Characterisation of nonlinearities of array spectroradiometers

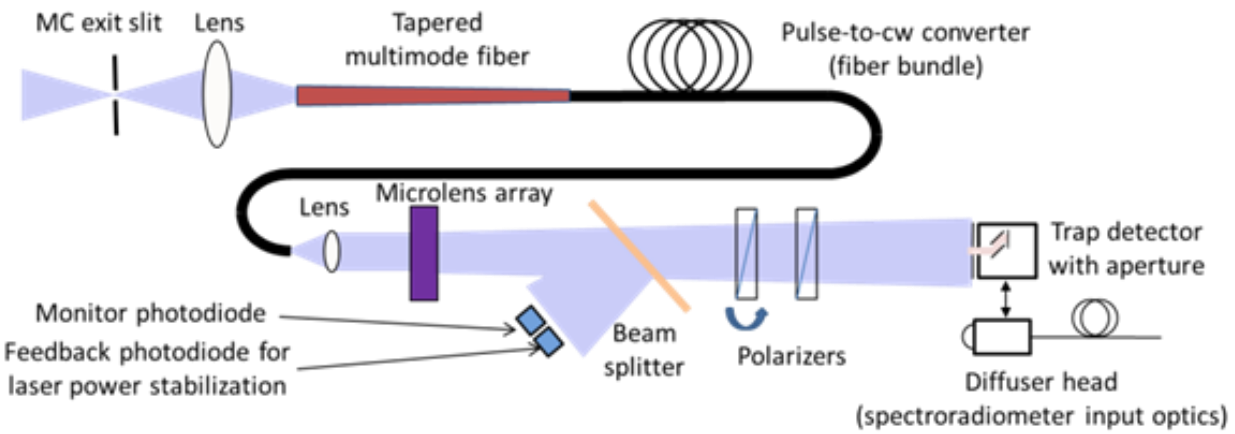
S. Nevas[1], P. Blattner[2], O. El Gawhary[3], T. Pulli[4], **P. Kärhä**[4], L. Egli[5], and J. Gröbner

1. PTB, 2. METAS, 3. VSL, 4. Aalto / MIKES, 5. PMOD/WRC

Overview

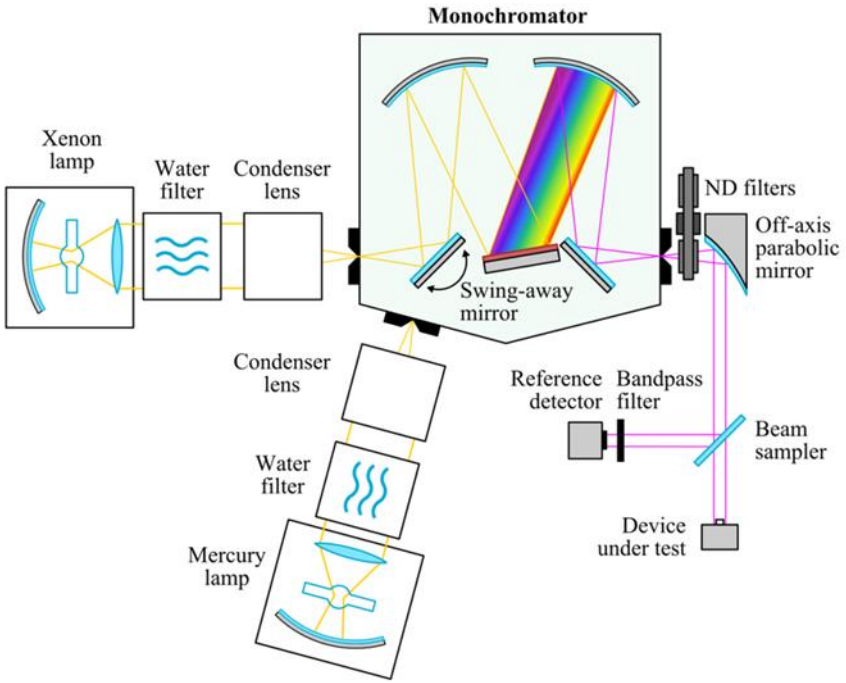
- Array spectroradiometers (spectrographs) are gaining popularity in Solar UV measurements
- Terrestrial solar UV irradiance varies over 5 to 6 orders of magnitude
- Spectrographs are known to be relatively nonlinear, so a linearity characterization is required
- Within the EMRP ENVo3 SolarUV project.
  - Measurement setups were developed at Aalto, METAS, PTB and VSL
    - Lasers / monochromators
    - Fixed wavelength / varied wavelength
    - Targeted irradiance levels 10^{-5} – 1 W m^{-2} nm^{-1}
  - Setups were compared by characterizing spectrographs
    - AvaSpec-ULS2048LTEC-USB2
    - Stellarnet Blue-Wave spectrometer

