OPTIMISE

Innovative Optical Tools For Proximal Sensing Of Ecophysiological Processes

PROTOCOLS FOR LABORATORY BASED FIELD SPECTROMETERS SPECTRAL AND RADIOMETRIC CALIBRATIONS

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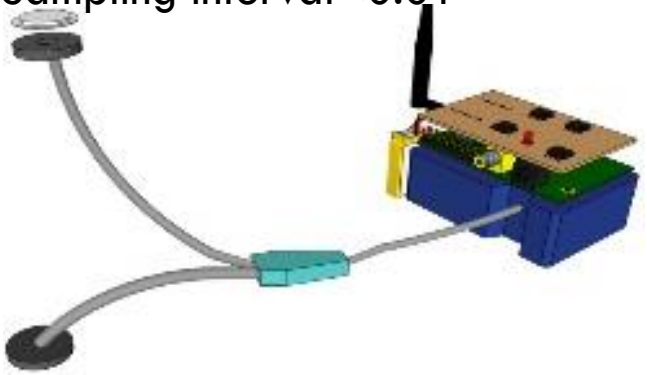
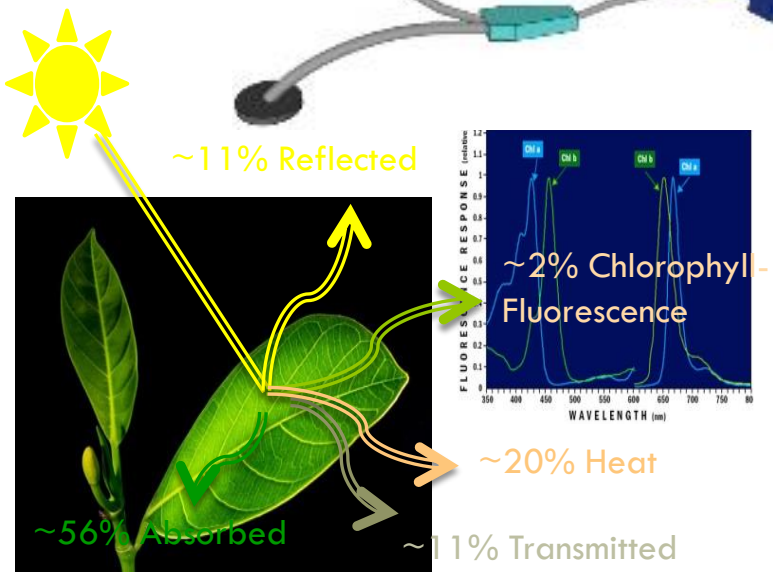
FWHM<0.03 nm

