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Quality Manual of Spectral Irradiance Responsivity

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2. Definition

The scope of this instruction manual is to instruct the reader on how to make spectral irradiance responsivity measurements with the spectral irradiance comparator facility utilizing a monochromator and a Xe-lamp. The setup is presently without a permanent location. The manual describes the measurement procedure, the alignment of the setup and the preparations needed for the measurements. Also the operation of the software needed is covered.

3. Equipment

Figure 1 shows a schematic picture of the measurement setup.

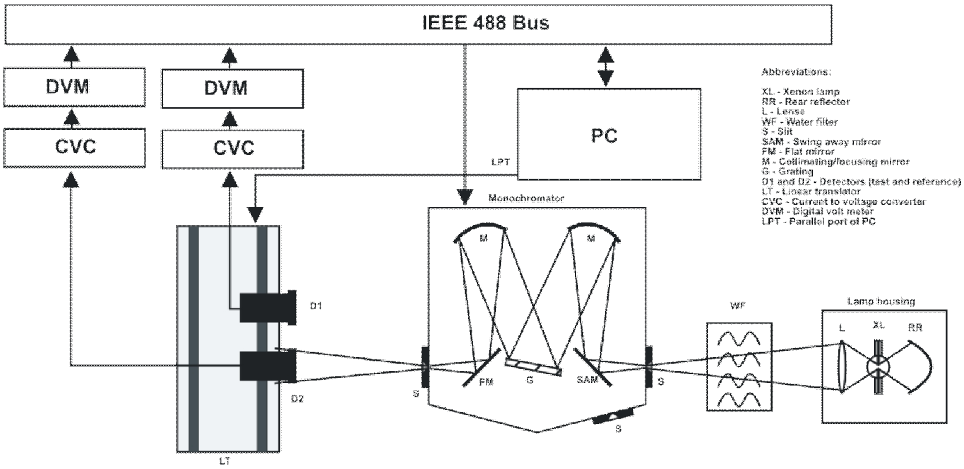

Figure 1. Measurement setup. [1]

The pieces of equipment needed for the measurement of spectral irradiance responsivity are listed below.

3.1. Xenon lamp

The light source used in the measurement is a 450-W xenon lamp manufactured by Spectraphysics / Newport. The lamp has its own power supply. Instructions for the lamp and the supply can be found in the lab and those should be read carefully before use.

3.2. Monochromator

Single grating monochromator TMc300 (Bentham Instruments) is used to adjust the wavelength during the scan.

3.3. Water filter

A water filter (Oriel) is used to absorb infrared radiation from the spectrum of the xenon lamp. This is done in order to prevent the monochromator (input slit, grating…) from overheating.

3.4. Water pump

In order to prevent the water filter from overheating, cooling water is pumped through it. This is done with water pump Eheim 1005. A water cooler may be used as well.

3.5. Linear translator

A linear translator (Isel-Automation) is used to switch detectors (the detector under measurement and the reference detector) in the output beam of the monochromator. Alternately, the devices may be interchanged using magnetic stands.

3.6. Current to voltage converter (1 or 2 pcs)

Current to voltage converters are used to convert the weak current signals of photodiodes or trap detectors into a measurable voltage. Converters are also needed to maintain the photodiodes in the linear region of operation. The calibration of the converters must be valid.

3.7. Digital volt meter (2 pcs)*

A digital volt meter (DVM) is used to measure the voltage provided by the current to voltage converter. This measurement setup uses two HP 3458A multimeters. The calibration of the multimeters must be valid.

3.8. Calibration requirements

Devices that need calibration include

1. The digital voltmeters (interval defined in Calsched)

2. The current to voltage converters (interval defined in Calsched)

3. Wavelength scale of the monochromator

4. The device used as irradiance responsivity standard

   - Pyroelectric radiometer

   - Trap detector or photodiode with aperture

4. Measurement traceability

The traceability and uncertainty of the measurement are dependent of the reference detector used. If the pyroelectric radiometer RsP-590/Rs-5900 or either of the reference photodiodes UVPD-8 or UVPD-13 is used, the traceability and uncertainty of the measurements is described in [1].

5. Calibration and measurement procedures including validation methods

5.1. Measurement procedure

The whole measurement is automized. The measurement is carried out with LabView program *spectral resp2multi*.vi*, where * denotes the version of the program. The current version (3.2.2005) is *spectral resp2multi2.vi*. The program uses the monochromator to scan over a certain wavelength region. Both the wavelength region and the steps used in the scan are specified by the user. At each wavelength the program first reads the signal of the reference detector, then switches to the detector under measurement, and then back to the reference. Before each reading the dark signal of the detector is recorded with help of the shutter that is located in the filter wheel inside the housing of the monochromator. That is, for each wavelength the program takes a total amount of six readings from the multimeters. Programs mentioned above and all required sub-vis can be found in the quality system directory

\\work.org.aalto.fi\T405\MIKES-Aalto\Quality\radiom\vis\spectralirradresp

5.2. Alignment and preparations

5.2.1. Switching on the lamp

The xenon lamp should be switched on before any other electrical devices because of possible electromagnetic disturbances it might cause. **OBS. Remember to remove the** tape from the input slit of the monochromator before switching on the lamp!!!

