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Instruction Manual for the Laser-Based Multi-Wavelength setup for Characterizing Optical Detectors

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2.   Definition

This document provides the instructions on operating the multi-wavelength setup and its custom-made LabVIEW software developed by Vaskuri [1]. The multi-wavelength setup based on lasers is used for the characterization of optical meters, detectors and materials over a wide spectral range of 325 nm – 940 nm. The setup can be used for various measurements, such as absolute power calibration of optical detectors and transmittance measurements of transparent materials. The absolute power of a detector is calibrated by comparing a response of the detector to a reference detector. It can also be used to perform a spatial scan of detector under test (DUT) to check if the detector has a uniform responsivity or has a dust particle. The setup is automated, and it can be controlled from a computer using the LabVIEW software.

3.   Equipment

3.1.   Lasers

Six lasers with different wavelengths are used as light sources in this setup. The lasers are helium cadmium (HeCd) laser with two wavelengths 325 nm and 442 nm [2], kryp-ton argon (KrAr^{+2}) laser with nine wavelengths between 476 nm and 647 nm [3], a green helium neon (HeNe) laser [4], a red HeNe laser [5], an ultraviolet (UV) diode laser, and an infrared (IR) diode laser. The beam of the lasers is coupled into coupling optics and can be selected using the custom LabVIEW software.

Table 1. Laser lines currently available in the multi-wavelength laser setup as provided by the manufacturers.

Laser type	Available wavelengths / nm	Minimum power / mW	Beam diameter / nm
Helium Cadmium	325 nm, 442 nm	10, 30	-
Ultraviolet diode	405 nm	60	-
Krypton Argon ion	476 nm, 483 nm, 488 nm, 496 nm, 515 nm, 520 nm, 568 nm, 647 nm, 676 nm	4, 10, 20 4, 10, 20 20, 20, 6	-, -, 1.0 -,1.2, - -, 1.4, -
Green Helium Neon	543 nm	0.5	-
Red Helium Neon	633 nm	0.5	1.6
Infrared Diode	933 nm	90	1.6

Table 2 shows the spectrum analysis of the laser lines present in the multiwavelength performed by Laser Spectrum Analyser (LSA - 2256). The wavelength of each laser given by the manufacturer and their corresponding measured air and vacuum wavelengths are recorded in the Table 2.

Table 2. Laser lines measured with the wavelength meter LSA-2256.

Laser type	Manufacturer wavelengths / nm	Air wavelengths / nm	Vacuum wave-length / nm
	462	462.056	461.926
	476	476.381	476.248
KrAr	488	448.129	487.993
(Series 643)	514	514.680	514.537
	647	647.278	647.009
	676	676.640	676.452
IR diode (DSIQ2A)	933	933.227	932.971
HeNe (ThorLabs HRP006S) 632	543	543.525	543.374
	633	632.822	
UV diode (DS IQ2A)	405	405.037	404.923
HeCd (IK Series 56)	325	325.132	325.038
	442	-	-

3.2.   Optical setup

This section provides a detailed overview of the optical setup and the accompanying LabVIEW software. The interface and operation of the LabVIEW software is also presented in this section.

Figure 1 presents the structure of optical measurement setup. Three out of the six lasers are shown in the figure. The setup is designed in a way that all the lasers can be switched on simultaneously. The laser beams are directed towards an optical rail using plane mirrors M1 - M3 and the beam is selected by sliding a plane mirror M4. The position of M4 is controlled using the software. The beam then travels to a pinhole located at a common focal point between the mirrors through a spatial filter (constructed using two off-axis parabolic mirrors). The spatial filter improves the profile of laser beam by producing a smooth beam profile with Gaussian intensity. The pinhole was empirically selected to be 150 um. A smaller slit size enables more accurate low power measurements.
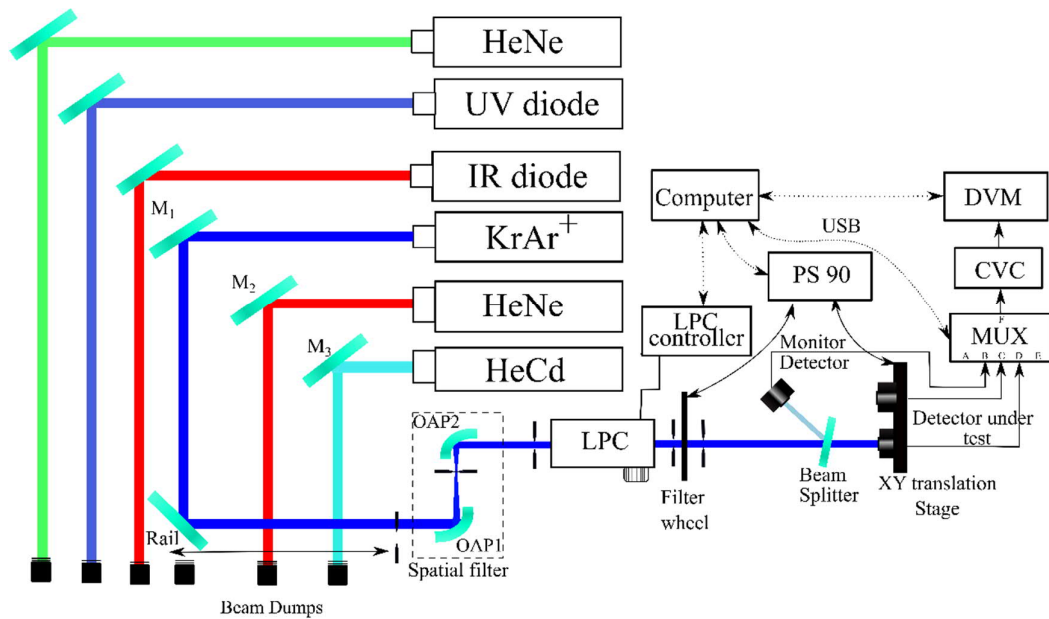
Figure 1. Optical setup.