Sampling interval<0.01





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INFLPR cetal

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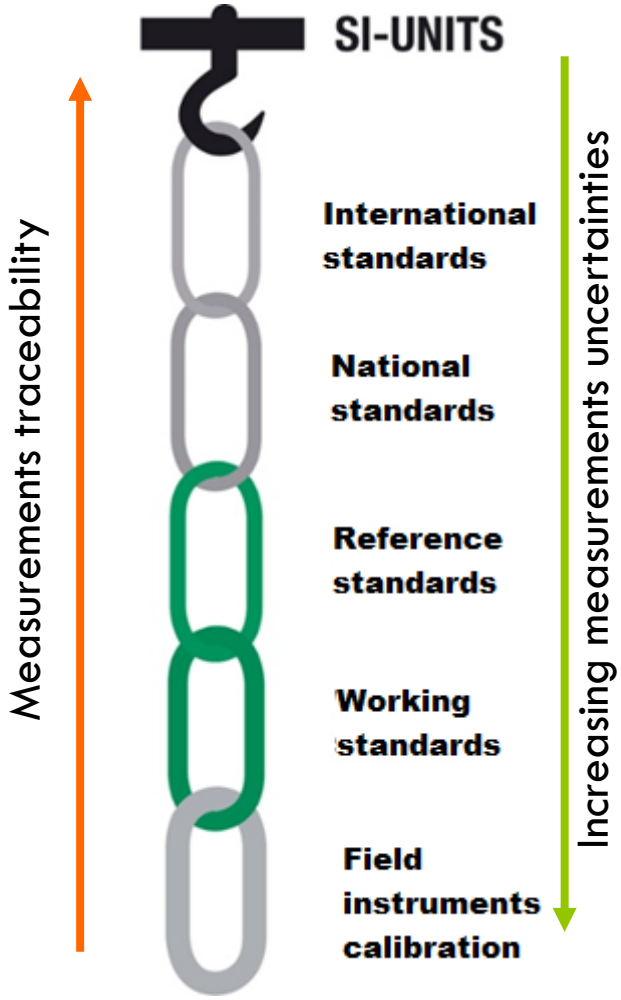
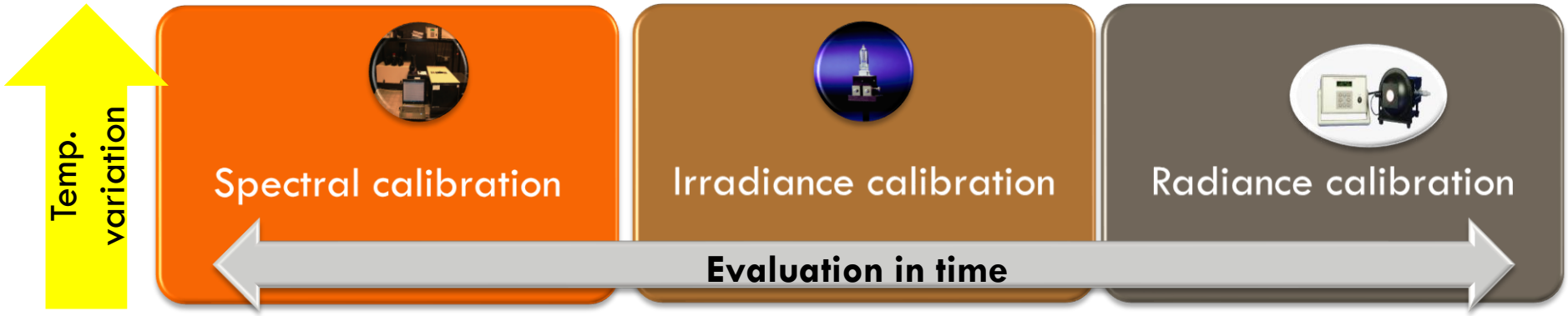
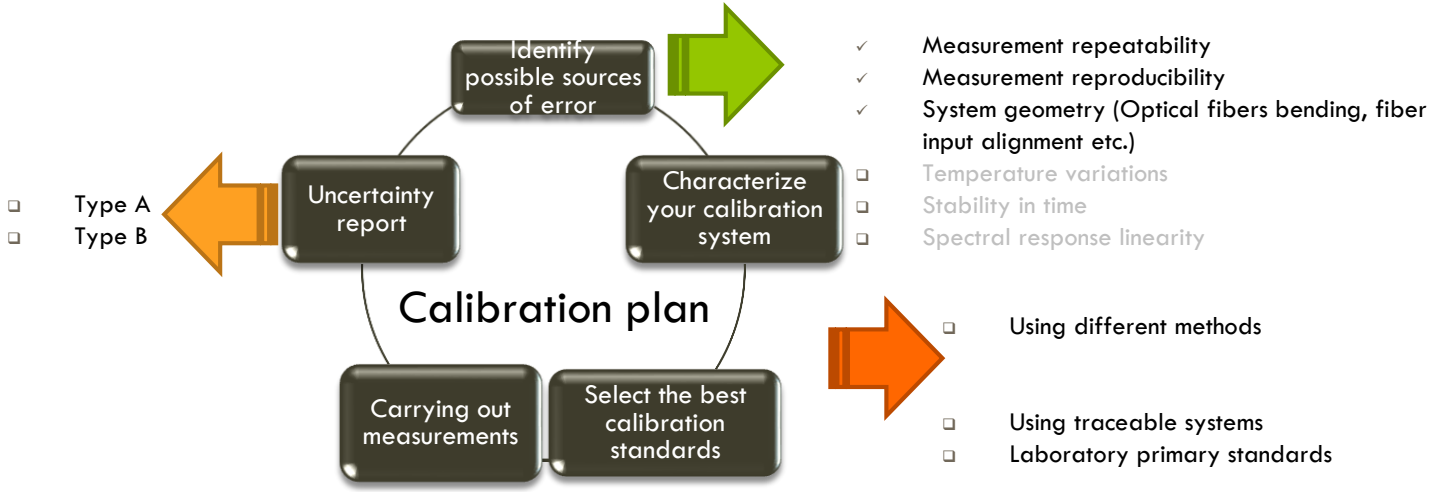
cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Results traceability