5.2.2. Cooling water

To provide proper cooling for the water filter, cooling water is pumped through it. The water pump is sunk in a bucket filled with cold water. Then the water hoses are connected so that the water returns from the filter back to the bucket. The pump should be switched on right after switching on the xenon lamp.

5.2.3. Switching on other devices

All other electrical devices should be switched on soon after the xenon lamp, because it is recommended to let them be switched on at least an hour before starting the measurements.

5.2.4. Adjusting the bandwidth

The bandwidth of the monochromator is defined by adjusting the widths of the entrance and exit slits of the monochromator. For grating n:o 1 the reciprocal dispersion is 1.8 nm/mm. For grating n:o two the reciprocal dispersion is 2.7 nm/mm. For example, with grating n:o 1, a bandwidth of 5 nm is obtained by adjusting the widths of the slits to be 5/1.8 = 2.78 mm. The program uses each grating at certain wavelengths, specified by the user. At the moment the program uses grating 1 with wavelengths shorter than 750 nm.

5.2.5. Alignment

The alignment of the setup is crucial for the success of the calibration. The alignment is done with the help of four LabView programs (vi's): *init MC.vi*, *set wavelength.vi*, *set filter.vi* and *lin.vi*. These are actually sub vi's that the measurement program *spectral resp2multi2.vi* uses, but they can also be used individually. The operation of these vi's is explained in the following.

5.2.5.1.init MC.vi

init MC.vi is used to initialize the monochromator. The only information it requires from the user is the GPIB address of the monochromator, which is set to be 30 at the factory.

5.2.5.2.set wavelength.vi

This vi is used to set the pass wavelength of the monochromator. The user writes this in the field `Wavelength/nm` in the front panel of the vi. Also the GPIB address of the monochromator is required.

5.2.5.3.set filter.vi

This vi is used to operate the filter wheel which is located inside the monochromator. If the monochromator is set to pass the wavelength λ_0, it also passes all the wavelengths λ_0/n, where n is an integer. This can be prevented by filtering the higher harmonic frequencies (shorter wavelegths) away from the output of the monochromator. In the field `Filter` the user has four options to choose from: `Shutter`, `OPEN`, `OS400` and `OS700`. `OS400` and `OS700` are order sorting filters, which are used when the set wavelength is over 400 or 700 nm, respectively. If the wavelength is less than 400 nm, the option `OPEN` is used. `Shutter` is used to block the output of the monochromator, for example when measuring the dark signal of a detector. The measurement vi *spectralresp2multi2.vi* uses this sub vi throughout the wavelength scan to choose the right filter at each wavelength.

5.2.5.4.lin.vi

This vi is used to operate the linear translator. The vi has four controls that the user may modify: `Port Address`, `Direction`, `Speed` and `N:o of steps`. `Port Address` is the address of the parallel port through which the PC operates the linear translator, this value is nominally 378 (hexa number). `Direction` decides whether the translator is moving `UP` or `DOWN`. The directions up and down are marked on the surface of the linear translator. Speed of the linear translator is set from the according control, the user is adviced to always use the highest speed. The distance of the travel is measured in steps. This distance is set with the control `N:o of steps`. The distance between the two detectors in this setup (and the distance that *spectral* resp2multi2.vi uses when swithing detectors) is 8500 steps. The distance must be changed in the resp2multi2.vi if different measurement setup is used. The principles of the alignment of the setup are depicted in the following.

5.2.5.5.Height

To adjust the height of the detectors to the height of the center of the exit slit of the monochromator, an alignment laser is used. The other beam of the laser is aligned at the center of the exit slit, while the other beam is used to align the detector. The user must make sure that the laser is not tilted, i.e. that the beams travel exactly horizontally. When aligning the two detectors linear translator is used to switch the detectors, while the alignment laser is kept at its place. Thorlabs collars are then used to lock the height.

5.2.5.6.Angle

To adjust the detector position so that the surface of its aperture is perpendicular to the optical axis, the user must set the wavelength of the monochromator to the visible region, for example 600 nm. Now the back reflection from the detector surface can be adjusted to hit the center of the exit slit of the monochromator. If the detector surface is such that it does not produce a strong enough back reflection, a small mirror can be used. The user should use a wide enough bandwidth (~5 nm) to have enough light available for the alignment.

