EMRP
European Metrology Research Programme
Programme of EURAMET

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Novel micromirror based diode array UV solar spectrometer

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pmod wrc

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PRINCIPAL OPTICS

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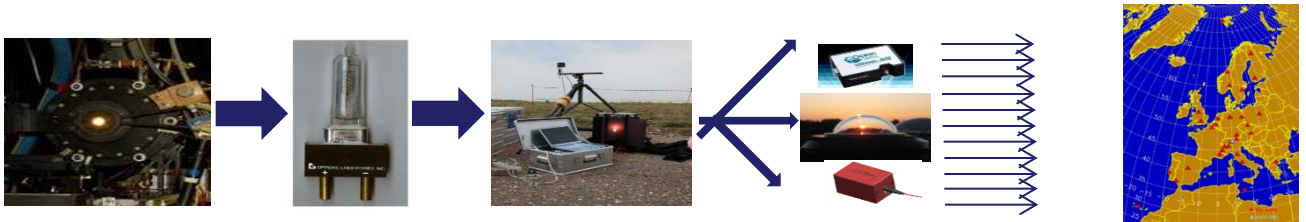
Uvnet Workshop, Davos, Switzerland, 15-16 July 2014

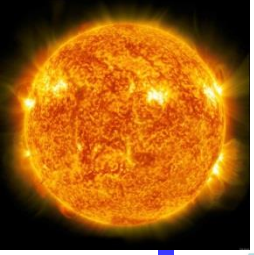
EMRP Joint Research Project **ENV03 Solar UV**



Primary Irradiance Standard | Transfer Standard | Reference Spectroradiometer | End-User Devices | Calibrated UV Network

This work is done within the EMRP Joint Research Project **ENV03 Solar UV** Work Package 4, Task 4.3:

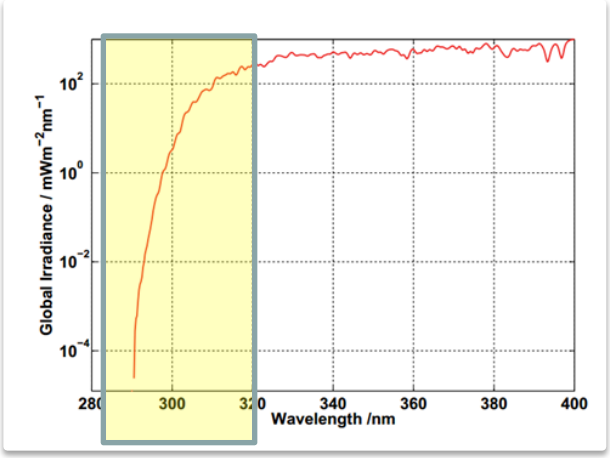
- Development of a UV array spectroradiometers with improved stray-light rejection.



Introduction

Solar spectrum

- 5 decades dynamic range in ~30 nm
- low irradiance below 300 nm

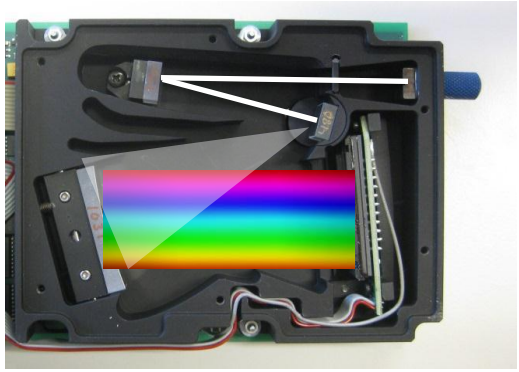


Measuring Terrestrial Solar UV (290 nm – 400 nm)

Scanning Double Grating monochromator

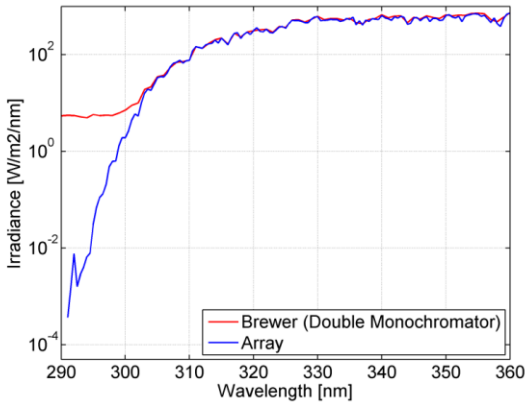
- Advantages
  - Traditional well established technology
  - Sufficient Wavelength accuracy ~0,1 nm
  - Stray-light reduction > 6 orders of magnitude
- Disadvantages
  - Scanning time ~ 20 minutes
  - High cost both for purchase and maintenance

DA Spectrometers



Pros:

- Instant acquisition of UV spectrum
- Cost effective for expanding global UV monitoring network



Cons:

- Straylight from other wavelengths with higher intensities
- Low dynamic range of diode array and inherent noise (~16 bit A/D)

IDEA

Wouldn’t it be possible to develop a sort of

„Double-grating array spectrometer“

where the role of second grating scanning monochormator is taken by Digital Light Processing Device (DLP), responsible for:

- Suppressing stray-light
- Extending dynamic range

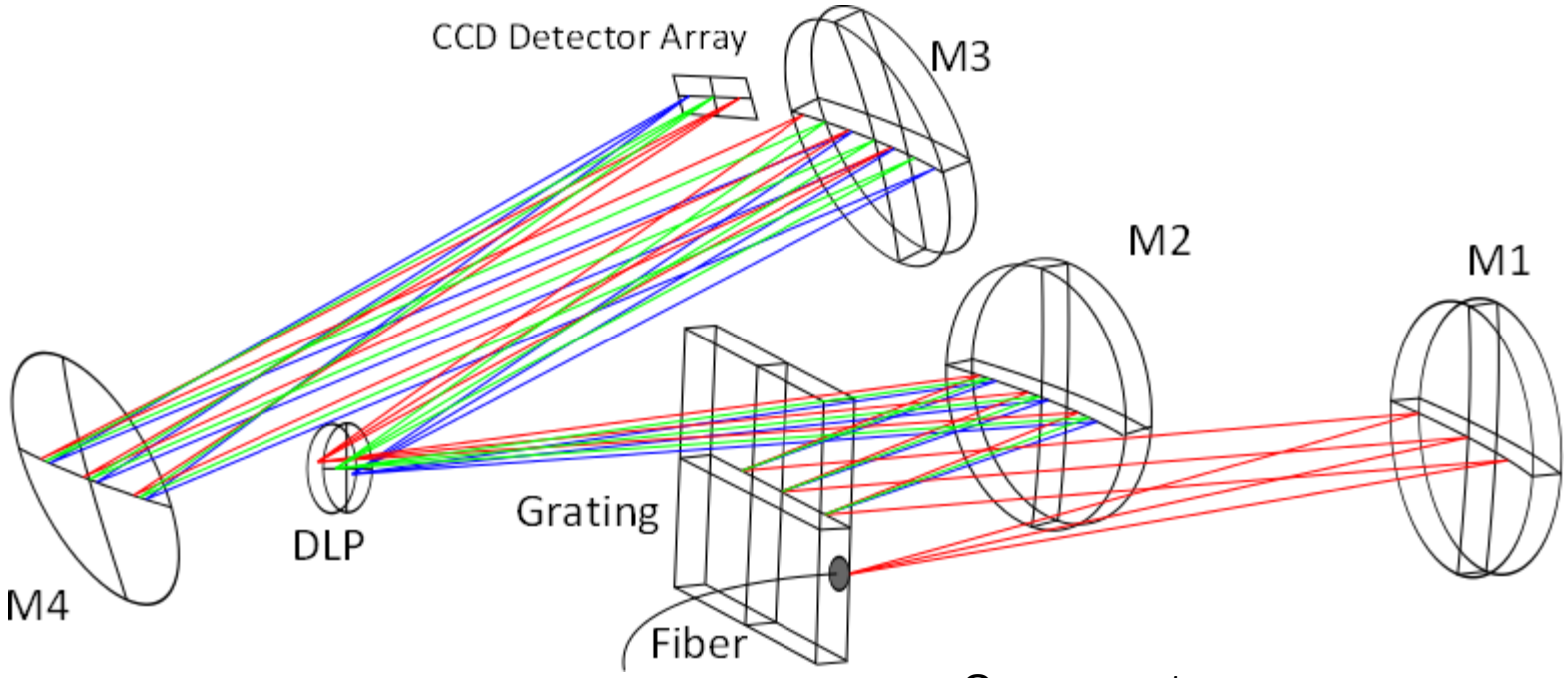
(µ-MUV)

IDEA

Criteria set for optical design:

- Compact optical set-up matching Optical grating, DLP and detector array to optimize fill-factor
- Utilizing off-the-shelf commercially available optical and mechanical elements to:
  - Simplify the prototyping
  - Keep the process cost efficient
- To maximize the optical throughput

µ-MUV 1st prototype design

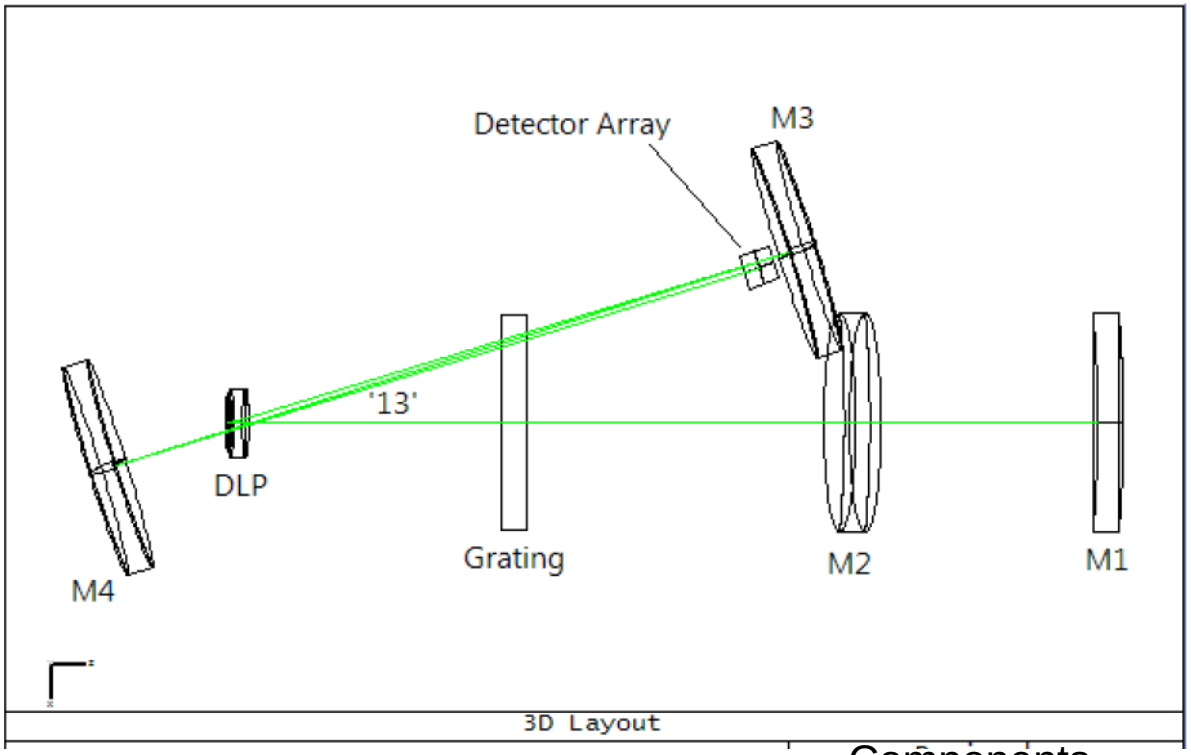


Components

- 100 µm core optical fiber
- 4 spherical mirrors (M1-M4)
- 600 G/mm diffraction grating
- 1024 x 720 pixel XGA DLP
- 2048 x 250 pixel CCD detector array

Burnitt T 2012 Optical Layout for Prototype DLP Spectrometer Tech. rep. Principle Optics

