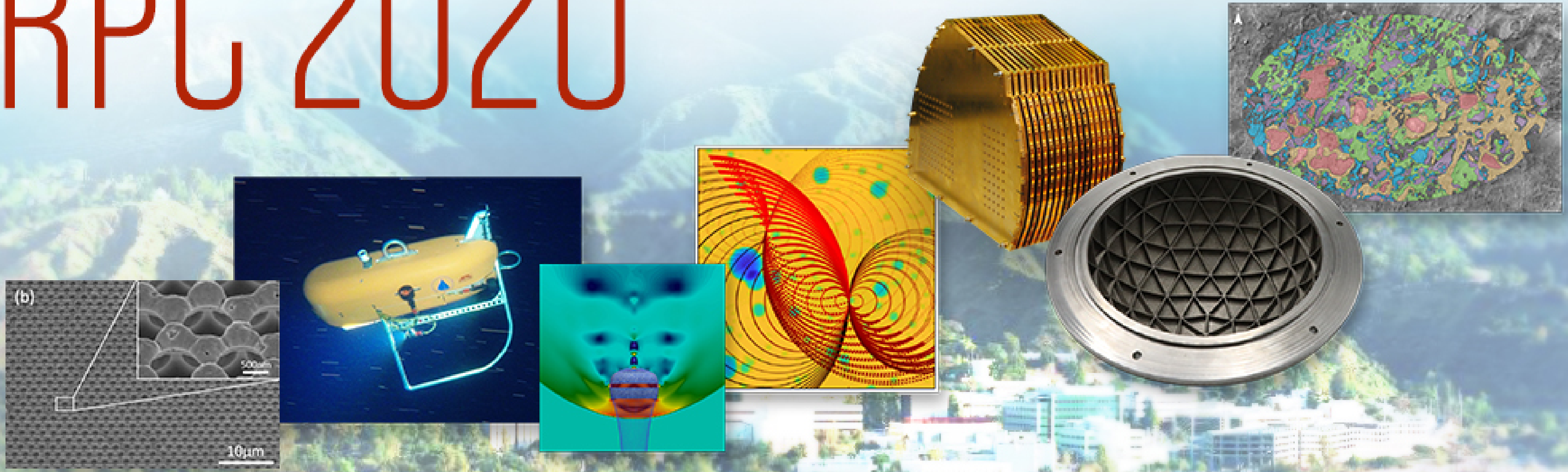
RPC 2020



Virtual Research Presentation Conference

Real-Time Reconfigurable Full-Frame / Hyperspectral Imager

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Program: R&TD Topic Area

Assigned Presentation RPC-228

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

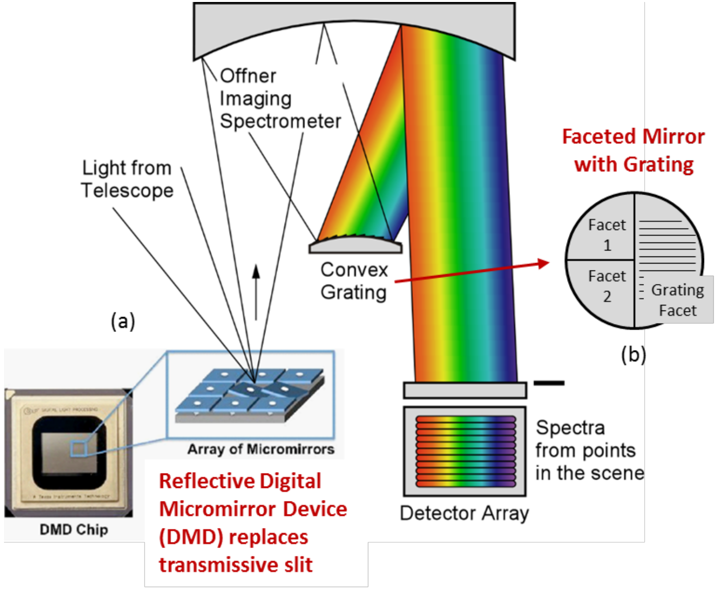
Our objective is to develop a compact instrument capable of switching between full-frame imaging and hyperspectral imaging of selected points within a scene.