5.2.5.7.Distance from the monochromator

In the measurement of spectral irradiance responsivity it is essential that the surfaces of the apertures of the detectors are at the same distance, measured from the exit slit of the monochromator. For this purpose, one of the posts is attached on a Thorlabs rail, while the other is located on a micrometer translation stage. **OBS! If using some alignment rod, beware of the edges of detector apertures!** Also, note that the reference plane of the detectors is the plane of the limiting aperture, not necessarily the outermost edge of the detector.

5.2.5.8.Distance in the direction of travel

Fine tuning of the position in the direction of travel of the linear translation stage can be done manually with the wheel located at the back side of the translator. Once the detector, located on the Thorlabs rail, is moved to the position of the optical axis, the linear translator used to move the detectors 8500 steps, and the other detector is aligned with help of the micrometer translation stage.

5.3. Measuring

The measurement of spectral responsivity is carried out by using the *spectral-resp2multi2.vi*. The front panel of the vi is shown in Figure 2.

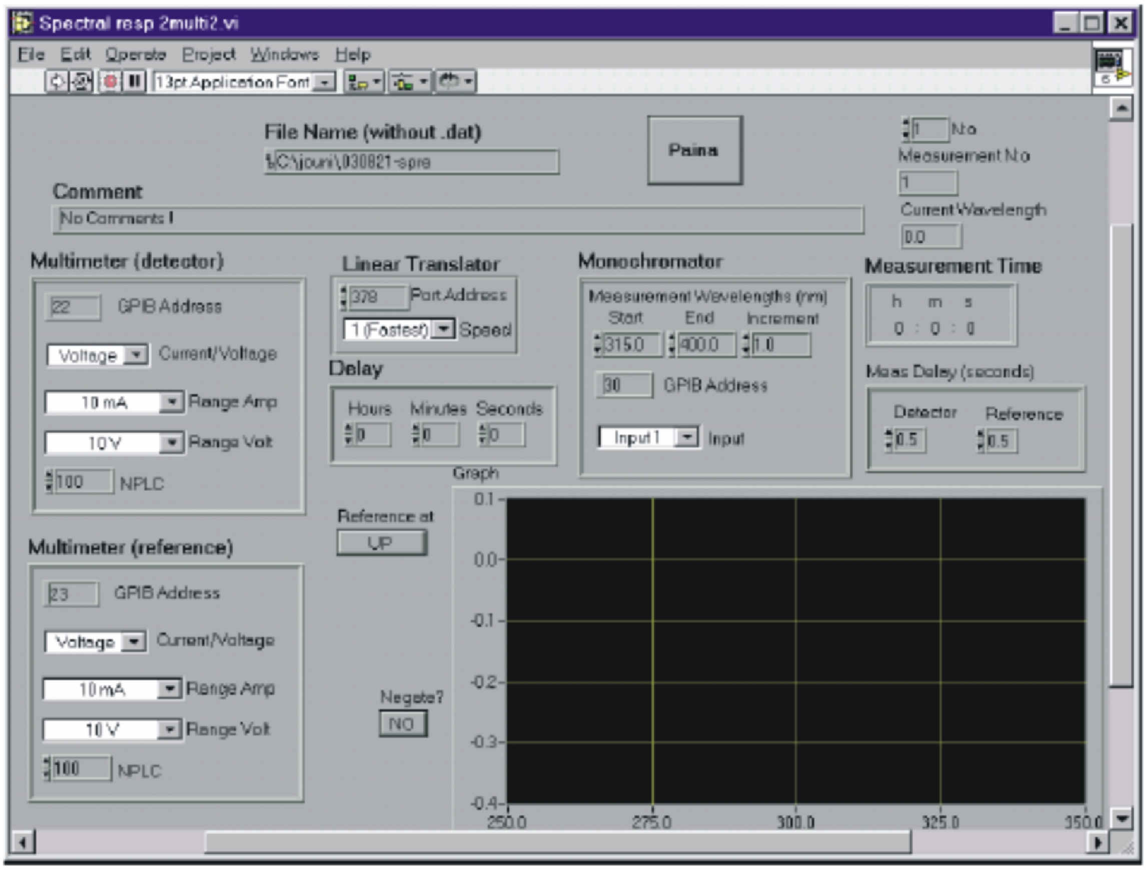

Figure 2. Front panel of spectral resp2multi2.vi.

Operation of the controls of the vi is described in the following.

5.3.1. File Name

The name of the file in which the measurement data is to be saved is entered in this field. The entire folder path must be included. The name of the file must not include any extension, the vi adds extension .dat to the file name.

5.3.2. Comment

Any information about the measurement settings etc. that is needed for later use is entered in this field.

5.3.3. Multimeter (detector) and Multimeter (reference)

These fields are used to adjust the settings of the two HP 3458 multimeters used in the measurement. These include the GPIB Addresses, measurement modes (current or voltage), measurement ranges and the amount of averaging (`NPLC`). Averaging of 100 samples corresponds to four seconds in integration time. If the measurement mode is set to be voltage, then `Range Amp` has no significance, and vice versa.

