)$	D_{ij} (BIM-VSL)	$u(D_{ij})$ (k=1)	$U(D_{ij})$ (k=2)
	/nm	/1	/1	/1	/1	/1
24699-1%	380 *	0.000421	0.0000038	0.000009	0.000006	0.000011
24699-1%	400 *	0.004040	0.0000104	0.000046	0.000023	0.000045
24699-1%	500	0.008255	0.0000058	-0.000035	0.000040	0.000081
24699-1%	546	0.009051	0.0000064	-0.000046	0.000041	0.000081
24699-1%	600	0.008659	0.0000070	-0.000048	0.000041	0.000081
24699-1%	635	0.010690	0.0000079	-0.000053	0.000051	0.000101
24699-1%	700	0.026113	0.0000179	-0.000069	0.000102	0.000203
24291-10%	380	0.025294	0.000131	0.00033	0.00028	0.00056
24291-10%	400	0.078536	0.000087	0.00035	0.00026	0.00053
24291-10%	500	0.096299	0.000052	-0.00028	0.00029	0.00059
24291-10%	546	0.099961	0.000060	-0.00028	0.00031	0.00061
24291-10%	600	0.092755	0.000070	-0.00030	0.00031	0.00062
24291-10%	635	0.101874	0.000044	-0.00034	0.00030	0.00061
24291-10%	700	0.153363	0.000059	-0.00022	0.00040	0.00081
23370-5D	380	0.34293	0.00076	0.0018	0.0010	0.0021
23370-5D	400	0.53525	0.00029	0.0005	0.0015	0.0030
23370-5D	500	0.55598	0.00021	-0.0004	0.0015	0.0029
23370-5D	546	0.56632	0.00016	-0.0004	0.0015	0.0029
23370-5D	600	0.54401	0.00030	-0.0003	0.0015	0.0030
23370-5D	635	0.54094	0.00016	-0.0006	0.0015	0.0029
23370-5D	700	0.56204	0.00029	-0.0004	0.0015	0.0030
23353-9N	380	0.91189	0.00038	0.0009	0.0015	0.0030
23353-9N	400	0.91306	0.00040	0.0012	0.0015	0.0030
23353-9N	500	0.91596	0.00030	0.0012	0.0015	0.0030
23353-9N	546	0.91675	0.00025	0.0014	0.0015	0.0030
23353-9N	600	0.91752	0.00025	0.0014	0.0015	0.0030
23353-9N	635	0.91792	0.00028	0.0014	0.0015	0.0030
23353-9N	700	0.91850	0.00025	0.0015	0.0015	0.0030