This capability will be enabled by combining:

1. JPL's techniques for electron-beam fabrication of diffraction gratings for Offner spectrometers
2. A programmable digital micromirror device (DMD) to rapidly select and reconfigure points of interest

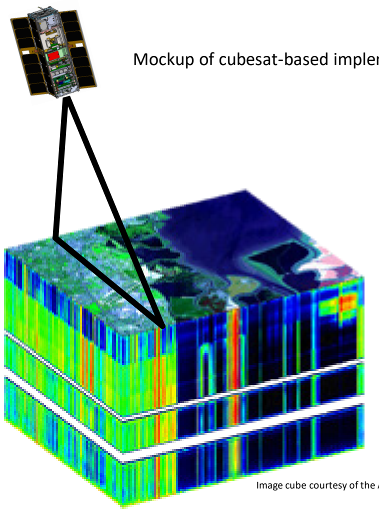
This goal is not new—a number of other groups have used DMDs in a variety of spectral imaging configurations, including use as the input point/object selector in the manner in which we are proposing.

However, to the best of our knowledge, **our implementation is novel and leverages unique JPL capabilities that will enable this type of system to be realized in a compact form.**



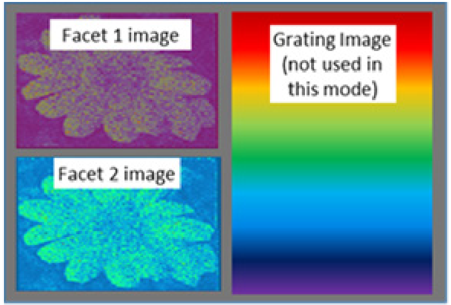
Problem Description

- Recent years have seen the development of a variety of new small science gathering platforms: airborne drones and unmanned aerial vehicles, and spaceborne cubesats and smallsats
- While they have the potential to host traditional imaging and spectroscopic instruments, they are often not as stable or flexible as traditional aircraft or spacecraft
- Goal: develop a rapidly-reconfigurable and two-in-one full-frame/hyperspectral system
- Enable new opportunities for in-situ and remote sensing of visible and short-wave infrared (VSWIR) sources
    - Vegetation productivity
    - Mineral composition
    - Anthropogenic activity such as pollution or wildfires

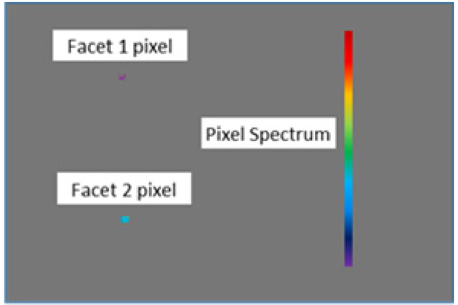


Mockup of cubesat-based implementation

Image cube courtesy of the AVIRIS program at NASA/JPL



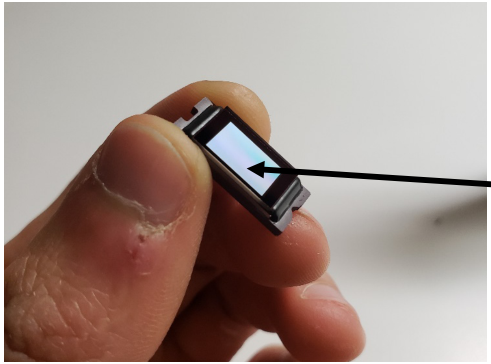
Multi-Band Mode FPA Image (more or fewer images possible)