The height of the beam is adjusted using a periscope. A laser power controller (LPC) is used to stabilise the beam. The LPC used requires vertically polarized light, and thus a polarizer is mounted in front of its entrance. The LPC stabilises the laser beam by attenuating the power of incoming beam. As an attenuator, the LPC contains a patented element which allows variable control of the beam. This enables the LPC to produce a range of laser powers, even using a laser which can only be operated at one power level. Unlike most attenuators, the LPC uses a liquid crystal cell to perform the attenuation.

A filter wheel mounted with attenuating filters of different optical densities is placed after the LPC. These can be used to block or attenuate the power of incoming beam in order to obtain dark measurements and to avoid saturation of detectors at times. The measurement setup provides an option to monitor the power level of the laser beam as a reference that can be used to compensate the remaining fluctuations of the stabilized beam power. This is implemented by reflecting a fraction of the stabilized beam back to a monitor detector with a wedged plate beam splitter. A silicon trap detector is used as a monitor detector in this setup. The DUT is mounted on a high precision translation stage, which enables us to control the position of the DUT from the computer. It also allows us to interchange between two or more detectors efficiently. Looking at the direction of the incident laser beam, the upper left corner of the XY translation stage is set to (0, 0) and the lower right corner is set to (300, 300).

3.3. Calibration requirements

The optical setup uses two Agilent digital voltmeters (HPS-9 and HPS-?) which are calibrated after every 2 years. A current-to-voltage converter (Vinculum-2) is also present

in the setup. The calibration for these electrical devices can be found in the quality system.

4.   Calibration and measurement procedures including validation methods
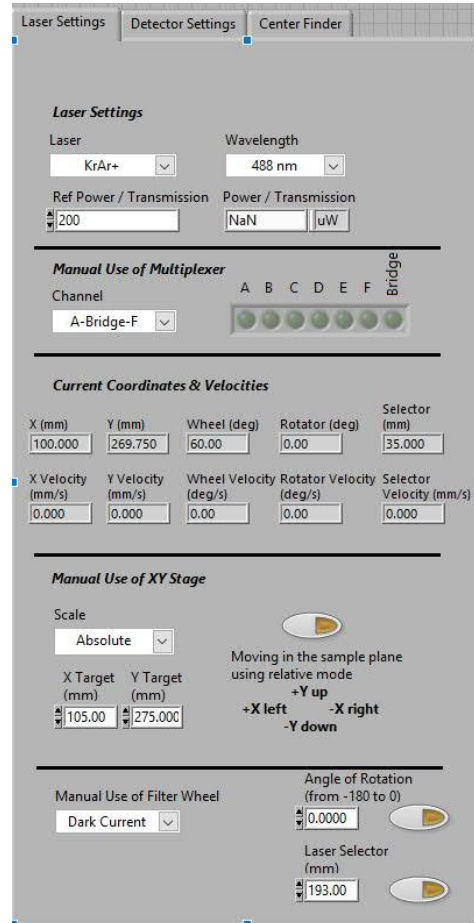

Figure 2. Laser settings module for selecting the type, wavelength, and power of the laser line.

The setup is controlled with LabVIEW software (LabVIEW 12.0). This chapter introduces the user interface and the main functionalities of the software. To run the software it is important to first open LaserSoftware.lvproj and then select main.vi from the LabView file. After the software is launched press run button shaped as an arrow on the top of the menu bar to run the software. It takes 5 - 10 seconds for the software to become functioning. The progress of the program being loaded can be monitored by the progress bars situated at the bottom of the GUI titled as "current progress" and "total progress".