Setup at PTB (and METAS)



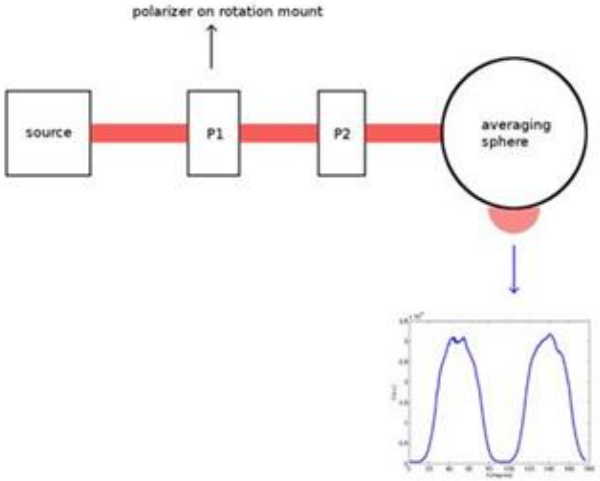
- Based on wavelength tuneable laser facility (TULIP)
- Frequency doubling and tripling of a mode-locked Ti:Sa fs-laser, wavelength tuneable within UV region
- A special fibre bundle as a pulse-to-cw converter
- Collimated beam, Variable filter for attenuating signal levels
- S1227 trap detector as linearity reference
- Corresponding setup also developed at METAS

Setup at Aalto



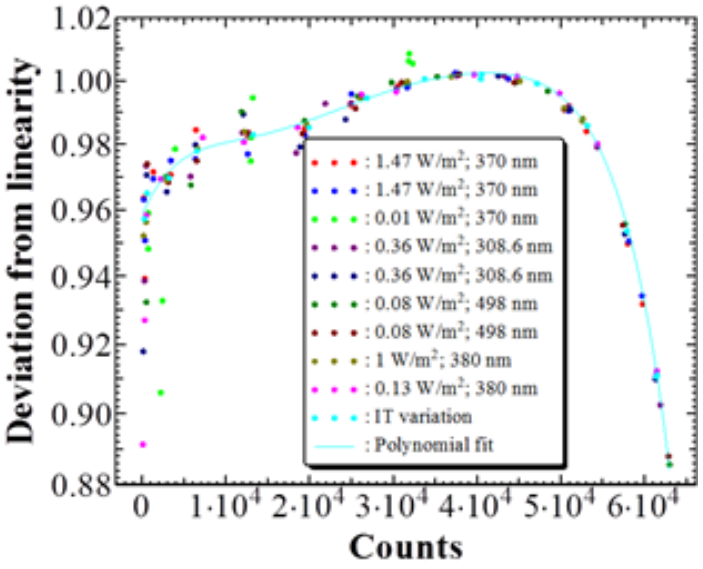
- Based on monochromator and lamps
  - 500-W Xe for spectral measurements
  - 1-kW Hg for high levels
- Collimated beam
- ND filter wheels for attenuation
- S1337 photodiode as linearity reference
- Simultaneous measurement of signal and reference