Laboratory based calibration process





- ✓ Measurement repeatability
- ✓ Measurement reproducibility
- ✓ System geometry (Optical fibers bending, fiber input alignment etc.)
- ❑ Temperature variations
- ❑ Stability in time
- ❑ Spectral response linearity

- ❑ Type A
- ❑ Type B

- ❑ Using different methods
- ❑ Using traceable systems
- ❑ Laboratory primary standards

Laboratory based spectral calibration

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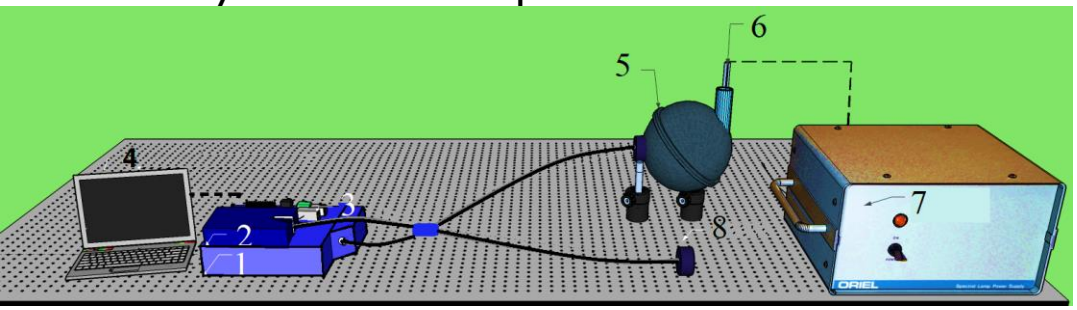
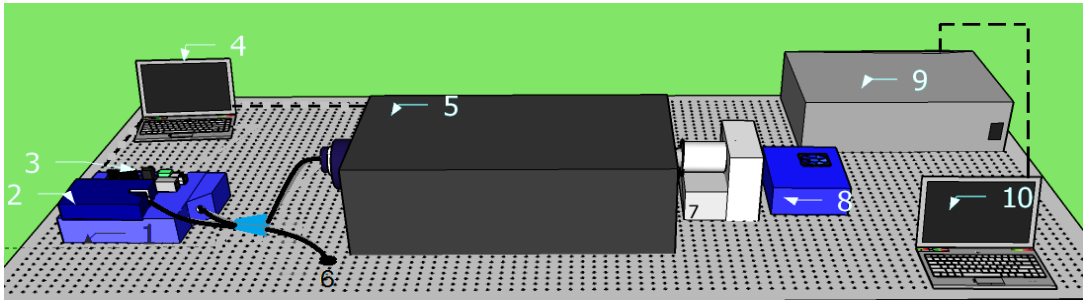
1.Pen-ray reference lamps

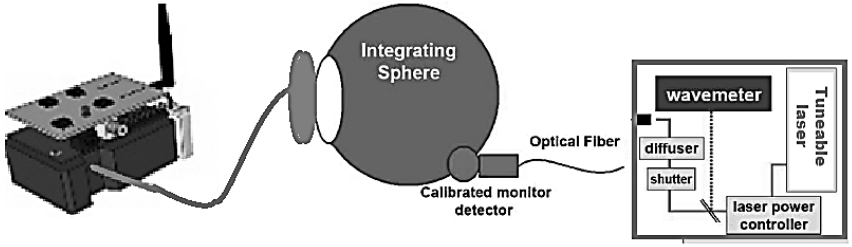


2.Double monochromator system



Mihai, L.; Mac Arthur, A.; Hueni, A.; Robinson, I.; Sporea, D. Optimized Spectrometers Characterization Procedure for Near Ground Support of ESA FLEX Observations: Part 1 Spectral Calibration and Characterisation. Remote Sens. ***2018****, 10, 289.*