Figure 2 shows the laser settings. The laser settings, detector settings and centre finder functions/options can be selected via the menu tab on the left. The laser settings allow

you to select the laser type by moving the mirror loaded on a rail. It also lets you set the required wavelength and power of the lasers. You can also manually change the bridge of the multiplexer. The current coordinates and velocity represent the position, direction, and speed of the xy translation stage. The filter wheel has six filters, these filters can be selected via the manual use of filter wheel.
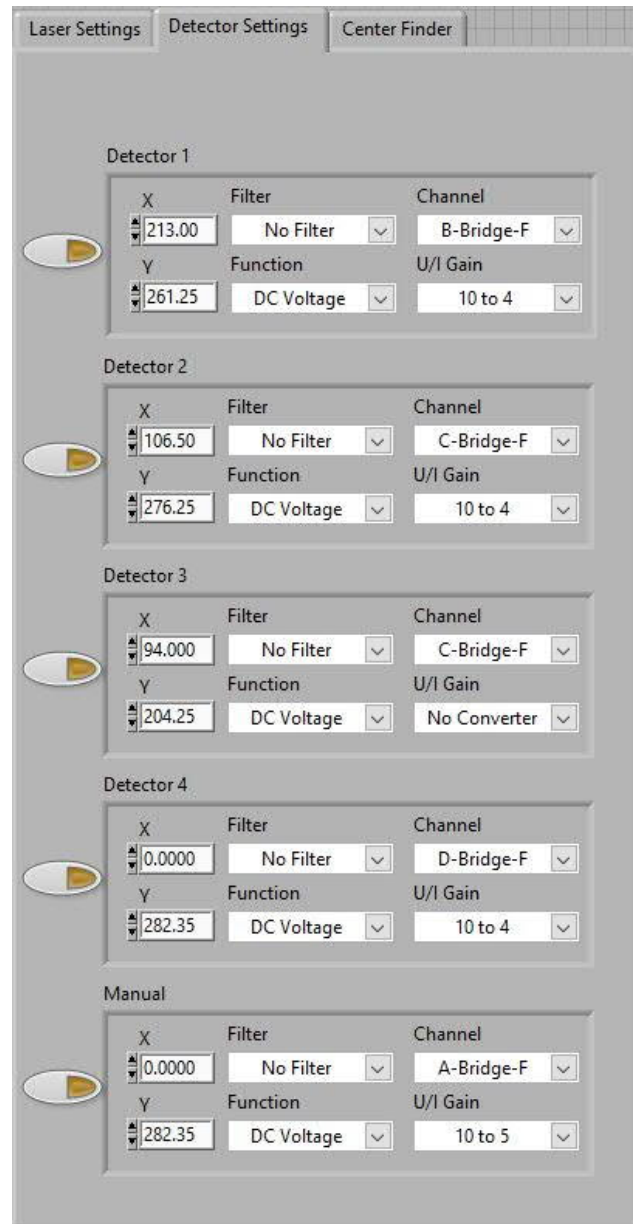

Figure 3. The position of the detector can be and saved here for up to four detectors (four simultaneous measurements).

Figure 3 shows the detector settings, through this the position of the xy translation stage so that the laser beam hits the centre of the detector. This position is then saved in the

computer. A filter can be selected to be used with the detector from the drop down titled 'Filter'. The MUX input with which the detector is connected to can be selected through channel.
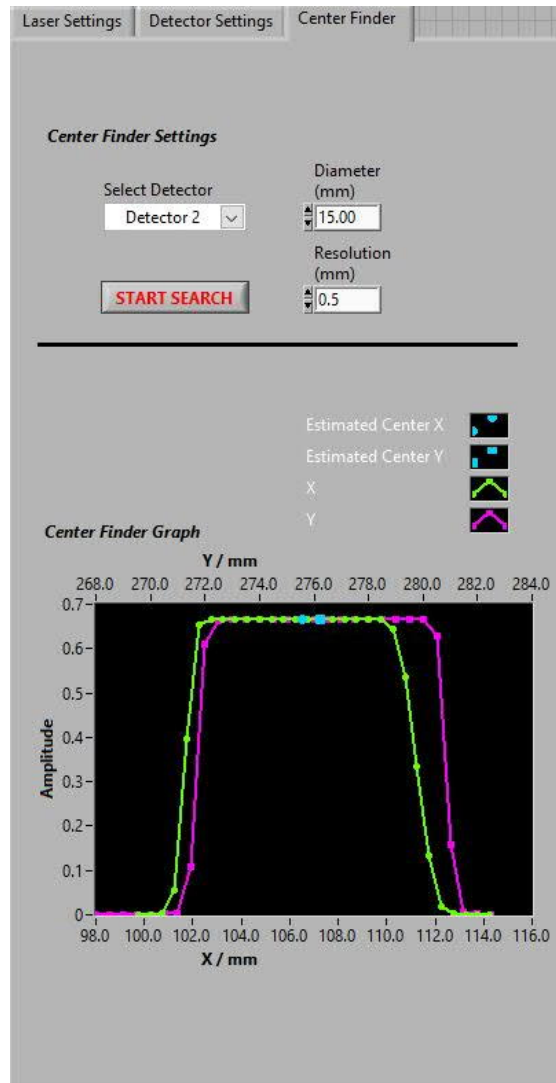

Figure 4. The centre finder modules search for the geometrical centre of the detector. The resolution and the diameter of the field of search can be set by the user.