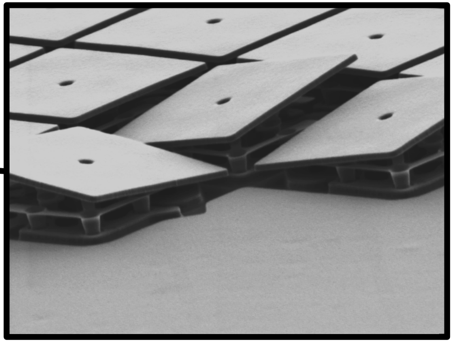


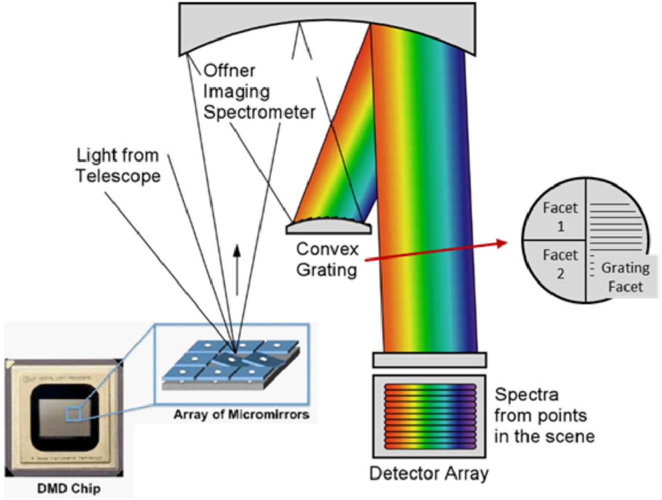
Hyperspectral Mode FPA Image (pixel or horizontal array of pixels)

Methodology

- Array of independently-controlled microscale mirrors
- Replaces the role of the slit in a traditional imaging spectrometer
- Our implementation places the DMD at the slit plane, allowing imaging mode switching, rapid measurement of single points of interest, variable slit sizes, and pushbroom scanning







New imaging-spectrometer implementation improves flexibility

Methodology

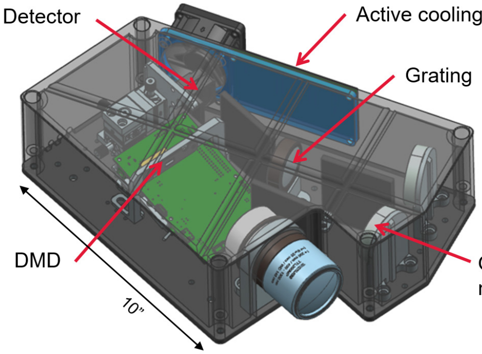
a) Utilized Zemax to design and optimize an Offner spectrometer, primary lens designs, and investigate DMD-tilted image planes

b) Completed assembly and alignment of a new, compact spectrometer design that reduced size 6x and weight 10x over existing benchtop setup

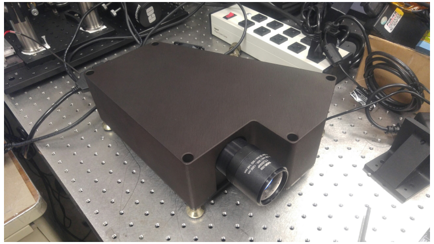
c) Programmed a custom software for real-time operation in full-frame and hyperspectral modes

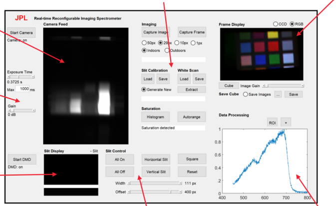
d) Began instrument calibration using spectral and spatial targets, and laboratory and outdoor measurements and

e) Began procurement of custom optics and faceted grating substrate for all-reflective, NIR design