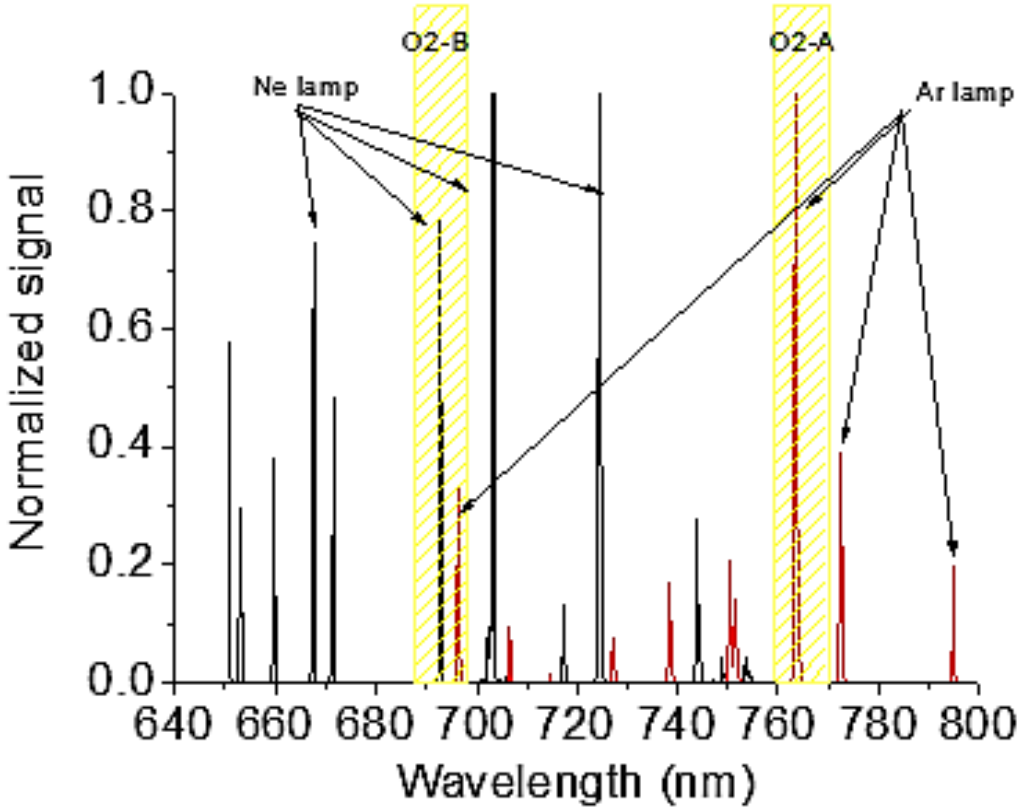
3.Tuneable laser source



Laboratory based spectral calibration

OPTIMISE

1.Pen-ray reference lamps



Ar				Ne			
λo	λref	λ error.	FWHM	λo	λref	λ error.	FWHM
nm	nm	nm	nm	nm	nm	nm	nm
696..431	696.543	0.112	0.293	653.080	653.290	0.210	0.388
706.639	706.722	0.082	0.366	667.637	667.830	0.193	0.301
727.252	727.294	0.042	0.439	671.522	671.700	0.178	0.290
738.368	738.398	0.030	0.435	692.825	692.950	**0.125**	0.504
750.374	750.387	0.013	0.429	724.479	724.520	0.041	0.379
763.511	**763.511**	**0.000**	**0.429**	-	-	-	-
772.4367	772.376	-0.061	0.422	-	-	-	-
794.851	794.818	-0.033	0.331	-	-	-	-

- Pen lamps have narrow emission lines
- Non-tuneable→ calibration using multiple line lamps (e.g. Ar, Ne) are needed!!!
- Optimization to only one wavelength → higher errors to the other wavelengths
- A total wavelength correction of **1.121** nm was applied for 687 nm.