Setup at VSL



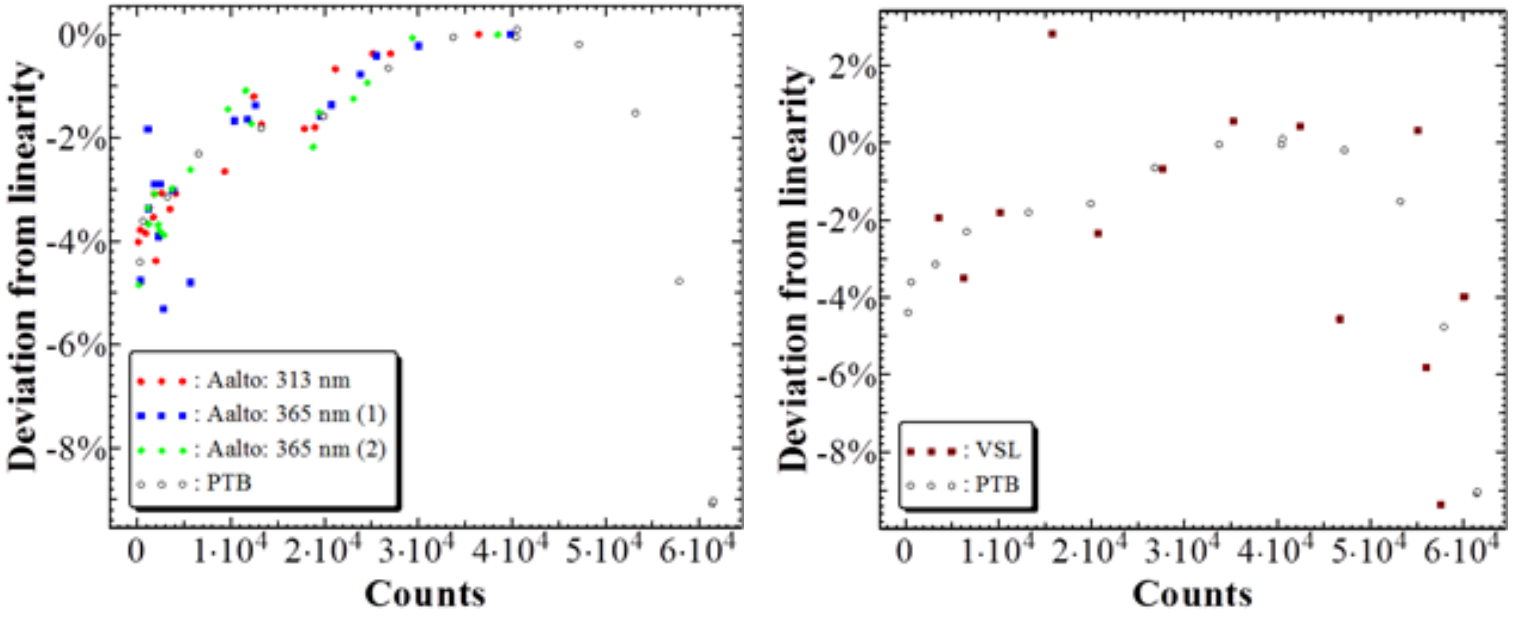
- Integrating sphere as output. Detectors and spectrographs mount to ports
- Attenuation obtained with two polarizers that can be rotated
- Powered with 372.7 nm UV laser
- Possibility to use other light sources, such as laser driven plasma light source (LDLS)
- Portable for field applications

AvaSpec results (PTB)



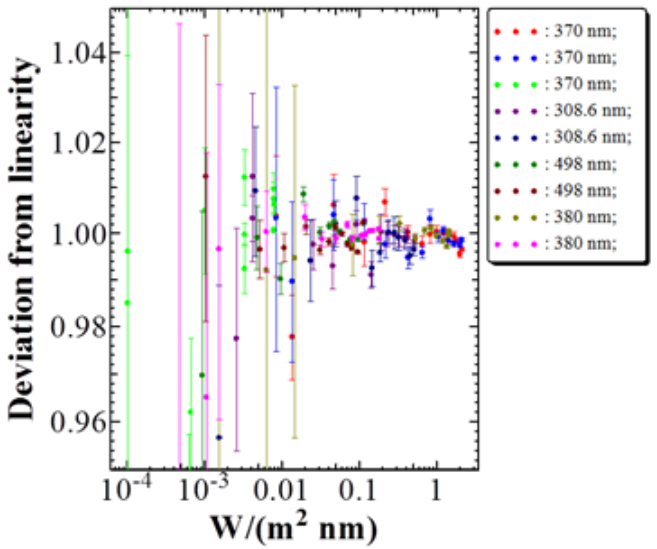
- PTB measurements with two methods:
  - 1. keeping the irradiance level fixed and varying the integration time,
  - 2. varying the irradiance level at fixed integration time.
  - Both methods gave similar results as a function of ADC counts.
- Results (Fig.) show significant nonlinearity that must (and can) be corrected
  - No wavelength dependence
  - Source most likely the electronics
- Setup works as expected

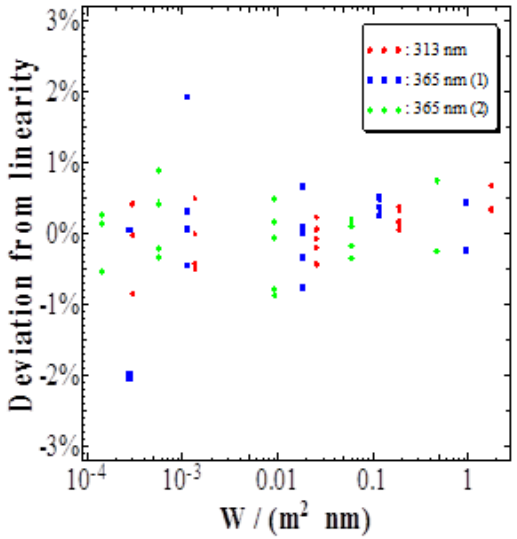
AvaSpec results (Aalto and VSL)