Figure 4 show the centre finder settings. This helps in finding the geometrical centre of the selected detector. The diameter is set 1.5 times larger than the diameter of the active area of the DUT and resolution can be increased or decreased for precise centre position. The centre values are then saved in the detector settings as the new position of the detector under test.

The functionality is implemented as follows. First, the laser beam is directed perpendicularly to the active area of the detector by moving the XY translation stage manually. Then, the detector is scanned horizontally with the desired resolution and diameter

throughout its active area. After scanning, the centre coordinate of the detector is cal-culated by ending coordinates where the response is half of the maximum response. The search is started from the outer coordinates with respect to the starting coordinate. Then, the detector is moved to the horizontal centre coordinate found. The vertical cen-tre coordinate is searched in the same way, and the detector is moved to the vertical coordinate found.

The software saves the results obtained in a .lvm file. The file location and name can be specified in the directory as seen in Figure 5.
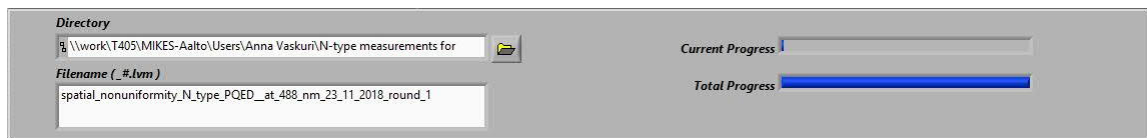

Figure 5. The location and name of the file can be customized.

It is possible to save additional information of the detectors in the. lvm output file pro-duced by the software. This module can be selected by the pop-up buttons present on the top right, shown in Figure 6.
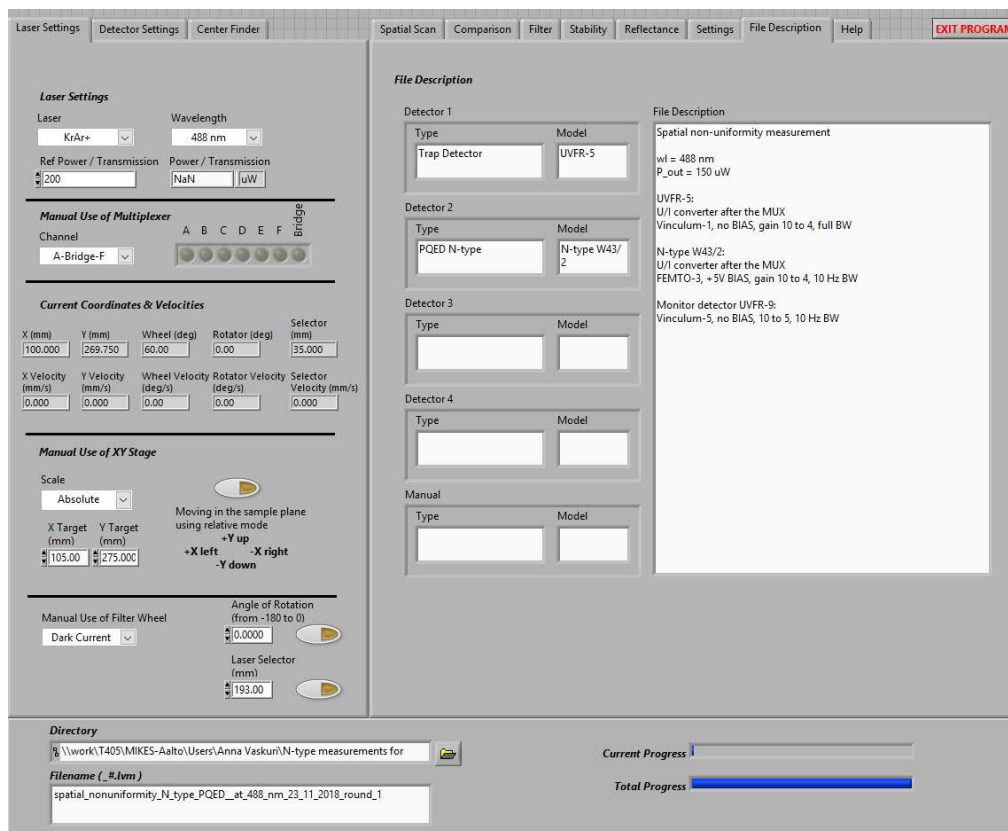

Figure 6. Additional description can be added to the generated .lvm file.