µ-MUV 1st prototype design - side view



Components

- 100 µm core optical fiber
- 4 spherical mirrors (M1-M4)
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- 1024 x 720 pixel XGA DLP
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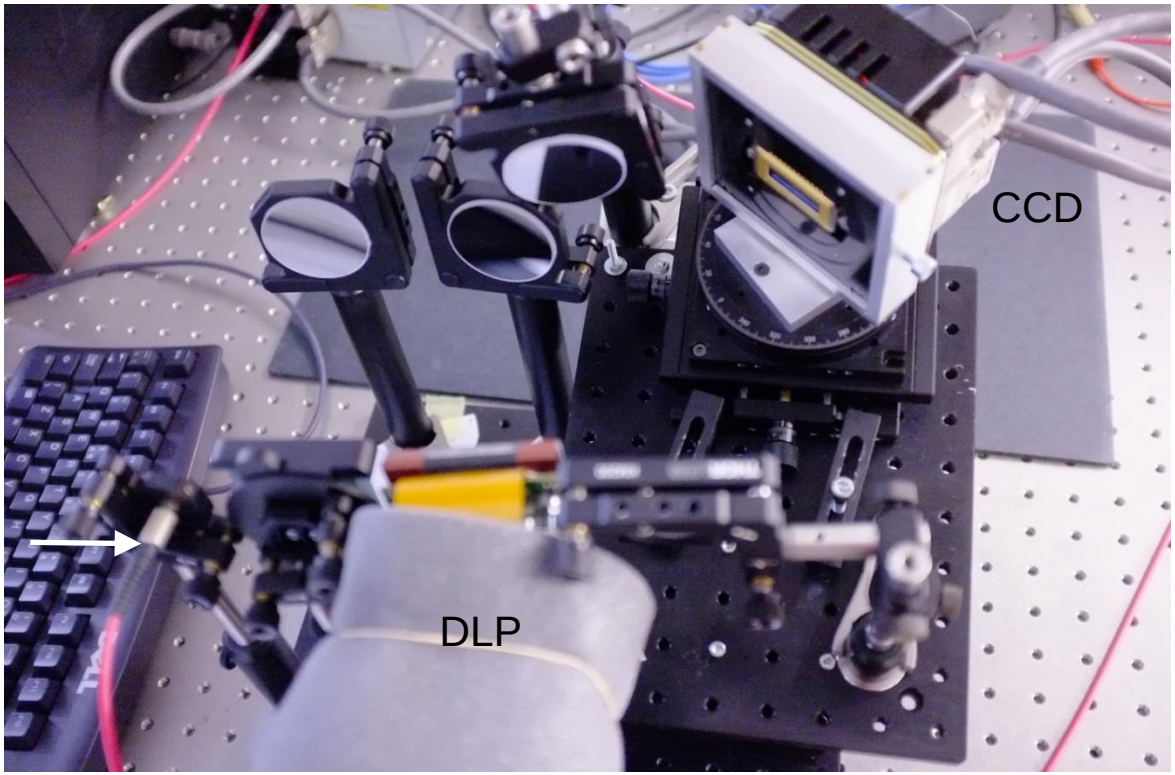
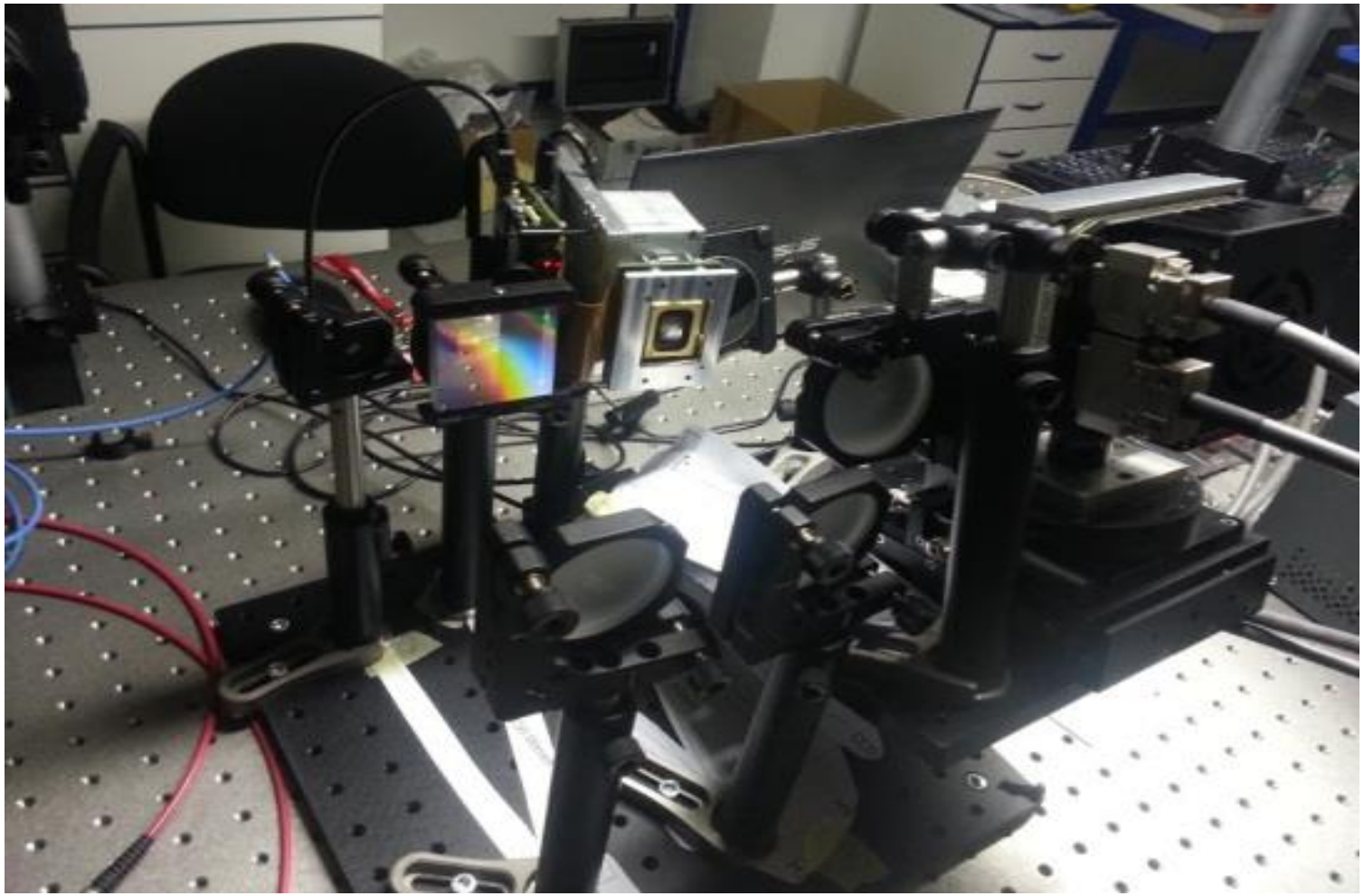
µ-MUV 1st prototype construction