- Results very similar to PTB
- Setups work as expected, VSL device has somewhat high noise in results
- All methods agree with each other

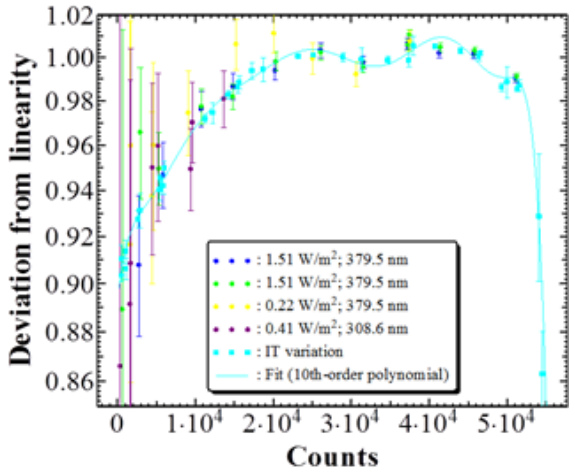
AvaSpec results (Spectral Irradiance)

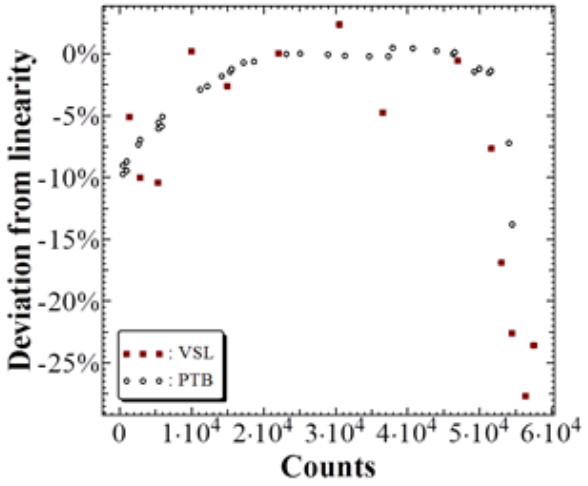




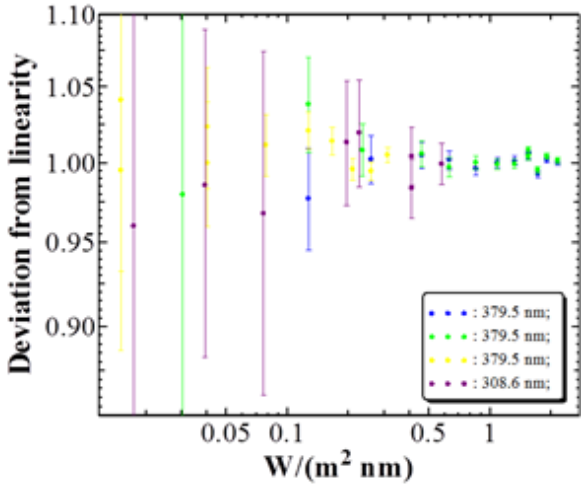
- Results of PTB (left) and Aalto (right) corrected mathematically for nonlinearity and converted to spectral irradiance
- Nonlinearity errors reduce to statistical noise only

Stellarnet Blue-Wave results (PTB, VSL)





- Similar results to the other spectrograph
- Significant non-linearity that can be corrected



Conclusion

- Two different array spectroradiometers were characterized to compare setups for the linearity characterizations at Aalto, PTB and VSL.
- The measurements in irradiance-variation mode could be carried out within a dynamic range from $1*10^{-4}$ – 2 W m^{-2} nm^{-1}. The lowest measurable irradiance was limited by the responsivity of the instruments.
- Results of the linearity measurements at the NMIs were in a good agreement. Also results obtained by irradiance variation were consistent with those collected by varying the integration time of the instruments.
- Both instruments showed noticeable nonlinearities that seemed to be caused by signal processing electronics (ADC) and could be corrected as a function of ADC counts.
- Having the correction applied, no additional nonlinearity for irradiances of up to 2 W m^{-2} nm^{-1} could be detected.