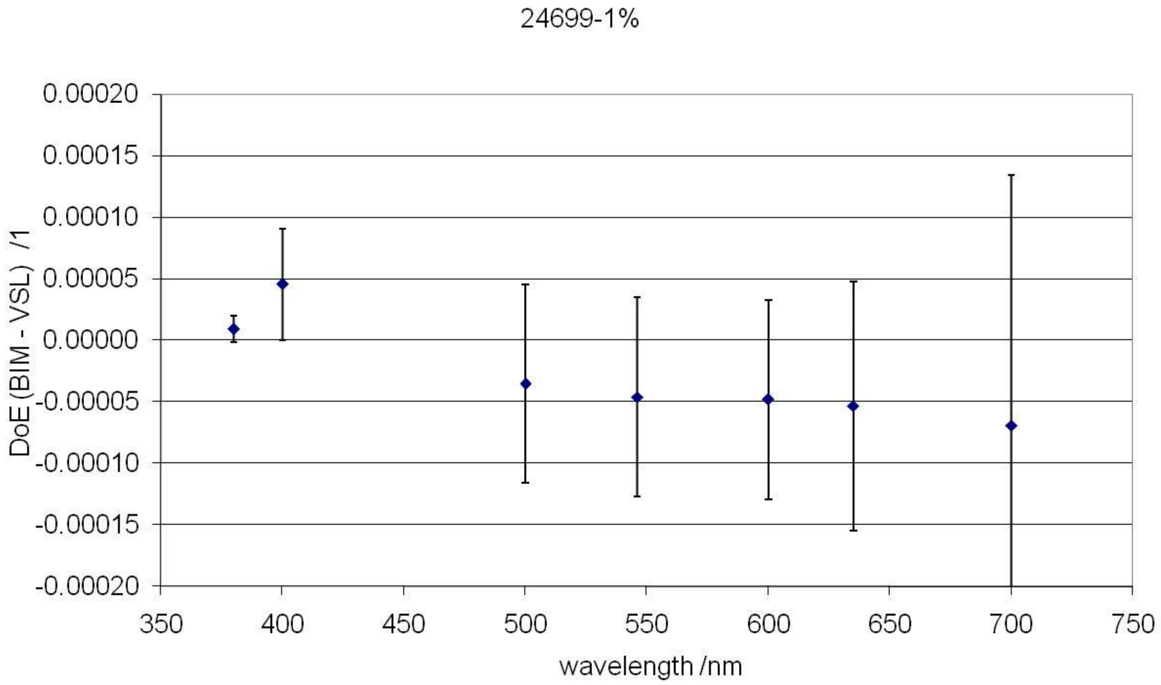
* Out of BIM's CMC range

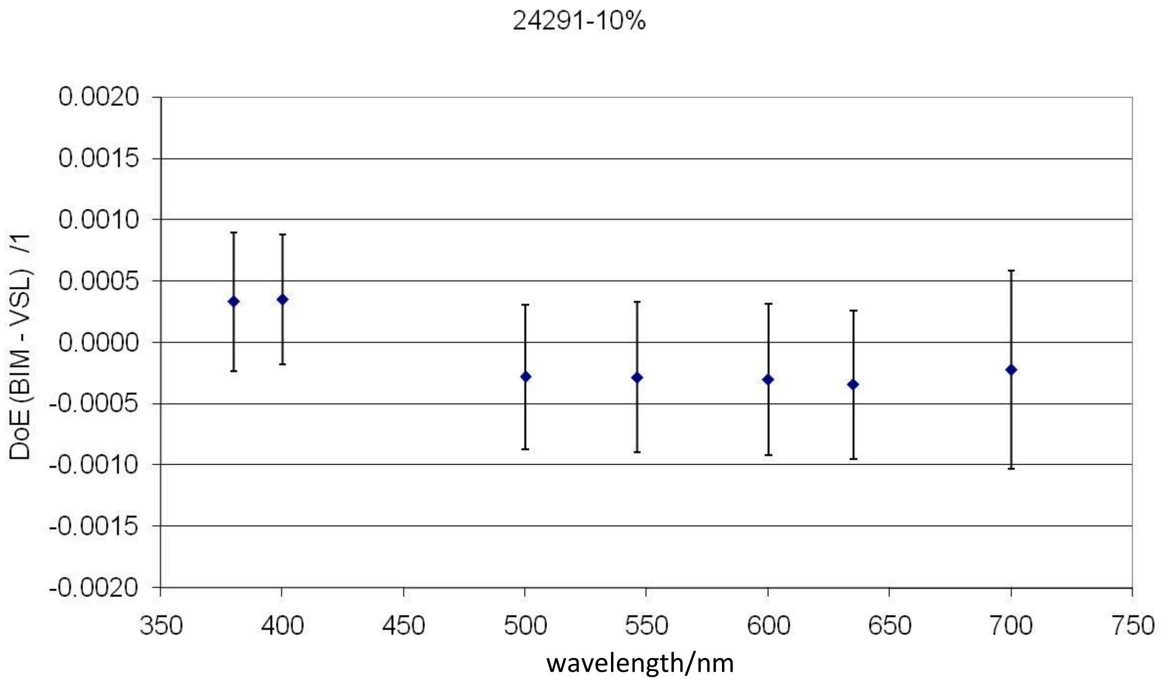
6. Conclusions

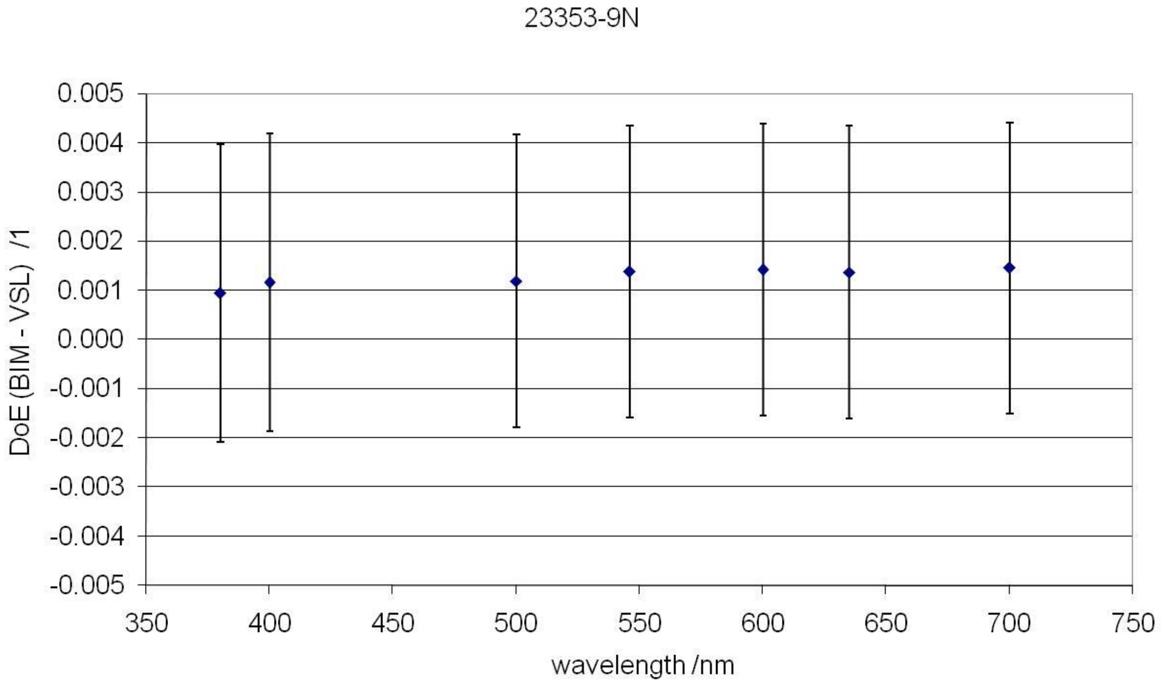
With the reported uncertainties, there is a good agreement for measurements of spectrum regular transmittance between BIM (Bulgaria) and VSL (The Netherlands).