200 µm core optical fiber



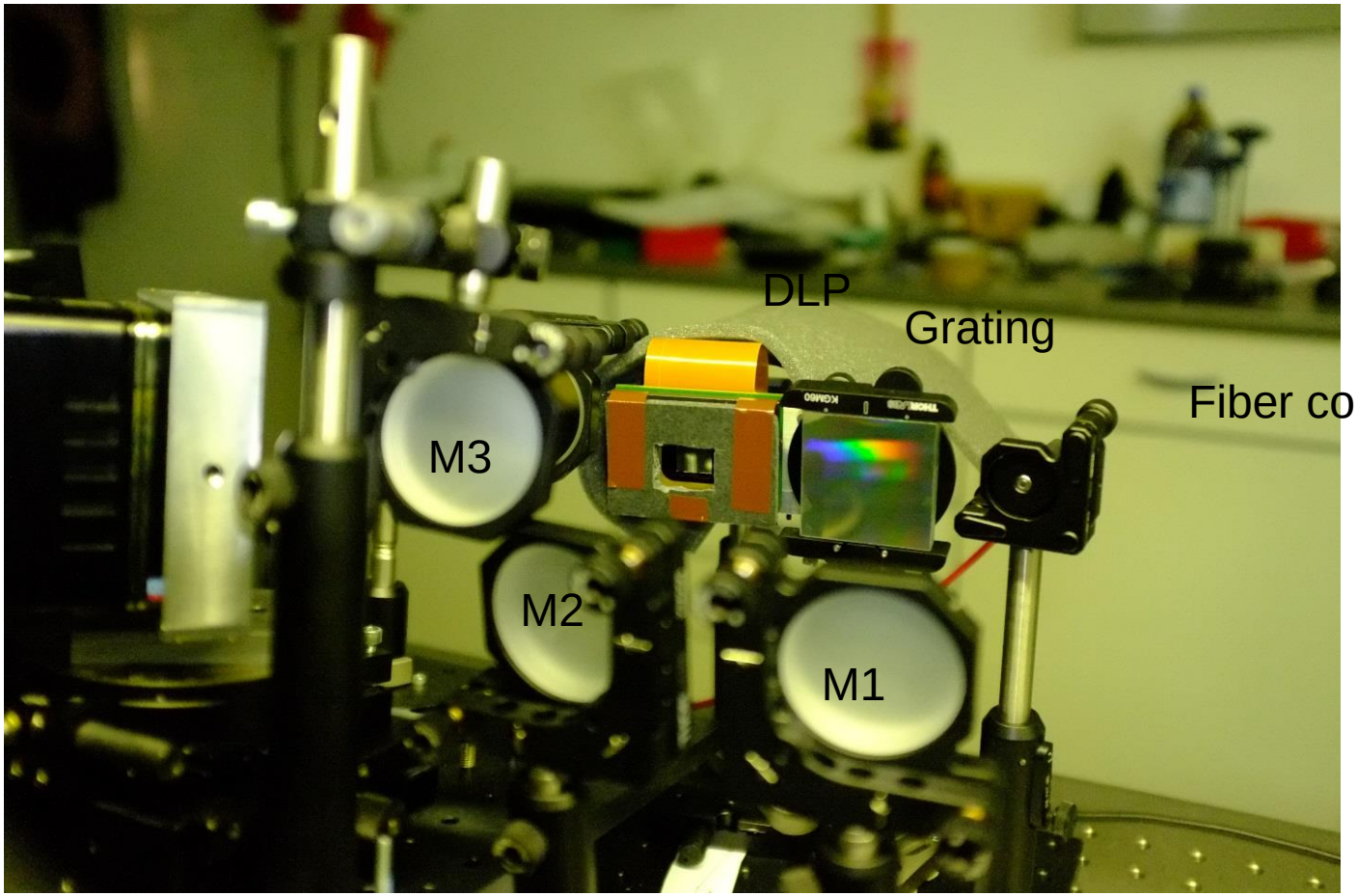
2nd Plane achieved by mounting small breadboard to goniometer