One of the main functions of this software is to measure the spatial non-uniformity of detectors. The area across and the interval with which the spatial uniformity can be selected. It is also possible to measure the dark current before every measurement to account for background noise. The software measures relative voltage in the x and y direction starting from top left to bottom right of the detector under test. The monitor detector can be used to correct the possible non-uniformity due to the instability of the laser. The output file then gives the xy position, distance travelled in xy direction, and the corresponding measured voltage of the detector under test. The .lvm file also contains the measured monitor signal. The raw data is then used to plot a spatial map in MATLAB.
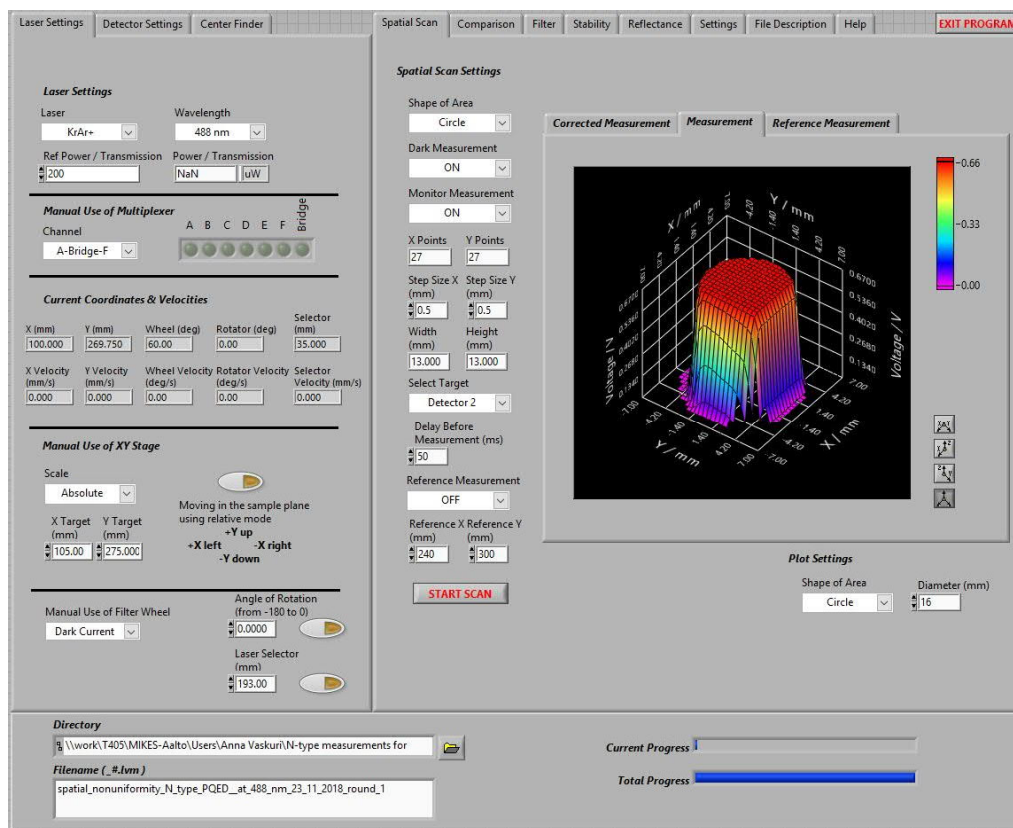

Figure 7. The spatial scan of a detector is performed by measuring the relative voltage across the whole detector. A monitor is also used to account for the instability of the laser.

The comparison measurement is usually used to calibrate detectors or optical power meters. Four detectors can be measured simultaneously. The position of these detectors is saved and set using detector settings as seen in Figure 8. A dark measurement is also measured at the same and subtracted from the detector signal. Monitor can be used to correct the voltages for laser fluctuations. The software can be given a time to wait before recording the measurement.

The optical setup has an automated filter wheel with neutral density filters as seen in Figure 9. These filters are used with detector at high power to avoid saturation of the

detectors. These filters have varying transmittance depending on the wavelength of the laser. The accurate transmittance at a particular wavelength can be measured by using the filter transmittance module. The transmittance of filter is calculated by taking the ratio of the signal measured with or without the filter inserted in front of the detector.
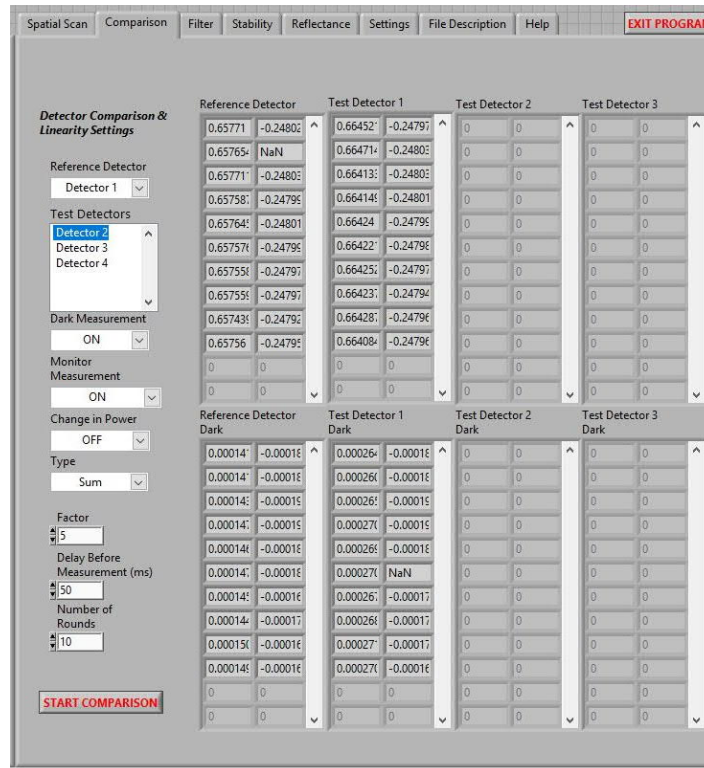