Annex A. Degrees of equivalence

The graphs below show the degree of equivalence between BIM, Bulgaria and VSL, The Netherlands for measurements of spectrum regular transmittance at different wavelengths in the visible range. The reported values are absolute values.






23353-9N
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
DoE (BIM - VSL) /1
350
400
450
500
550
600
650
700
750
wavelength /nm

Annex B. Link to CCPR-K6

The results of this comparison are to be linked to the CCPR K6 comparison[1] for Spectral regular transmittance, which was organized by LNE-INM. The measurements for the CCPR K6 comparison were performed in 2000 and 2001. The link is determined from the result of VSL in the CCPR K6 comparison and the bilateral comparison, EURAMET.PR.K6.2, between VSL and BIM.

$D_{CCPR\ K6,VSL}$ is the degrees of equivalence of VSL with respect to the reference value, $RV_{CCPR\ K6}$, of the CCPR K6 comparison. The degrees of equivalence as well as the associated uncertainties $U(D_{CCPR\ K6,VSL})$ are given in the CCPR K6 report [1, pp. 104–105]. The results of the EURAMET.PR.K6.2 comparison are to be expressed in relation to the $RV_{CCPR\ K6}$. For this purpose the degrees of equivalence of comparison EURAMET.PR.K6.2, now indicated by $D_{EM.K6.2}$, will be corrected by a correction d. This correction is determined from the results of VSL in both comparisons:

$$d = D_{CCPR\ K6,VSL} - D_{EM.K6.2,VSL} \qquad \text{B-1}$$

Please note that because in the EURAMET.PR.K6.2 the VSL values are the key comparison reference value $D_{EM.K6.2,VSL} = 0$.

The corrected results for the BIM measurements in EURAMET.PR.K6.2 in terms of $RV_{\mathrm{CCPR\ K6}}$ are then given by:

$$D_{CCPR\ K6,BIM} = D_{EM.K6.2,BIM} + d \qquad \text{B-2}$$

with the uncertainty:

$$U\left(D_{CCPR\ K6,BIM}\right) = \sqrt{\left(U\left(D_{EM.K6.2,BIM}\right)\right)^2 + \left(U(d)\right)^2} \qquad \text{B-3}$$

The results from BIM in terms of $RV_{CCPR\ K6}$ are shown in Table B-1 and Figure B-1.

Table B-1. Degrees of equivalence of VSL and BIM with respect to $RV_{\mathrm{CCPR\ K6}}$ with the expanded uncertainty (k=2).

Filter ID	*Wavelength* /nm	$RV_{EM.K6.2}$ /1	$D_{CCPR\ K6,VSL}$ /1	$U(D_{CCPR\ K6,VSL})$ /1	$D_{EM.K6.2,BIM}$ /1	$U(D_{EM.K6.2,BIM})$ /1	$\boldsymbol{D_{CCPR\ K6,BIM}}$ **/1**	$\boldsymbol{U(D_{CCPR\ K6,BIM})}$ **/1**
23353-9N	380	9.119E-01	7.432E-05	9.790E-04	9.000E-04	3.000E-03	**9.743E-04**	**3.156E-03**
23353-9N	400	9.131E-01	7.488E-05	1.030E-03	1.200E-03	3.000E-03	**1.275E-03**	**3.172E-03**
23353-9N	500	9.160E-01	-3.559E-04	7.054E-04	1.200E-03	3.000E-03	**8.441E-04**	**3.082E-03**
23353-9N	600	9.175E-01	-3.150E-04	8.354E-04	1.400E-03	3.000E-03	**1.085E-03**	**3.114E-03**
23353-9N	700	9.185E-01	-3.288E-04	6.721E-04	1.500E-03	3.000E-03	**1.171E-03**	**3.074E-03**
23370-5D	380	3.429E-01	1.900E-04	2.015E-03	1.800E-03	2.100E-03	**1.990E-03**	**2.910E-03**
23370-5D	400	5.353E-01	-6.346E-05	1.121E-03	5.000E-04	3.000E-03	**4.365E-04**	**3.203E-03**
23370-5D	500	5.560E-01	-2.856E-04	9.610E-04	-4.000E-04	2.900E-03	**-6.856E-04**	**3.055E-03**
23370-5D	600	5.440E-01	-2.136E-04	8.780E-04	-3.000E-04	3.000E-03	**-5.136E-04**	**3.126E-03**
23370-5D	700	5.620E-01	-1.045E-04	9.031E-04	-4.000E-04	3.000E-03	**-5.045E-04**	**3.133E-03**
24291-10%	380	2.529E-02	-6.432E-05	7.506E-04	3.300E-04	5.600E-04	**2.657E-04**	**9.365E-04**
24291-10%	400	7.854E-02	-6.133E-05	4.165E-04	3.500E-04	5.300E-04	**2.887E-04**	**6.741E-04**
24291-10%	500	9.630E-02	1.512E-04	4.292E-04	-2.800E-04	5.900E-04	**-1.288E-04**	**7.296E-04**
24291-10%	600	9.276E-02	1.251E-04	3.734E-04	-3.000E-04	6.200E-04	**-1.749E-04**	**7.238E-04**
24291-10%	700	1.534E-01	7.117E-05	6.723E-04	-2.200E-04	8.100E-04	**-1.488E-04**	**1.053E-03**
24699-1%	380	4.210E-04	-2.030E-06	5.614E-05	9.000E-06	1.100E-05	**6.970E-06**	**5.721E-05**
24699-1%	400	4.040E-03	-3.011E-05	3.603E-05	4.600E-05	4.500E-05	**1.589E-05**	**5.765E-05**
24699-1%	500	8.255E-03	-7.313E-07	5.254E-05	-3.500E-05	8.100E-05	**-3.573E-05**	**9.655E-05**
24699-1%	600	8.659E-03	1.215E-05	6.303E-05	-4.800E-05	8.100E-05	**-3.585E-05**	**1.026E-04**
24699-1%	700	2.611E-02	2.424E-05	1.449E-04	-6.900E-05	2.030E-04	**-4.476E-05**	**2.494E-04**