5.3.4. Linear Translator

This field defines the port address of the linear translator (hexa number) and the speed of the linear translator. Typically this field does not have to be modified.

5.3.5. Delay

Here the user sets the amount of delay that the vi waits before starting the measurement, leaving the user enough time to turn off the lights (including the PC monitor) and leave the laboratory. When the user starts the vi, a pop up window will appear, in which the time left to start the measurement is shown. If the user for some reason wants the measurement to start immediately, he/she can press the button `Start now` in the pop up window. If the `Cancel` button is pressed, the vi will not start the measurement. In this case the user must manually close the pop up window before starting any new measurements.

5.3.6. Refrence at

Here the user defines the position (UP/DOWN) of the reference detector.

5.3.7. Negate?

If this is set to `YES`, the readings of the detector under calibration are negated. This is practical when the detector would otherwise give negative output signals.

5.3.8. Monochromator

The settings of the monochromator and the measurement wavelengths are defined here. `Start` and `End` refer to the first and last wavelength of the measurement. It should be noted that the `Start` wavelength does not have to be smaller than the `End` wavelength, however, the user is advised to do the wavelength scans always in the same direction (up or down) because of the possible hysteresis of the step motor of the monochromator. `Increment` implies the wavelength step with which the measurement is carried out. The GPIB addres of the monochromator and the input slit used in the measurement are also defined in this field. Input 1 is the input slit that is directly opposite to the exit slit of the monochromator.

5.3.9. N:o

Here the user specifies how many times the measurement is repeated. If this is greater than one, the names of the data files of different measurements have the same beginning, defined in `File Name`, and the file names are separated with an ascending integer number.

5.3.10. Measurement N:o

This field is an indicator that shows the user the number of the measurement that is in progress.

5.3.11. Measurement Time

The total time of the measurement is shown here, this is also stored in the measurement data file.

5.3.12. Meas Delay

Because of the dark signal measurement, the shutter of the monochromator is switched on and off. The finite rise and fall times of the detectors may thus cause problems. To reduce this effect, the vi waits a certain amount of time after the opening/closure of the shutter until it takes the reading from the multimeter. This time can be set for the detector and the reference separately. For example, for the pyroelectric radiometer RsP-590/Rs-5900 this delay should be 10 seconds, while for most of the photodiodes and trap detectors 0.5 seconds ought to be long enough.

5.3.13. Graph

The measured spectral responsivity is shown in this chart. The curve that is shown is the signal of the measured detector divided by the corresponding averages of the reference detector signals in each wavelength. Also the background signals are taken into account. However, this plot is not necessarily the actual spectral responsivity curve of the measured detector, because the spectral responsivity of the reference detector is not included in the calculation of the curve. If the pyroelectric radiometer is used as the reference, the shape of the plot is correct, but the absolute values are not.

5.3.14. Paina

Pressing this button will give the user a definition of him/her as a human being (only in Finnish).

6. Handling of calibration items

No special requirements.

7. Uncertainty budgets

To be carried out with any possible calibrations. A sample uncertainty budget for a UVA meter has been given in [2].

8. Accommodation and environmental conditions

The setup presently has no room allocated. With possible recommissioning, low dust room is preferred.

9. Field calibrations

Not applicable.

10. Control data

Measurement results are to be archived.

11. Certificates

Results are given in W m^{-2} nm^{-1}. Alternately a relative spectral irradiance may be given.

12. Intercomparisons

An intercomparison of UVA radiometer responsivities has been carried out with STUK, University of Dundee, Guy's & St. Thomas Hostpital and UME-Tübitak [3]. Results indicated agreement within uncertainties.

13. References and publications

P1. Jouni Envall, Optical power measurements – applications in fiber optics and ultraviolet radiometry, Doctoral Thesis, Helsinki University of Technology, 2006.

1. J. Envall, Spektrisen irradianssivasteen kalibrointilaitteisto ultraviolettialueen radiometreille, Thesis for the degree of Master of Science in Technology, Helsinki University of Technology (2003).
2. Jouni Envall, Petri Kärhä, and Erkki Ikonen, "Calibration of broadband ultraviolet detectors by measurement of spectral irradiance responsivity," *Rev. Sci. Instrum.* **77**, 063110 (2006); doi: 10.1063/1.2209970
3. Jouni Envall, Lasse Ylianttila, Harry Moseley, Andrew Coleman, Murat Durak, Petri Kärhä, and and Erkki Ikonen, Investigation of comparison methods for UVA irradiance responsivity calibration facilities, *Metrologia* **43**, S27 (2006); doi:10.1088/0026-1394/43/2/S06