Mihai, L.; Mac Arthur, A.; Hueni, A.; Robinson, I.; Sporea, D. Optimized Spectrometers Characterization Procedure for Near Ground Support of ESA FLEX Observations: Part 1 Spectral Calibration and Characterisation. Remote Sens. ***2018****, 10, 289.*

Laboratory based spectral calibration

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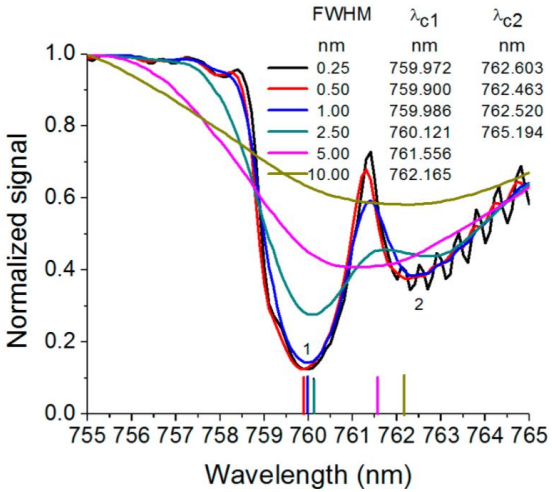
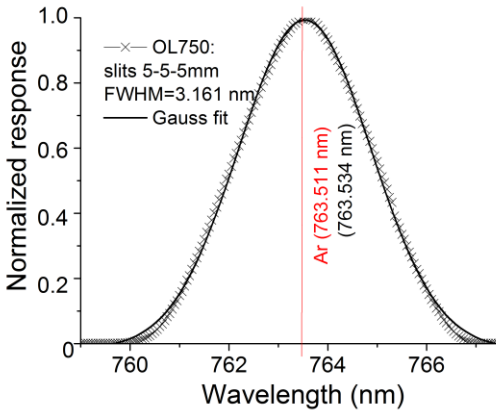
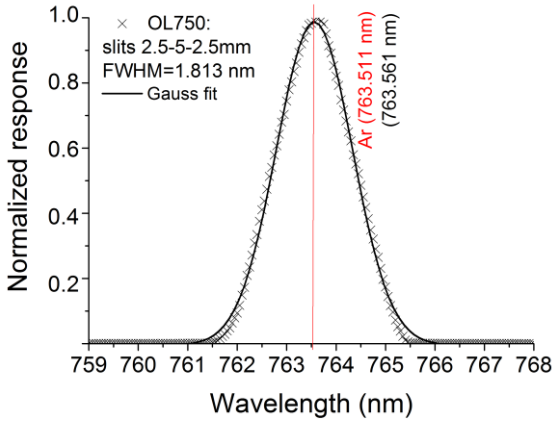
2. Double monochromator system

- Can be set for any wavelength between 200 and > 2500 nm, with a scanning step of min. 0.01 nm
- Standard calibration is done using pen-ray lamps