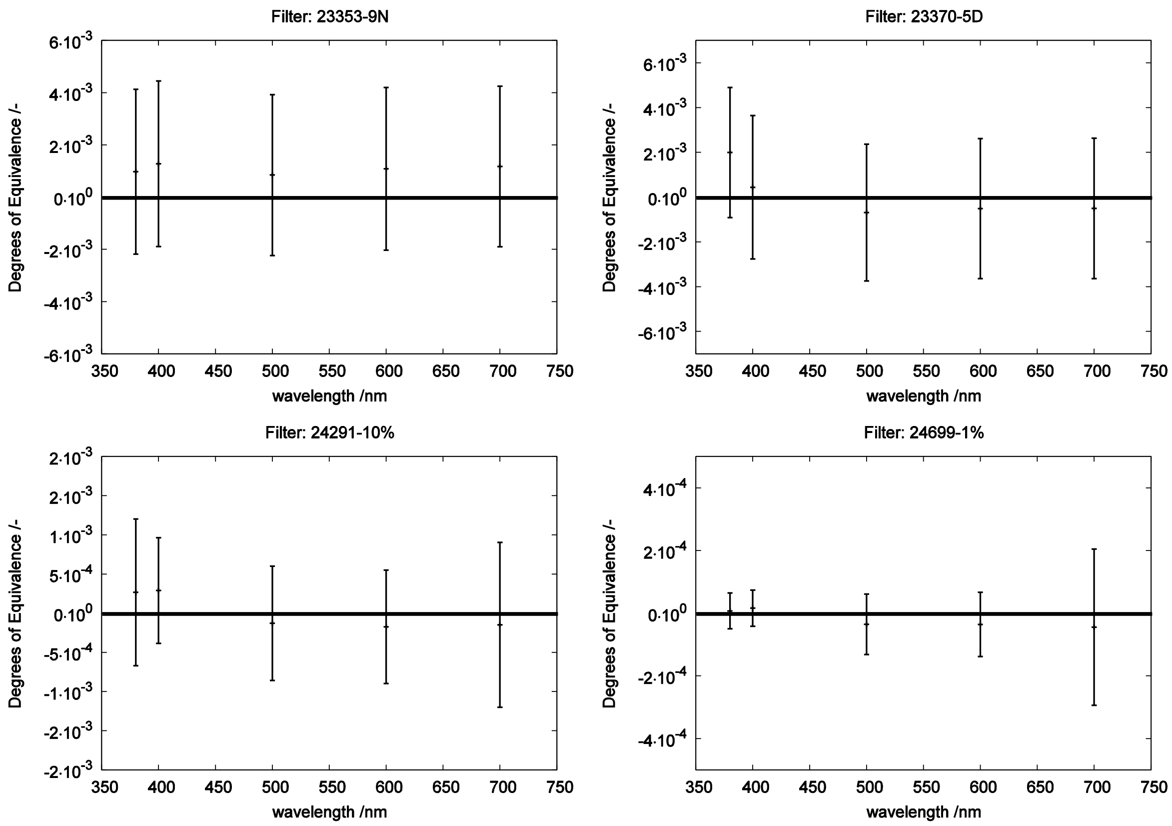


Figure B-1. Degrees of equivalence of BIM in EURAMET.PR.K6.2 with respect to $RV_{CCPR\ K6}$ with the expanded uncertainty (k=2).