Figure 8. The comparison module allows signal measurement of four detectors simultaneously. This is usually in calibration of detectors or optical power meters.
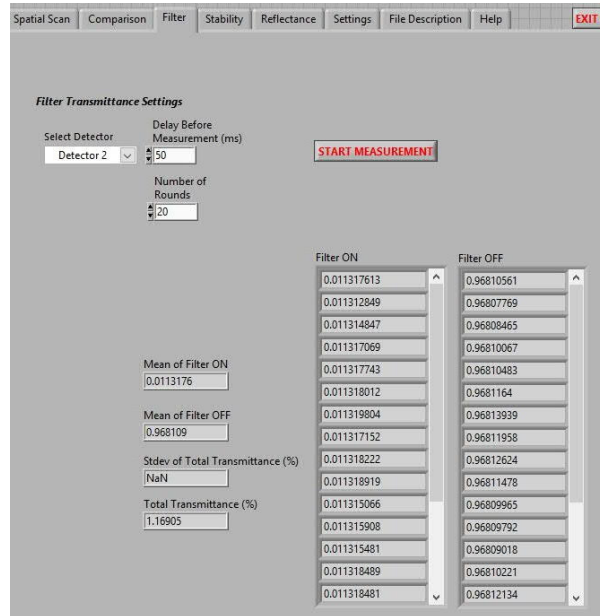
Figure 9. The transmittance of the filter is measured by calculating the ratio of the detector current with and without the filter.

Detector calibrations and characterizations may take significant amount of time. During these measurements, it is essential that the laser beam remains stable. Therefore, the stability of the laser is measured to estimate the factor of the uncertainty due to instability of the source. The stability is tested by measuring the voltage signal of the DUT over a period after a given interval. The results are given as a plot as seen in Figure 10 or as an external .lvm file.
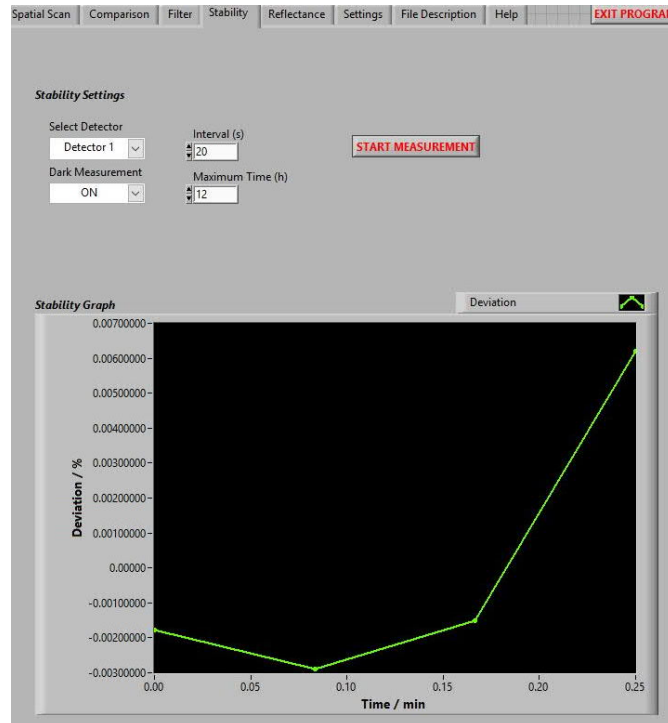
Figure 10. The stability of a detector under test is measured over a certain period by measuring the voltage of the detector under test periodically.