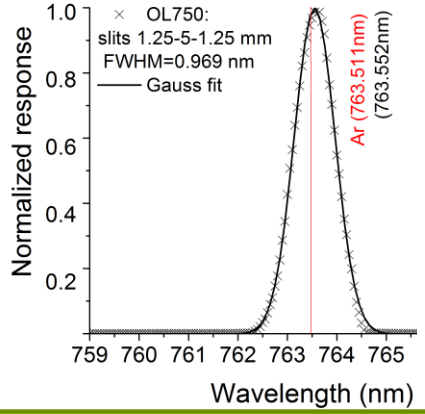


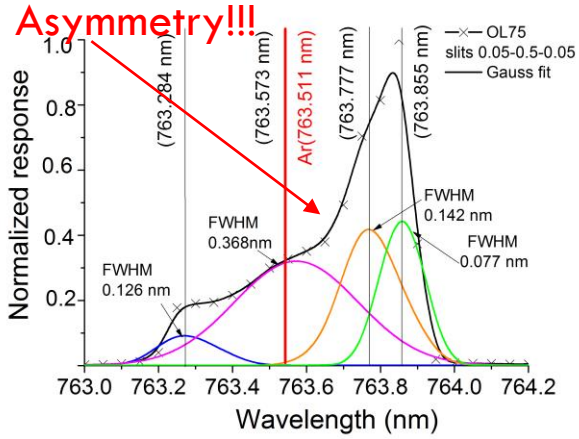
System characterization needed





- The wvl. corr. value (1.11nm) validated the pen ray lamp corr.
- Each component of the standard system should be characterized separately and calibrated → **time consuming…**





Laboratory based spectral calibration

- Has more intense signal→ can be used to obtain very narrow emission lines

- Can be tuned over a reduced spectral range
- The high spatial and temporal coherence of the laser sources → care has to be taken to avoid errors due to interference effects inside the device under test!!!

- We will consider in our future work

http://nvlpubs.nist.gov/nistpubs/hb/2015/NIST.HB.157.pdf

Laboratory based spectral calibration

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Other considerations:

- **Temperature variation effect** → wavelength shifts due to thermal expansion of optical and mechanical parts

  →recommended to wait for a thermal stabilization of the instruments according to the manufacturer recommendations and to use cooling system for the system

  (Hueni, A; Damm, A; Kneubühler, M; Schläpfer, D; Schaepman, M. E. Field and airborne spectroscopy cross validation—some considerations. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **2017**, 10(3):1117-1135)

  →Use compact spectrometer design and materials with low expansion coefficients → good reproducibility of wavelength measurements and provides a low wavelength shift
- **Optics for light coupling** → mismatch between the connecting optical fibre and the spectrometer input optics →wavelength shift or to the decrease in spectral data reproducibility.

  →the numerical aperture (NA) of the coupling optical fibre have to be larger than the NA of the instrument.

  → for spectrometers having entrance slits width less than 70 microns it is recommended to select an optical fibre core tree times larger than the slit width.

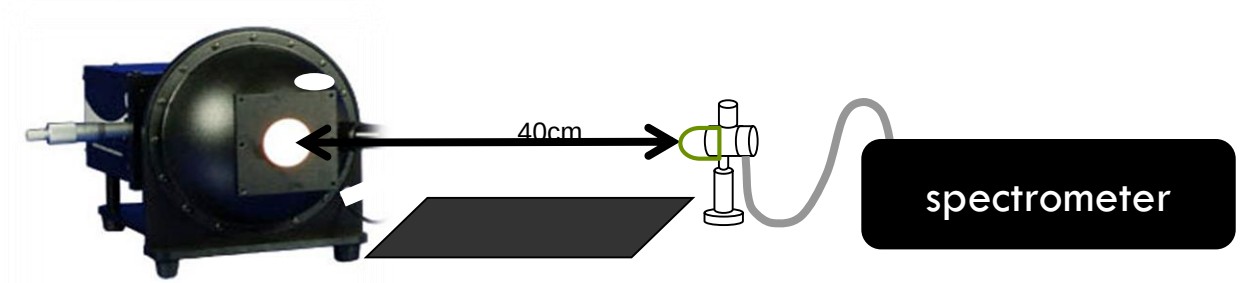
  (Mini-spectrometers, Hamamatsu, https://www.hamamatsu.com/resources/pdf/ssd/mini-spectrometer_kacc9003e.pdf, accessed January 31, 2018
  Avantes Catalog X, https://www.avantes.com/support/downloads/catalog/356-avantes-catalog-x/file, accessed January 31,2018)

Laboratory based radiometric calibration

1. Radiance calibration

Requirements:

- dark room, constant room temperature 22^0 C
- spherical integrating source radiance standard traceable to an international recognized metrology laboratory
- spectral radiance calibration file, precision photometer