References

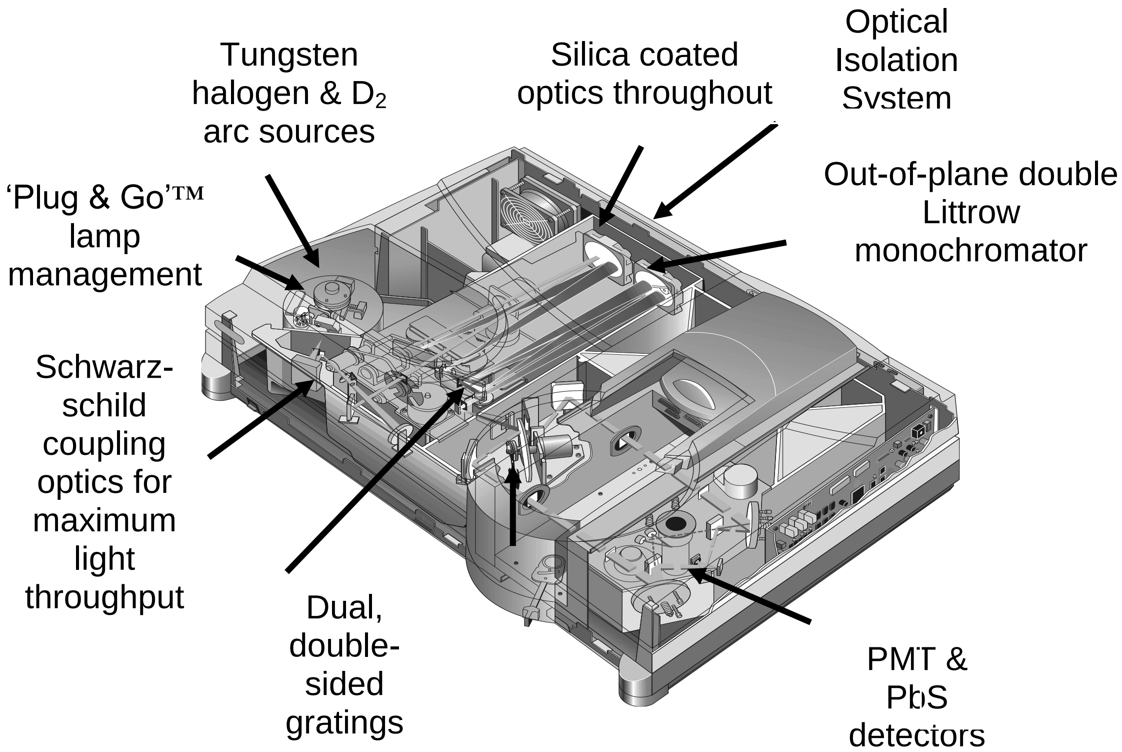
[1] G. Obein en J. Bastie, *Report on the CCPR Key Comparison K6 Spectral regular transmittance*. 2008.

Annex C. Methods of measurement

C.1 Method of BIM

The filters were checked for contamination, but did not need to be cleaned before the measurements. Only dust was removed with an air pump.

Measurement setup



The measurements in BIM have been performed using a commercial double beam UV-Vis-NIR spectrophotometer Cary 5000, manufactured by Varian, Inc. Australia. The Cary 5000 UV/Vis/NIR Spectrophotometer covers the wavelength range of 175 nm to 3300 nm with an accuracy of 0.1 nm in the UV/Vis range. Spectral bandwidths is from 0.01 - 5.00 nm for UV-Vis. It includes double out-of-plane Litttrow monochromator and dual double-sided gratings. The sources are Tungsten halogen visible source and quartz window deuterium arc UV source. Supplied as standard is Hg lamp for automatic wavelength accuracy validation. Detection in the UV/Vis range is with a high performance R928 photomultiplier tube.

This spectrophotometer has been calibrated with reference filters:
- SRM 930D and SRM 2031 manufactured by NIST, which are traceable to PTB from November 2005.
- SRM 2065 manufactured by NIST traceable to NIST from March 2002.

The wavelength settings of the spectrophotometer were also checked with D_2 arc and Hg spectral lamps, for the specific wavelengths.
The bandwidth used for the measurement was 1 nm.
The angle of incidence on the filter is 0^{o} towards normal. The illuminated filter area beam is 2 mm wide and 12 mm high. The beam geometry is near parallel.
The transfer filters were directly measured against air with the spectrophotometer.
Two sorts of spectral measurements were performed:
- 5 independent measurements with signal averaging time 0.1s, 1 s or 2 s and the scan rate between 30 nm/min and 600 nm/min in a scanning method;
- 5 independent measurements at average time between 1 s and 5 s in a fixed wavelength method.

All measurements for each method were independent runs involving realignment and repositioning of the filters. Before each of the measurements, a baseline correction was made. No significant differences were found in the results of the different sorts of measurement. Repeatability of both methods of measurement was checked with 2 series of 10 measurements in a row, in the same conditions for each filter.
The reproducibility was calculated for 10 independent measurements for each filter at every wavelength.

Table C-1. Ambient conditions at BIM.

	Temperature °C	Uncertainty in temperature °C	Relative Humidity %	Uncertainty in Humidity %
BIM	22.9 ± 1.8	0.2	31 ± 6	2

C.2 Method of VSL

Measurement setup

The measurements at VSL have been performed using a double grating monochromator in additive dispersion, Type: 2035, McPherson, f = 350. The operational details are:

Wavelength range	380 nm to 700 nm
Grating type	ruled
Grating dimensions	(69 x 69) mm
F- number	4
Lines/mm	1200
Inverse linear dispersion	1.0 nm/mm
Slit width	2 mm
Bandwidth	1.5 nm (FWHM)
Output power	0.5 µW @ 380 nm to 7.0 µW @ 1000 nm (Halogen lamp 250 W)
Spotsize at filter	circular 4.4 mm in diameter

For the measurements reported in this comparison, a Tungsten Halogen lamp was used, Type Osram Xenophot HLX 250 W. The source was imaged on the entrance slit of the monochromator using a quartz lens. A shutter and an order selection filter (no filter @ 380 nm; KV389 @ 400 nm to 700 nm) were placed at the entrance slit. The monochromator was calibrated using low-pressure spectral lamps, Cs and He-filled.