µ-MUV 1st prototype construction

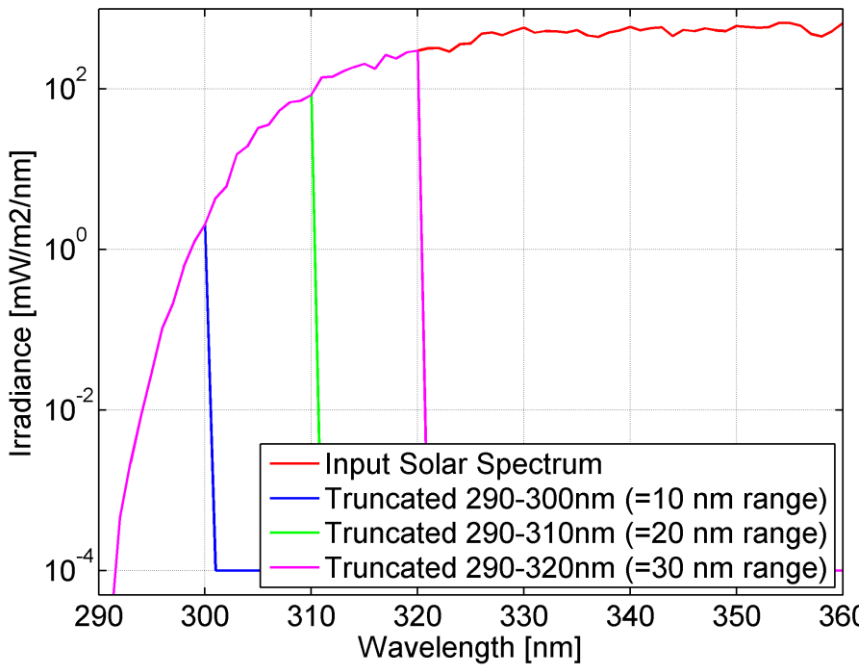


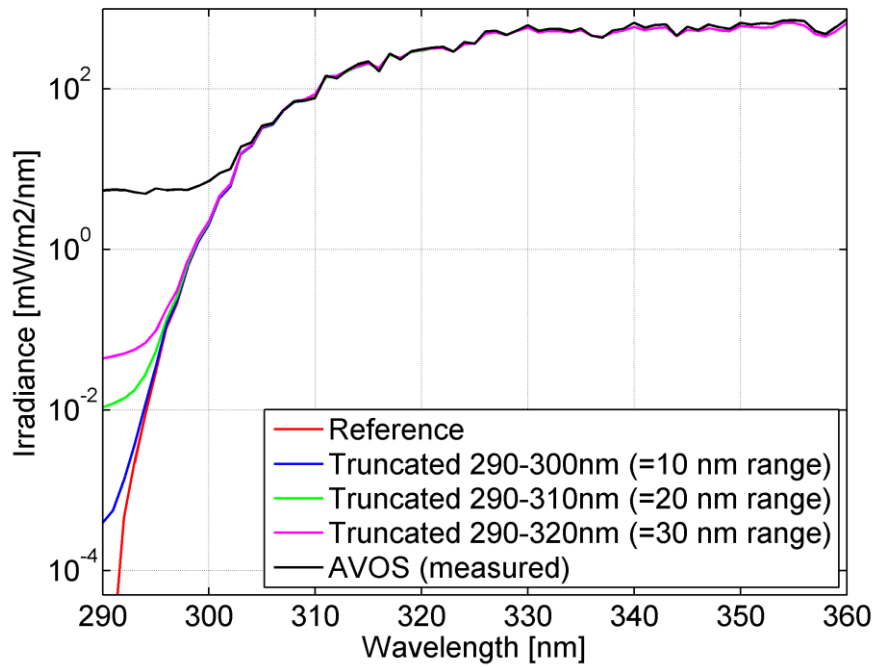
µ-MUV 1st prototype construction

CCD Housing



Spectral Range Selection

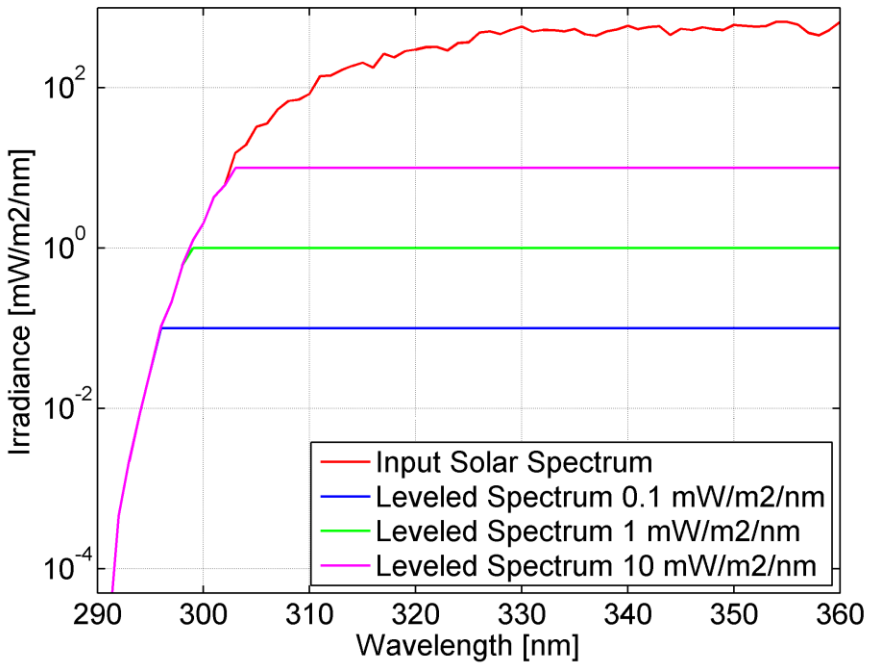


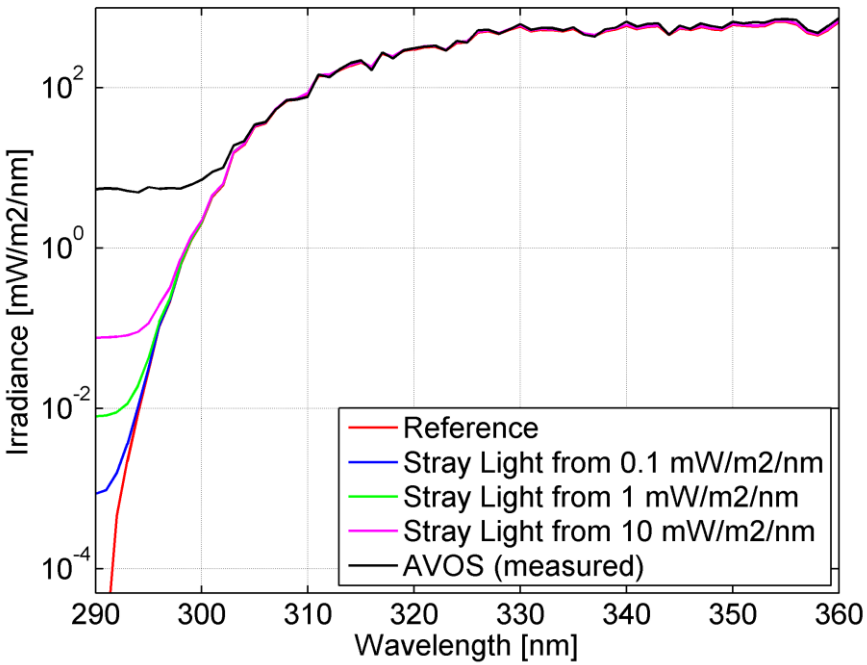


Egli L, Grobner J, Smid M, Porrovecchio G, Burnitt T, Nield K M, Gibson S, Dubard J, Nevas S, and Tormen M 2013 New technologies to reduce stray light for measuring solar UV with array spectroradiometers AIP Conference Proceedings vol 825

Rice J and Neira J 2009 DMD diffraction measurements to support design of projectors for test and evaluation of multispectral and hyperspectral imaging sensors *Proc. SPIE* **7210**

