NEWRAD 2005: Preparing Final Camera-Ready

Mutual comparison of detectors spectral responsivity to prove stated measurement uncertainty

V. Skerovic, P. Vukadin, V. Zarubica
Bureau for measures and precious metals, Belgrade, Serbia and Montenegro

Abstract. Realization of the scale of spectral responsivity of the detectors in the Bureau of Measures and Precious Metals (ZMDM) is based on silicon detectors traceable to BNM-INM. For a laboratory, which do not has own scale realization, and establishes its traceability to other NMI, the main goal is to develop appropriate method for tracing the value of spectral responsivity. In order to provide objective information about calibration and measurement capabilities in that field, the method for proving stated measurement uncertainty based on mutual comparison of at least three detectors, is developed. In this paper, method of mutual comparison is presented, and the results with measurement uncertainty analysis are given.

Introduction

Tracing the value of the unit based on the realization of foreign Laboratory (NMI), is the case in the most of the smaller countries NMI′s. In order to evaluate measurement uncertainty of tracing the value, received measurement uncertainty must be integrated with uncertainty of the realized method of comparison. However, in such cases of tracing the value of the unit in multiple steps, stated measurement uncertainty will not always represent real truth about calibration and measurement capabilities.

Based on long tradition in realization and tracing the values of light quantities based on International Mean of the candela and lumen conserved in the BIPM [1], the method of proving measurement uncertainty by means of mutual comparisons is developed in the Laboratory for photometry and radiometry of ZMDM.

Realization of the method for comparison of spectral responsivity of silicon detectors

Measurement system [2, 3] for comparison of spectral responsivity of silicon detectors is shown in Figure 1.

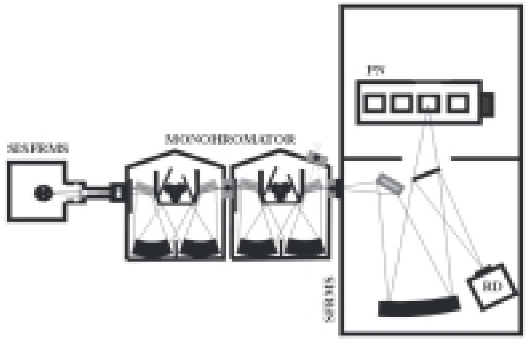

Figure 1. System of spectral comparisons. SISFRMS, light source; SFRMS, measurement station; RD, monitor detector; PN, translation stage.

System is based on double monochromator, halogen light source with 3 mW optical power at 550 nm. Beam divergence (full angle) is f/6, and spot size at focal point of the system is approximately 4 mm with bandwidth of 4 nm.

Three detectors (Hammatsu S1337 1010BQ) were calibrated at the end of year 2003 in BNM-INM. Calibrations were made in spectral range from 300 nm to 1000 nm at 23 different wavelengths. Bandwidth was 3 nm, and spot size ≈5 nm [4].

Method of comparison [5], is based on measurement equation

$$S_X(\lambda) = \frac{N_X(\lambda)}{N_0(\lambda)} \cdot \frac{G_0}{G_X} \cdot S_0(\lambda)\,, \qquad (1)$$

where: Sx(l), S_O(l) – spectral responsivity of the test and standard detector; N_X(l), N_O(l) – ratios of the signals from test/standard and compensation detector; Gx, Go – transimedance amplifier gain for two channels (for test and standard detector signal measurements).

Detectors are automatically exchanged in the path of the light beam. Signal from main and compensation detectors are measured simultaneously, ten times each detector. Correction of dark current is applied. Signal from detector is measured with transimpendans amplifier and digital voltmeter with scanner. Transimpedance amplifier is calibrated by means of low current source calibrator and digital voltmeter. Measurement uncertainty of the method of comparison is evaluated and given in table 1.

Table 1. Uncertainty budget.

Uncertainty component	Uncertainty (Type A)	Uncertainty (Type B)
u(Nx)	2×10^{-4}	
u(No)	2×10^{-4}	
u(Gx)		$2{,}5\times 10^{-4}$
u(Go)		$2{,}5\times 10^{-4}$
DVM uncertainty		2×10^{-4}
beam-divergence		negligible
Nonuniformity of detectors		not analized
Nonlinearity		2×10^{-4}
Wavelength accuracy		$0{,}2 \times 10^{-4}$
Bandwith efect		negligible
Stray light		negligible
Standard uncertainty (1σ)	$2{,}8 \times 10^{-4}$	$4{,}5 \times 10^{-4}$
Combined standard uncertainty (1σ)	$5{,}3 \times 10^{-4}$	

Mutual comparison

Mutual comparison of three standard detectors (SR1, SR2, SR3) is preformed by method of comparison each by each, in both directions (measurement sequence). It means that six different comparisons are made: SR1-SR2, SR1-SR3, SR2-SR3, SR2-SR3, SR2-SR1, SR3-SR1. For each of these comparisons, five measurement cycles are made at 23 wavelengths with ten readings at every wavelength.

Results of comparison SR1-SR2, for example, is calculated as relative deviation [6] of the results of measurements for SR2 detector responsivity, using SR1 as standard, from its values given in BNM-INM certificate. Calculations are made at each point of measurement. Average value of relative deviation for every wavelength is presented. Standard deviation of all mutual comparison measurements is calculated and given as measure of reproducibility of measurements.

Preliminary results show that average deviations from certificate values for all mutual comparison measurements (all three detectors) is 0,93 % relative. Larger difference from certificate values shows detector SR3, while detectors SR1 and SR2 shows differences of about 0,7 % relative. Reproducibility of the method is tested with SR1-SR2 and SR2-SR1 measurement after complete repositioning and changed conditions in two days. The results show agreement within 0,1 %. Correction or reduction of deviations from certificate values should be made through the measurements that are still in progress. Detailed analysis of all results will be presented in the paper.

Conclusion

Differences between certificate values and values that are reproduced in the laboratory, which traces the value from other NMI, are not unusual. Dealing with that, is the one of the most complex jobs for the laboratories of that kind.

Method of mutual comparisons can be good model for smaller countries laboratories (NMI′s), to deal with that problem. Result of mutual comparison can provide basis for improvements of realized method, and can be used to prove stated measurement uncertainty. Result of mutual comparison represents real truth of uncertainty of reproducing the value of the unit that is traced from other NMI.

Acknowledgments The authors wish to thank to Prof. Lj. Zekovic and all associates from department for metrology of the Physical faculty of Belgrade, who was engaged in the project of realization of our system. Also, authors wish to thank to Dr. Z. M. Markovic who help us with his advises in writing this paper.

References

[1] Vukadin, P., Skerovic, V., Zarubica, V., *Tracing the values of light quantities in Federal bureau of measures and precious metals*, Publication CIE x020 – 2001: Proceedings of the CIE Expert Symposium 2001 on Uncertainty Evaluation Methods for Analysis of Uncertainties in Optical Radiation Measurement, January 2001, Vienna, Austria.

[2] Skerovic, V., Vukadin, P., Zarubica, V., Zekovic, Lj., Realization of primary spectrophotometric system, *Proc. Fifth General Conference of the Balkan Physical Union.*

[3] Skerovic, V., Vukadin, P., Zarubica, Application of the concept of virtual instrument in realization of primary spectrophotoradiometric system, *Proc. XLVII ETRAN Conference*.

[4] Calibration certificate N°1076-Ra-04, BNM-INM, 2003.

[5] Larason, T. C., Bruce, S. S., Parr, A. C., Spectroradiometric detector Measurements,NIST Special Publication 250-41.

[6] ISO, Guide To The Expression Of Uncertainty In Measurement, 1993.