The exit slit is imaged on the filters by three mirrors. The mirrors increase the F-number from the monochromator to 8 on the filters; the image from the exit slit is increased with a factor 2,2. The light transmitted through the filter is imaged with a flat mirror and a quartz lens on a silicon detector, Type S1337-1010BQ, Hamamatsu. The filter is positioned on a translation stage, which allows horizontal and vertical displacement and rotation around the vertical axis. Part of the light from the exit slit is directed, using a beamsplitter, on a monitor detector of the same type as the latter. The monitor dectetor is used to compensate for drift of the source. The photocurrents of both detectors were measured using two Keithley 486 Picoammeters.

Measurement procedure

Before a transmittance measurement the monochromator was calibrated using the Cs Spectral lamp. The filters were measured with a circular spot of 4.4 mm in diameter. A horizontal, vertical and rotational scan over the filter was performed to measure the inhomogeneity of the filter and the influence of the angle of incidence. These variables are taken in account as uncertainties over an area of 5.4 mm and an angle of ±1 °.

The final measurements were taken in mostly 10 runs, in a period of several days. The transmittance of the filters was determined by measuring nearly monochromatic light with and without the filter in its path.

Table C-2. Ambient conditions at VSL.

	Temperature °C	Uncertainty in temperature °C	Relative Humidity %	Uncertainty in Humidity %
VSL	23.0	0.5	45	10

Annex D. Uncertainty budgets

D.1 Detailed uncertainty budget of BIM

The reported uncertainties are relative uncertainties.

BIM: 24699-1%

Wavelength, nm	Type	380	400	500	546	600	635	700
Standard deviation (n = 10), %	A	0.000	0.054	0.018	0.025	0.047	0.051	0.024
Wavelength setting, %	B	0.107	0.018	0.004	0.015	0.009	0.013	0.003
Uncertainty of Cary 5000,% **	B	0.655	0.508	0.463	0.457	0.460	0.446	0.388
Photometric resolution,%	B	0.671	0.071	0.035	0.032	0.034	0.027	0.011
Total (k=1),%		*0.944	*0.516	0.465	0.459	0.464	0.450	0.389

* Out of measurement range

** Uncertainty from calibration by means of certified reference materials SRM 930D and SRM 2031

BIM: 24291-10%

Wavelength, nm	Type	380	400	500	546	600	635	700
Standard deviation (n = 10), %	A	0.065	0.035	0.012	0.020	0.025	0.022	0.016
Wavelength setting, %	B	0.018	0.010	0.004	0.014	0.008	0.013	0.005
Uncertainty of Cary 5000,%	B	0.976	0.317	0.302	0.303	0.320	0.291	0.262
Photometric resolution,%	B	0.011	0.004	0.003	0.003	0.003	0.003	0.002
Total (k=1),%		0.978	0.319	0.303	0.304	0.321	0.292	0.263

BIM: 23370-5D

Wavelength, nm	Type	380	400	500	546	600	635	700
Standard deviation (n = 10), %	A	0.021	0.008	0.003	0.005	0.005	0.006	0.008
Wavelength setting, %	B	0.007	0.007	0.003	0.012	0.007	0.013	0.007
Uncertainty of Cary 5000,%	B	0.203	0.271	0.262	0.257	0.268	0.270	0.259
Photometric resolution,%	B	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total (k=1),%		0.204	0.271	0.262	0.257	0.268	0.270	0.259

BIM: 23353-9N

Wavelength, nm	Type	380	400	500	546	600	635	700
Standard deviation, %	A	0.005	0.005	0.004	0.006	0.005	0.007	0.012
Wavelength setting, %	B	0.0046	0.0074	0.0034	0.0133	0.0075	0.0133	0.0077
Uncertainty of Cary 5000,%	B	0.1588	0.1586	0.1585	0.1582	0.1586	0.1586	0.1581
Photometric resolution,%	B	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Total (k=1),%		0.159	0.159	0.159	0.159	0.159	0.159	0.159

D.2 Detailed uncertainty budget of VSL

Only the uncertainty budgets for the first set of measurements from VSL are reported here. The uncertainties for the second set of measurement are only different in the standard deviation of the measurements. The reported uncertainties are relative to the measured values.