Level the Dynamic Range via DLP Modulation





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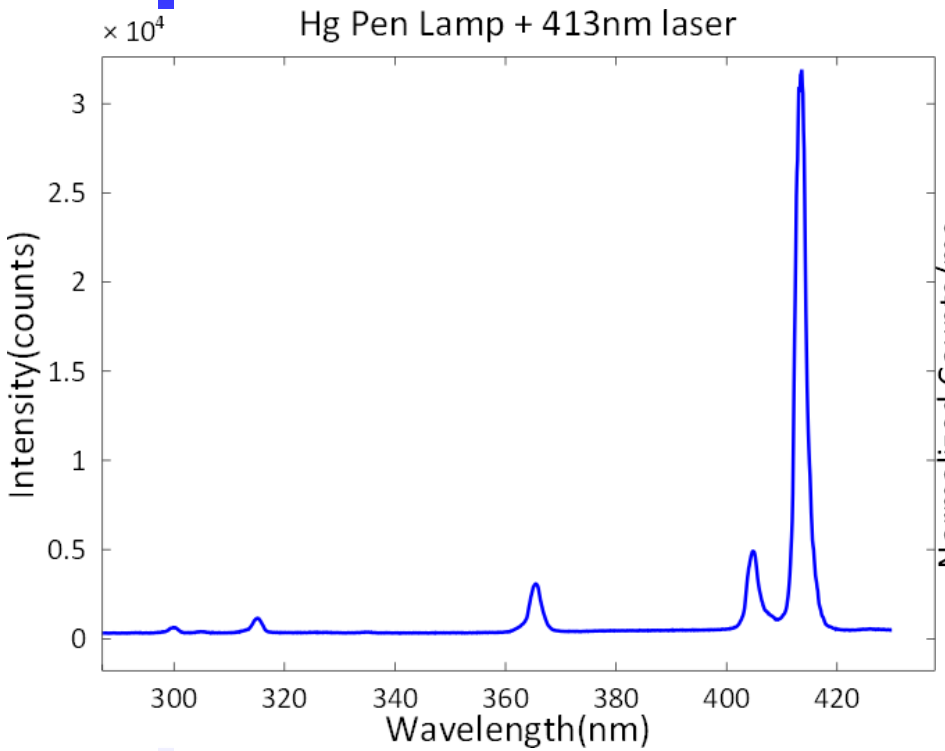
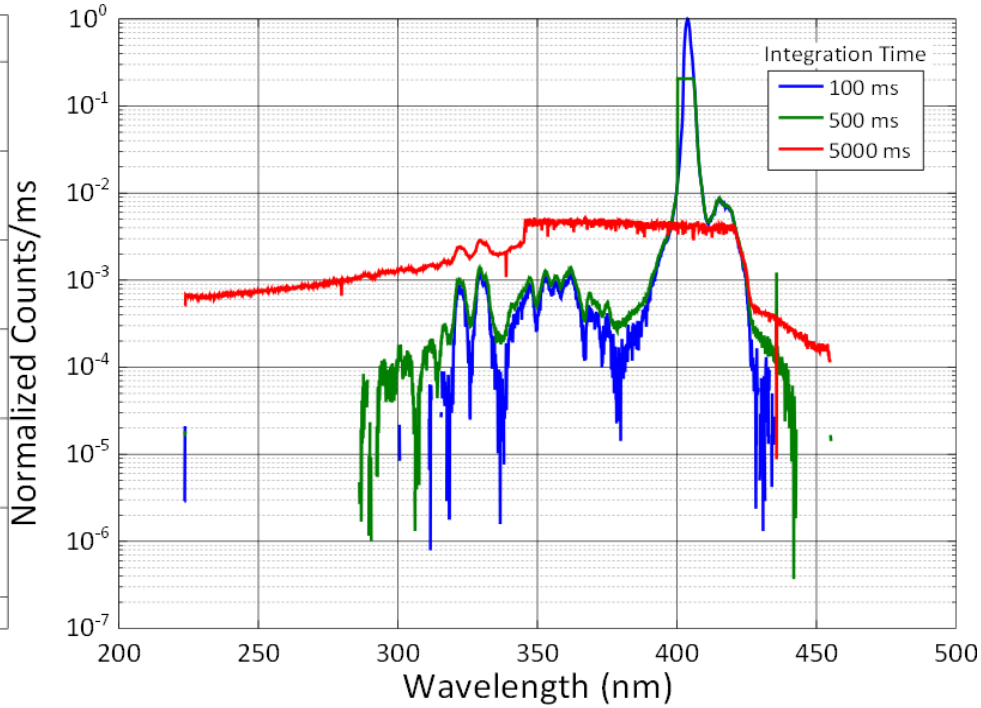
Spectral Range, Spectral Resolution, & Bandwidth