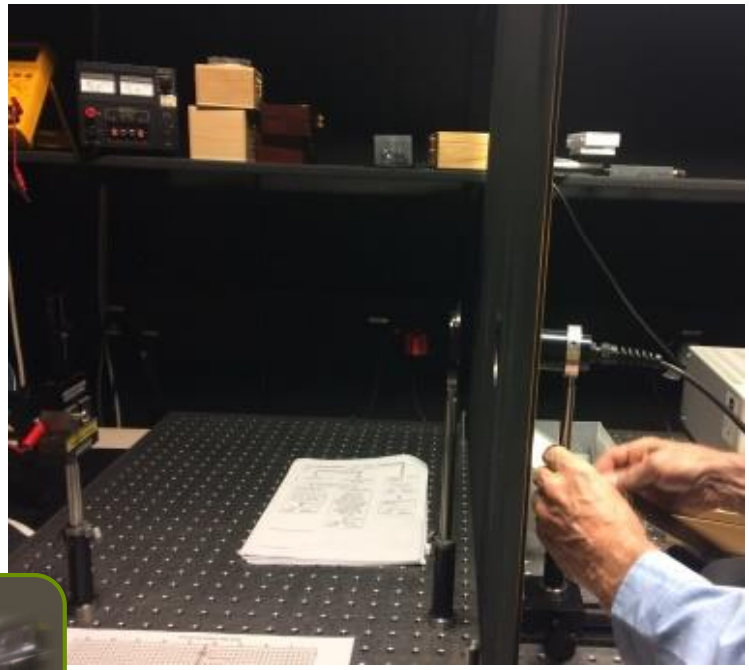
Considerations:

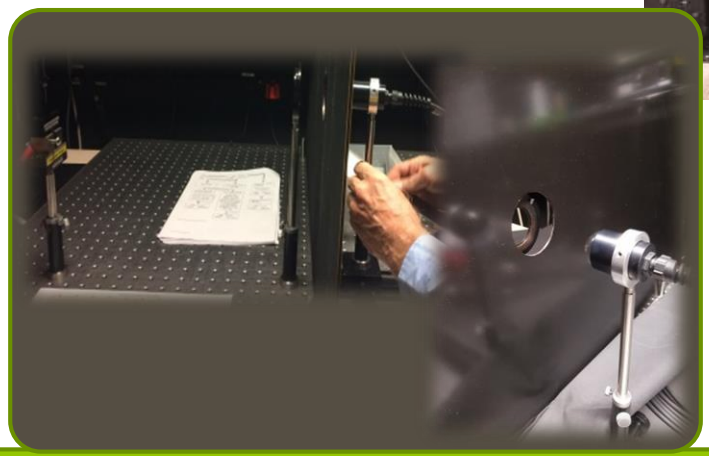
- Periodic checks of integrating sphere lamp signal (intensity and spectra)
- Signal linearity
- Optics alignment to the integrating sphere input port→ reproducible geometry for your calibration setup
- A larger number of tests reduce the measurement uncertainties from 0.0485±0.0185% (5 tests) to 0.0118±0.0022% (90 tests)

Laboratory based radiometric calibration

Requirements:

- dark room, constant room temperature 22^0 C
- FEL Lamp 1000W or tungsten/ halogen standard lamp traceable to an international recognized metrology laboratory
- spectral irradiance calibration file





Some conclusions

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- *to calculate the wavelength errors considering the difference between each standard line (NIST database) and the measured spectral lines → wavelength correction of ±3.2 nm, with an accuracy of ±0.3 nm or*

- *to optimise the wavelength correction close to O2-A and/or O2-B features, obtaining minimum error at specific wavelengths, but higher error outside this range →better option for high resolution spectrometers used for SIF studies.*
- *if the correction is optimised to only one wavelength in close to O2-A absorption line, an error of ±0.125 nm is obtained for the O2-B line → highly recommended to have wavelength correction around both telluric bands using an additional line lamp (Ne) to minimize the error.*

- *double monochromator could be used at any desired wavelength → uncertainty due to limited standard calibration has to be considered.*
- *better accuracy for a larger spectral range can be using a tuneable laser as a spectral standard…*

http://nvlpubs.nist.gov/nistpubs/hb/2015/NIST.HB.157.pdf

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Thank you for your attention!