VSL1: 24699-1%

	Type	Wavelength /nm						
		380	400	500	546	600	635	700
Standard deviation /%	A	0.134	0.079	0.035	0.052	0.083	0.061	0.041
Linearity detector /%	B	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uncertainty meters /%	B	0.175	0.175	0.060	0.060	0.060	0.060	0.058
Non-uniformity /%	B	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Angle /%	B	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Wavelength /% [1]	B	0.645	0.156	0.002	0.000	0.003	0.003	0.004
Total (k=1) /%		0.682	0.248	0.070	0.080	0.103	0.086	0.072
Total (k=2) /%		1.363	0.495	0.140	0.160	0.206	0.172	0.143

VSL1: 24291-10%

	Type	Wavelength /nm						
		380	400	500	546	600	635	700
Standard deviation /%	A	0.073	0.033	0.029	0.050	0.037	0.025	0.030
Linearity detector /%	B	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uncertainty meters /%	B	0.029	0.029	0.029	0.029	0.029	0.017	0.017
Non-uniformity /%	B	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Angle /%	B	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Wavelength /% [1]	B	0.432	0.071	0.002	0.001	0.002	0.001	0.002
Total (k=1) /%		0.439	0.084	0.042	0.059	0.048	0.032	0.036
Total (k=2) /%		0.878	0.168	0.084	0.117	0.096	0.063	0.072

VSL1: 23370-5D

	Type	Wavelength /nm						
		380	400	500	546	600	635	700
Standard deviation /%	A	0.025	0.095	0.051	0.039	0.087	0.018	0.046
Linearity detector /%	B	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uncertainty meters /%	B	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Non-uniformity /%	B	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Angle /%	B	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Wavelength /% [1]	B	0.145	0.006	0.001	0.000	0.000	0.000	0.000
Total (k=1) /%		0.148	0.097	0.054	0.043	0.089	0.026	0.050
Total (k=2) /%		0.297	0.194	0.108	0.086	0.178	0.052	0.099

VSL1: 23353-9N

	Type	Wavelength /nm						
		380	400	500	546	600	635	700
Standard deviation /%		0.015	0.027	0.018	0.019	0.018	0.010	0.018
Linearity detector /%		0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uncertainty meters /%		0.017	0.017	0.017	0.017	0.017	0.017	0.017
Non-uniformity /%		0.003	0.003	0.003	0.003	0.003	0.003	0.003
Angle /%		0.003	0.003	0.003	0.003	0.003	0.003	0.003
Wavelength /% [1]		0.007	0.017	0.001	0.000	0.000	0.000	0.000
Total (k=1) /%		0.025	0.037	0.026	0.026	0.026	0.021	0.026
Total (k=2) /%		0.049	0.073	0.051	0.053	0.051	0.042	0.051

[1] Stray light is assumed to be negligible because the out-of-band suppression of the double monochromator is known to be better than 10^{-6}.

Annex E. Comparison protocol

Ref.1073

EURAMET.PR-K6.2

Bilateral Comparison on Spectral Regular Transmittance

Technical Protocol

1. Introduction

1.1 The metrological equivalence of national measurement standards is 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). In the field of photometry and radiometry the key comparison CCPR-K6 deals with comparing the spectral regular transmittance of a set of gray filters.

1.2 In the framework of Phare project BG 2005/017-353.02.02, LOT 1, it was decided that a key comparison of spectral regular transmittance shall be carried out, between the optical laboratory of BIM (Bulgaria) acting as organizing laboratory and VSL (The Netherlands) acting as reference or linking laboratory to the corresponding CCPR-K6 comparison.

1.3 This technical protocol has been drawn up by experts from BIM and VSL. It follows closely the technical protocol of the corresponding CCPR-K6 comparison.

1.4 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, is based on current best practise in the use of standard filters and takes account of the experience gained from the previous comparisons organised in this field.

1.5. This technical protocol was approved by the CCPR WG-KC on January 10, 2010.

2. Organisation

2.1 Participants

2.1.1 The list of participants was drafted by the pilot laboratory.

2.1.2 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.

2.1.3 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.

2.2 Participants: details

The following laboratories will participate:

VSL	Mr Paul Dekker VSL Dutch Metrology Institute Optics Thijsseweg 11 PO Box 654 2629 JA Delft The Netherlands	Phone : + 31 15 269 1738 Fax : E-mail : pdekker@vsl.nl
BIM	Mrs. Angela Kunova Bulgarian Institute for Metrology GD National Centre of Metrology Section “Optical measurements” 2,”Prof. Peter Mutafchiev” str. 1784 Sofia Bulgaria	Phone : +359 2 974 31 61 Fax : +359 2 974 08 96 E-mail : a.kunova@bim.government.bg

2.3 Form of comparison

2.3.1 The comparison will principally be carried out through the calibration group of transfer standard filters. Each participant will use a set of filters to minimise the time needed for the completion of the comparison.

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

2.3.3 The comparison will take the form of a key comparison, carried out in one single phase. The artefacts (filters) will initially be calibrated by the linking laboratory. They will then distributed to the organizing laboratory who will perform the calibration. They will be returned to the linking laboratory to carry out a repeat calibration to check the stability.

2.3.4 BIM will act as the organizing laboratory. All results are to be communicated directly to the linking laboratory (VSL) as soon as possible and certainly within 6 weeks of completion of the measurements by a laboratory. BIM will do the data evaluation in agreement with the "Guidelines for CCPR Comparison Report Preparation", rev.1, March 2006. The final report will be submitted to the CCPR for approval.

2.3.5 Each laboratory has one month for calibration and transportation. With its confirmation to participate, each laboratory has confirmed that it is capable to perform the measurements in the time allocated to it.