<u>Spectroradiometer Device Parameters</u>

Spectral Range: 270 nm to 425 nm

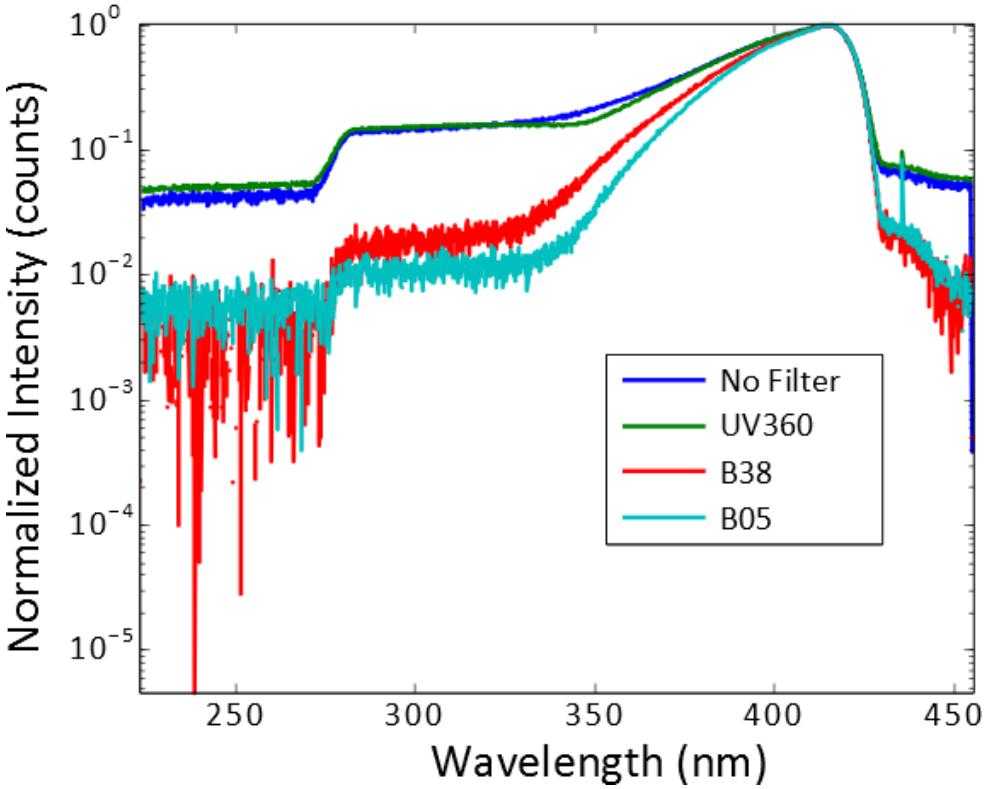
Spectral Resolution: 0.2 nm per pixel

Bandwidth: 2.5 nm

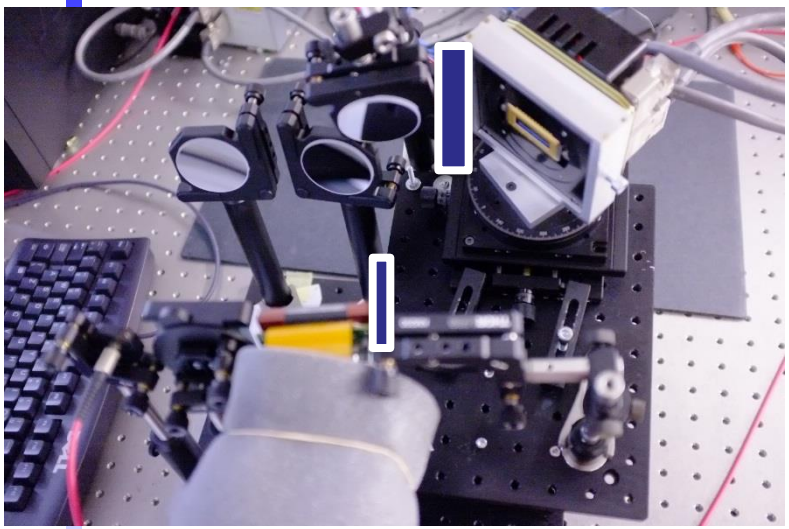
Filtering

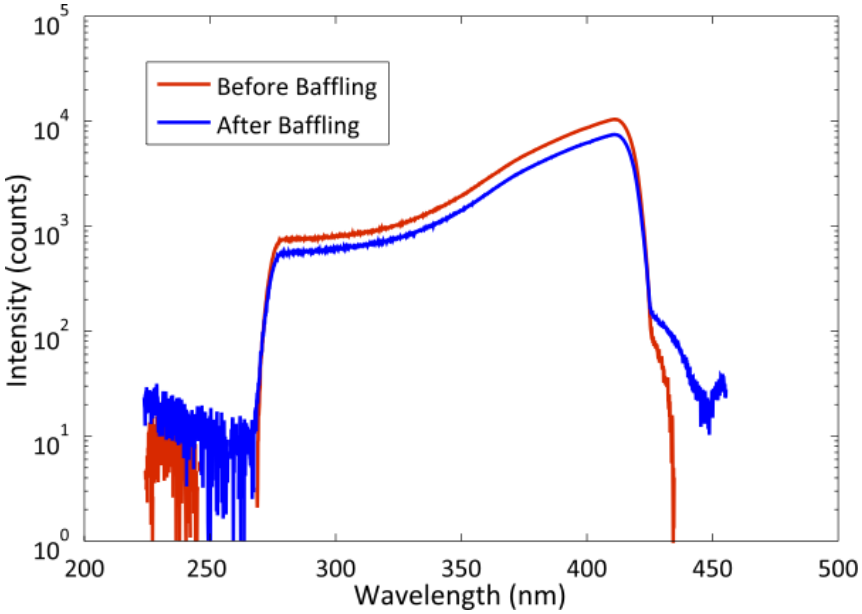
Schott glass filters placed in front of detector

UV360: High-pass filter> 260 nm
B38: Bandpass 320 nm – 700 nm
B05: Bandpass 340 nm – 540 nm