5.   Implementation of functionalities of the software

5.1.   Comparison measurement

Before measuring, the user sets the reference detector and all detectors to be calibrated. In addition, the user sets the number of rounds to be measured. Responses of all detectors selected are measured during one round including their dark responses, and all settings and readings are automatically saved to a text file created in the beginning of the calibration.
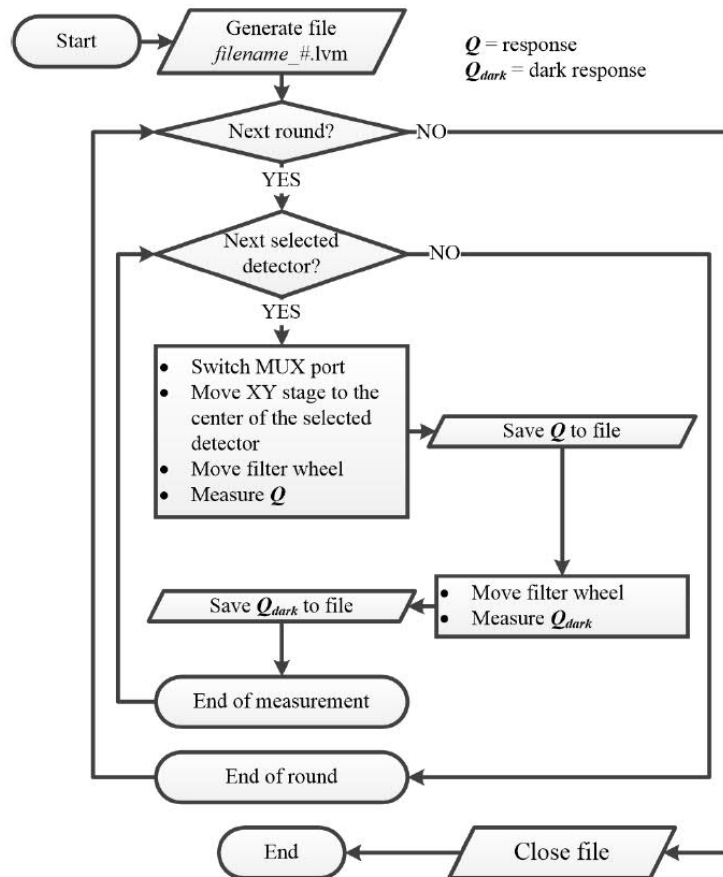
Figure 11. Implementation of the detector calibration functionality.

5.2.   Spatial Uniformity

Before scanning a detector, it is recommended to determine its centre coordinates with the functionality introduced in the last chapter. The scanning functionality contains various elements listed below.

-Select target (Detector 1 / . . . / Detector 4 / Manual)

- Shape of area to be scanned (Rectangle / Circle)

- Number of points (horizontally and vertically separately)

- Resolution (horizontal and vertical separately)

- Dark measurement (ON / OFF)

- Reference measurement (ON / OFF)

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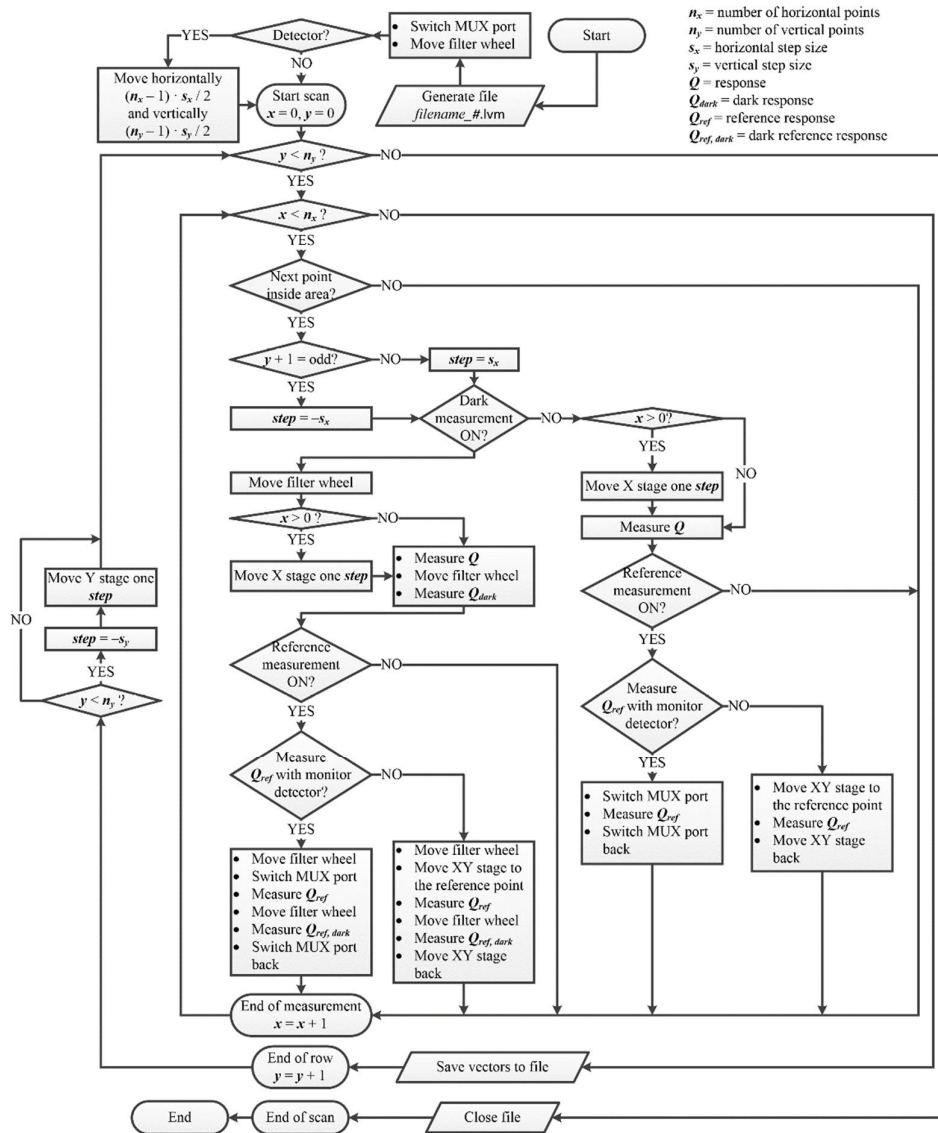**School of Electrical**
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Figure 12. Implementation of the spatial scan functionality.