2.3.6 If for some reasons, the measurement facility is not ready or customs clearance takes too much time in a country, the participant laboratory must contact the linking laboratory immediately. It may be possible for the participant to continue to take part by returning the calibrated filters back to the linking laboratory at an agreed later date.

2.3.7 Revised Timetable

Activity	**Date**
Invitation to participate	April 2008
Receipt of request to participate	July 2008
First measurements of the filters in VSL	October 2008
Measurements of the filters in BIM	November 2008
Filters returned to VSL	January 2009
Draft A comparison report circulated	December 2009
Draft B comparison report submitted to CCPR	after EUROMET.PR-K6

2.4 Handling the artefacts

2.4.1 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.

2.4.2 The standard filters should only be handled by authorised persons and stored in such way as to prevent damage.

2.4.3 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 linking laboratory.

2.4.4 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.

2.5 Transport of artefacts

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

2.5.2 Artefact should be marked as “fragile”.

2.5.3 The artefacts should be accompanied by a suitable documentation identifying the items uniquely (where appropriate).

2.5.4 Arrangement for transportation and proper insurance of the standards is each laboratory’s responsibility. The costs for measurements, transportation and any customs charges as well as insurance costs for the transfer standards can be declared from "PHARE Project BG 2005/017-353.02.02, LOT 1". Each participant must make sure that the transfer standards are properly insured for loss or damage during the stay in its laboratory and during transport to the next participant.

3. Description of the standards

3.1 The filter set to check the photometric scale is constituted by 4 neutral coloured glass filter plates 12.5 mm X 45 mm with nominal transmittance, at the wavelength of 546 nm, of approximately 92%, 56%, 10%, 1% . The filters are contained in a box specially design for transportation.

3.2 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.

3.3 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

3.4 The manufacturing tolerances are for:

Size: (12.5 x 45) mm (+0/-0.3) mm.

Flatness: better than 5 μm over a central diameter of 10 mm.

Parallelism: better than 0.02 mm

4. Measurement instructions

4.1 Traceability

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

4.2 Measurand

4.2.1 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 is required to be included.

4.3 Measurement instructions

4.3.1 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.

4.3.2 The spectral transmittance measurement of the filters should be performed at the following wavelengths: 380, 400, 500, 546, 600, 635 and 700 nm.

4.3.3 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. The suitable size of the beam is 2 mm wide and 10 mm high.

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

4.3.5 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.

4.3.6 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 linking laboratory who will be responsible for co-ordinating how the information should be disseminated. No communication whatsoever regarding any details of the comparison other than the general conditions described in this protocol shall occur between any party external to the comparison without the written consent of the linking laboratory. The linking laboratory will in turn seek permission of all the participants. This is to ensure that no bias from whatever accidental means can occur.

5. Measurement uncertainty

5.1 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 appropriate to include dependent on specific measurement facilities and these should be added with an appropriate explanation and or reference. As well as the value associated with the uncertainty, participants should give an indication as to the basis of their estimate. All values should be given for a coverage factor of k=1.

5.2 Type A

5.2.1 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.

5.2.2 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 characterises 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.

5.3 Type B

5.3.1 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.

5.3.2 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.

6. Reporting of results

6.1 After BIM has completed its measurements, BIM will send its measurement report to the link laboratory. When the link laboratory has received this measurement report, BIM is no longer allowed to make any changes in its results or in its uncertainties. When the link laboratory has completed its measurements they will also make a measurement report of its results. When all measurements reports have been completed they will be send to BIM who will do the data analysis and write the comparison report.

6.2 The link laboratory will check the data analysis as performed by BIM, and make sure that none of the BIM data has been changed. The link laboratory will check the comparison report.

6.3 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.

6.4 The measurement report forms in appendix A.1, A.2, A.3 of this document will be sent by e-mail to participating laboratories. It would be appreciated if the report form (in particular the results sheet) could be completed by computer.

7. Determination of the reference value

To be completed following discussion by Key comparison working group.

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 the filter :

Ambient temperature :

Wavelength nm	Spectral transmittance	Bandwidth nm	Standard deviation	Number of runs	Uncertainty
380					
400					
500					
546					
600					
635					
700					

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
oooooo.oooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo.

Method of characterisation of the spectrophotometer
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
ooooooooooooooooooooooooooooooooooo.

Description of measuring technique (please include a diagram if appropriate)
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo
oooooooooooooooooooooooooooooooooo.

Description of calibration laboratory conditions : e.g. temperature, humidity, cleaning of the filter if it has be done due to accidental pollution etc.
ooooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooooo

Laboratory :

Date : Signature :

A.3 Uncertainty of measurement

Parameter	Type A	Type B	Uncertainty in spectral transmittance
Repeatability	U1		
Non linearity		U2	
Wavelength setting		U3	
Beam displacement		U4	
Inter-reflection		U5	
Obliquity effect		U6	
Polarisation		U7	
Drift		U8	
Others		U9	
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 dependent 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 : Paul Dekker VSL / Optics,

PO Box 654, Thijsseweg 11, 2629 Delft, The Netherlands

Fax : +31 15 269 17 38 E-mail : pdekker@nmi.nl

From : (participating laboratory)

We confirmed having received the standards of the EURAMET 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 :