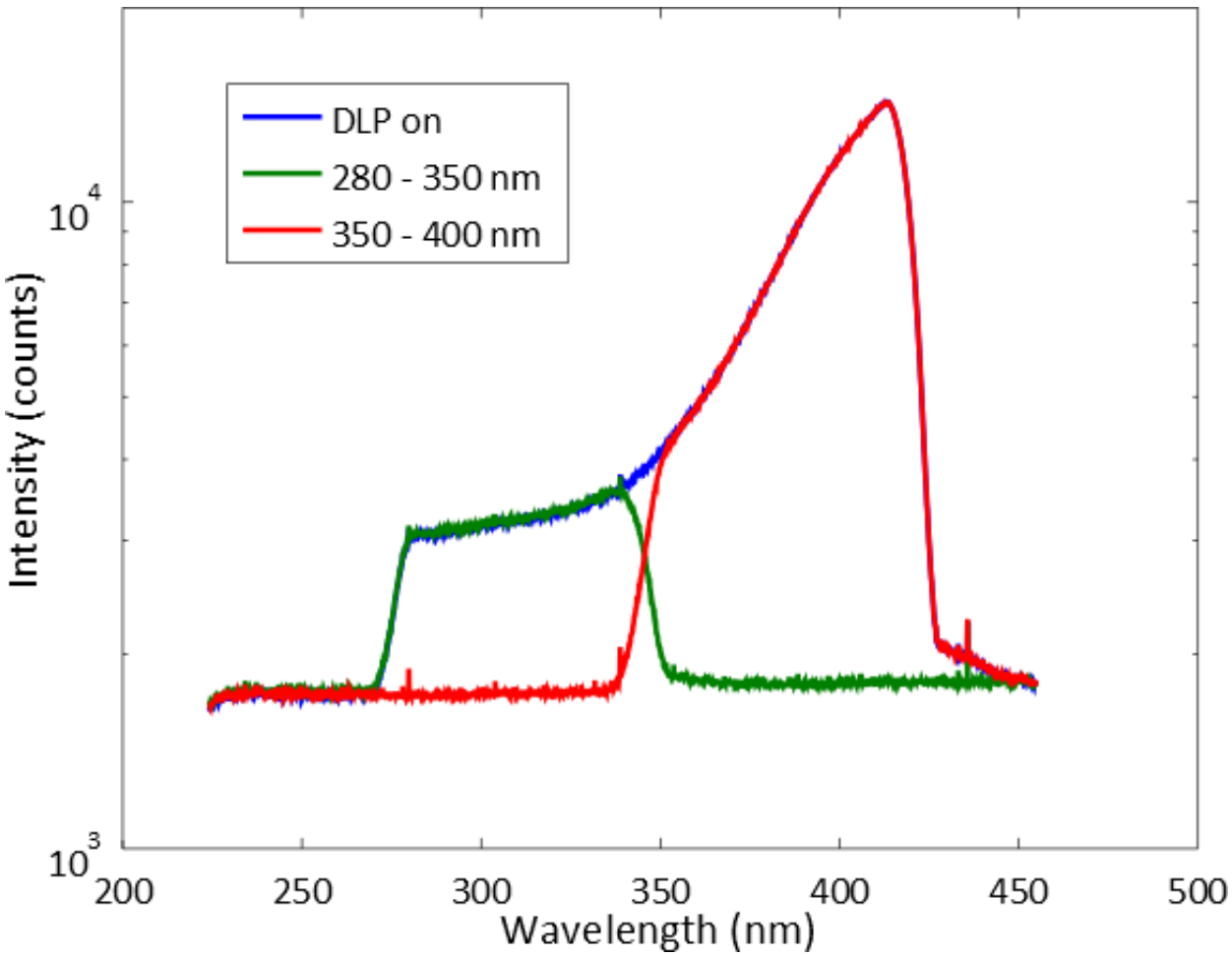
Baffling Attempts





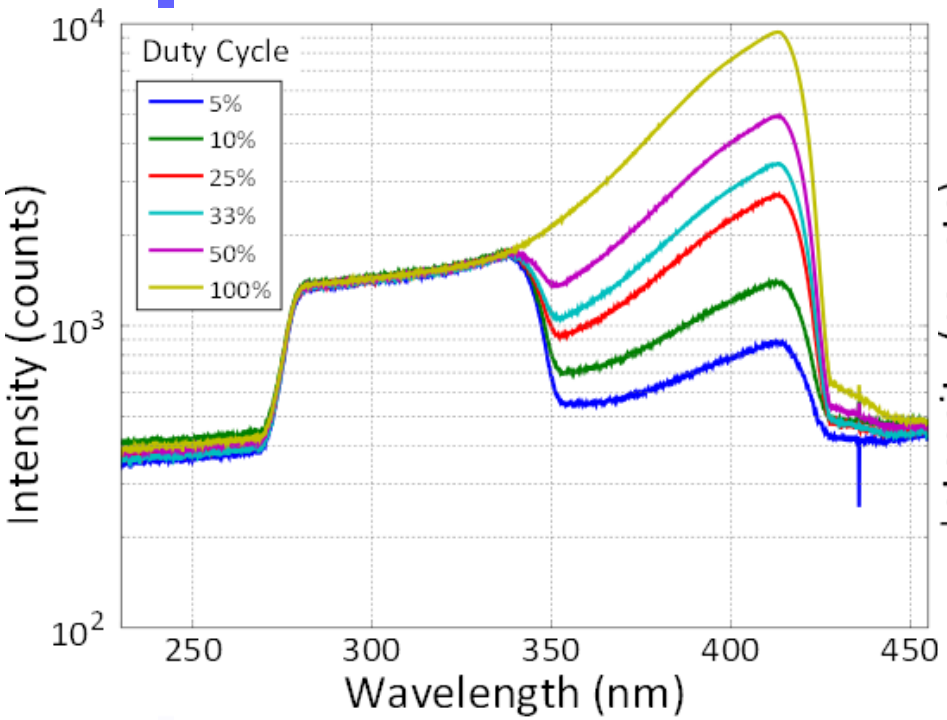
Approximately 30% broadband improvement

Spectral Range selection

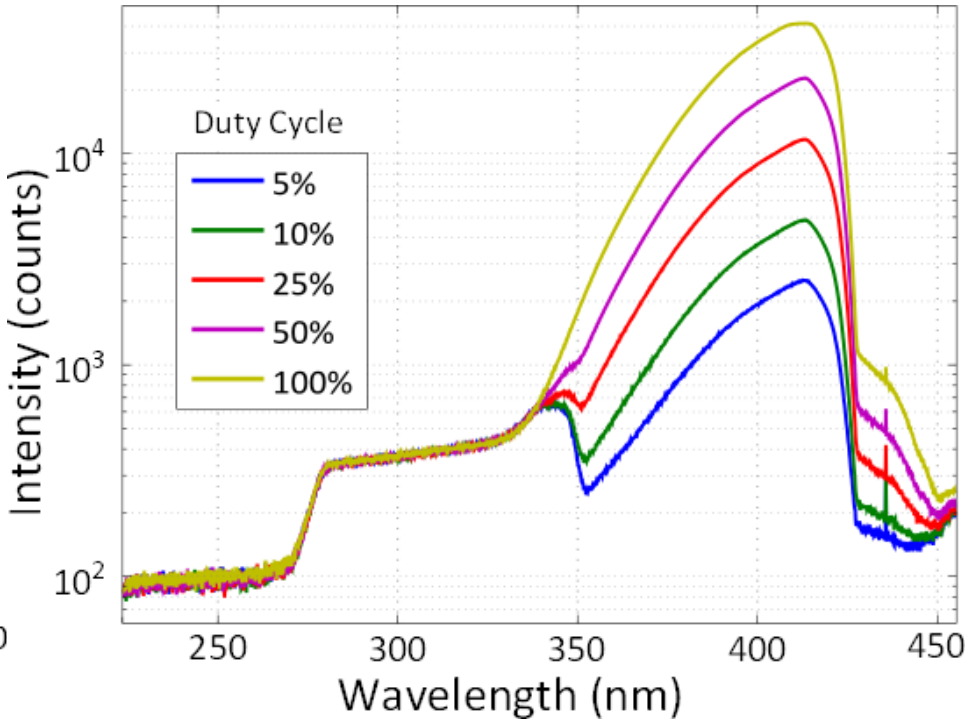


White Light modulation

DLP Modulation



Modulation with B05 Filter



Conclusions & Future Work

- µ-MUV Prototype constructed from off-the-shelf components based on Zemax modeling
- Basic device parameters measured:
  - Spectral Range: 270 nm to 425 nm
  - Spectral Resolution: 0.2 nm per pixel
  - Bandwidth: 2.5 nm
- Stray light reduction techniques verified: Spectral range selection and Modulation
- In comparison to commercially available spectrometers, no notable advantage, but is capable of active stray light reduction.
- **Future Work**
- New light tight enclosure
- New optical bench including light traps?
- Optimizing the DLP window
- Actively cooled CCD chip on order
  - increase sensitivity
  - reduce dark currents
- Better DLP programming with spectral feedback
- **=> 2nd prototype**

Texas Instruments DLP NIRscan spectrometer – 3/3/14

- 1350nm to 2450nm wavelength range
- ≥30,000:1 signal to noise ratio (typical)