Novel micromirror based diode array UV solar spectrometer

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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
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)
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
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)
- 600 G/mm diffraction grating
- 1024 x 720 pixel XGA DLP
- 2048 x 250 pixel CCD detector array
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

DLP
Grating
Fiber coupler
Spectral Range Selection


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


2013 New technologies to reduce stray light for measuring solar UV with array spectroradiometers AIP Conference Proceedings vol 825
Spectral Range, Spectral Resolution, & Bandwidth

Spectroradiometer Device Parameters
Spectral Range: 270 nm to 425 nm
Spectral Resolution: 0.2 nm per pixel
Bandwidth: 2.5 nm

Hg Pen Lamp + 413nm laser

Normalized Counts/ns

Integration Time
100 ms
500 ms
5000 ms

Integrating Time

Wavelength (nm)

Wavelength (nm)
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

![Graph showing spectral analysis](image)

- DLP on
- 280 - 350 nm
- 350 - 400 nm

Intensity (counts)

Wavelength (nm)

10^3

10^4

200

250

300

350

400

450

500

Uvnet Workshop, Davos, Switzerland, 15-16 July 2014
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
- $\geq 30,000:1$ signal to noise ratio (typical)