The size and the resolution of the area have the largest impact on the total time consumed with the scan. The scan can be slightly expedited by selecting a suitable shape of the area to be the scanned. For example, most detectors have a circle-shaped light sensing area, so the corresponding shape is optimal.

Dark measurement can be set ON to correct for the effect of stray light and offset of the measurement electronics. In addition, the reference measurement can be set ON to consider the effect of changes in the detector response due to the fluctuations in the laser power. If the reference

measurement is selected, the reference response is always measured after the actual response. However, this will also increase the scan time of the DUT.

The scan is started in the upper left of the area if the target is set as the detector. If the manual mode is selected, the scan starts from the point where the XY translation stage is at that moment. The odd rows, starting from the first row, are scanned from left to right and the even rows in the opposite direction. After every scanned row, the results are automatically saved to the text file.

5.3.   Filter transmittance

Before measuring, user sets the filter, the detector and the number of rounds to be measured.
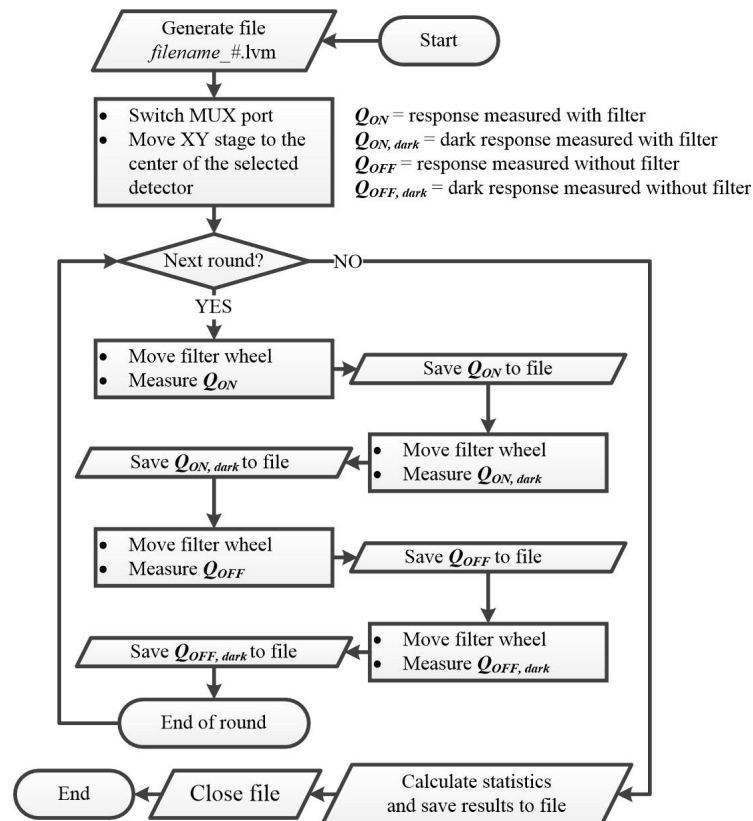

Figure 13.

6.   Accommodation and environmental conditions

The optical setup is in laser laboratory, room 1569, which is temperature and humidity stabilized. The ambient temperature and the relative humidity of air were periodically measured. The ambient temperature is maintained at T = (25 ± 3) °C.

7. Control data

The LabView software associated with the multiwavelength setup is archived at \\work\T405\MIKES-Aalto\Quality\Radiom\Instruction manual of laser setup\Laser Software 2.0 - 23.11.2018.

8. Publications

Publications relevant to performing calibrations are filed with the paper copy of the Quality/Instruction Manual. This includes e.g. publications and intercomparison results.

1. A. Vaskuri, *Multi-Wavelength setup based on lasers for characterizing optical detectors and materials*, Master's Thesis, Aalto University, March 2014.

2. Kimmon Koha, *He-Cd laser instruction manual KP2014C*, Kimmon Koha Co., Ltd, Japan, 2017.

3. Melles Griot, *Air-coooled argon lasers, Series 543*, Melles Griot Laser Group, California, USA, 1999

4. Melles Griot, *Cylindrical helium neon laser systems*, Melles Griot Laser Group, California, USA, 1999.

5. ThorLabs, *Red, self contained HeNe laser systems, operating manual*, ThorLabs Ab, Sweden, 2010.

6. BEOC, *BEOC laser power controller user's manual*, Brockton electro-Optics Corp, Bridgewater, MA, 2015. Available: work/T405/MIKES-Aalto/Resources/Equipment/BEOC Laser Stabilizer