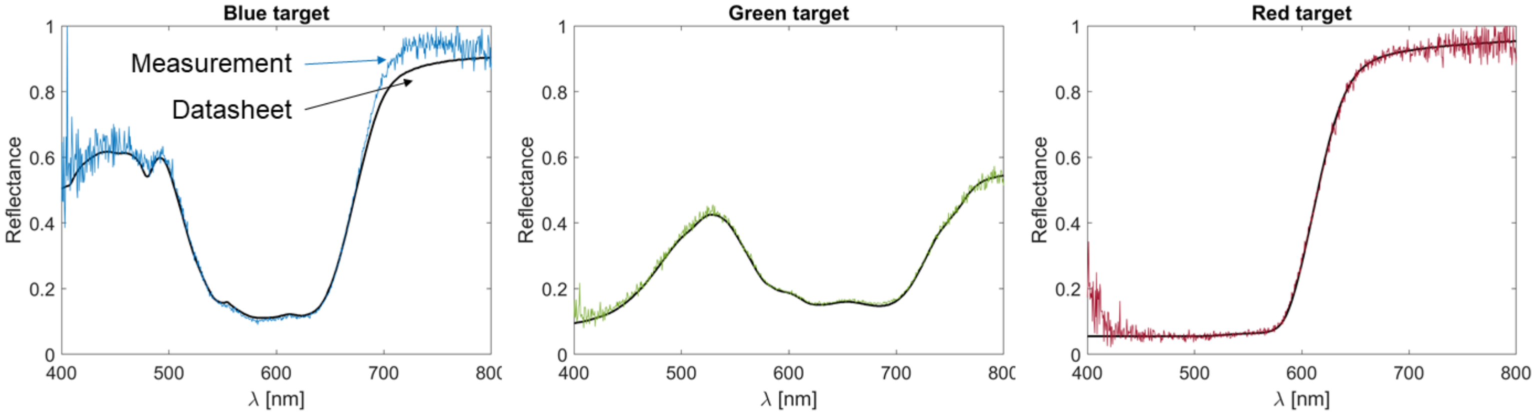
1^{st} Order System Properties	
F-number	F/20
FOV	~2.9°
Focal length	400mm - ∞
Spectral range	460 – 720 nm
Spectral sampling	0.53 nm
Volume	5.5 U (5,500 cm^3)
Detector pixels (0^{th} and 1^{st} order)	4112 x 3008
Imaging time (narrowest slit)	10 min
Imaging time (broadened slit)	20 s





Results

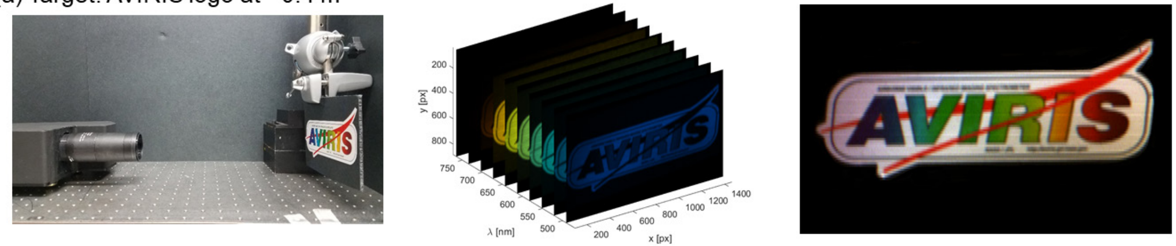
- Laboratory calibration involved measurements of Spectralon (white) targets to understand system response
- Measurements of laboratory spectral targets show strong agreement



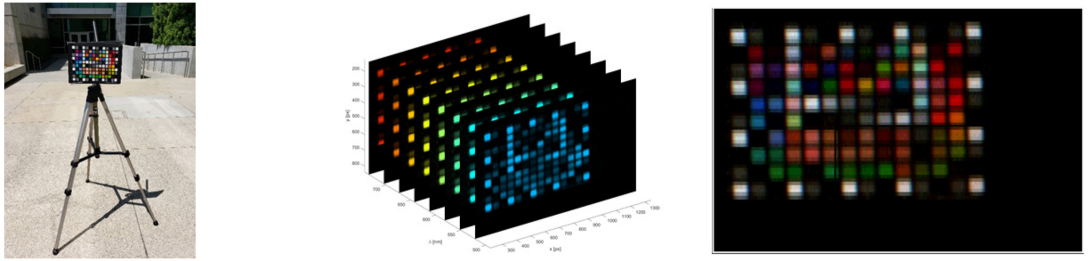
Results

- System used to produce full image cubes on indoor and outdoor targets at both near and far range
- Exploration of tradeoff between slit width (spectral and spatial resolution) and acquisition time

(a) Target: AVIRIS logo at ~0.4 m



(b) Target: MacBeth ColorChecker chart at ~50 ft.

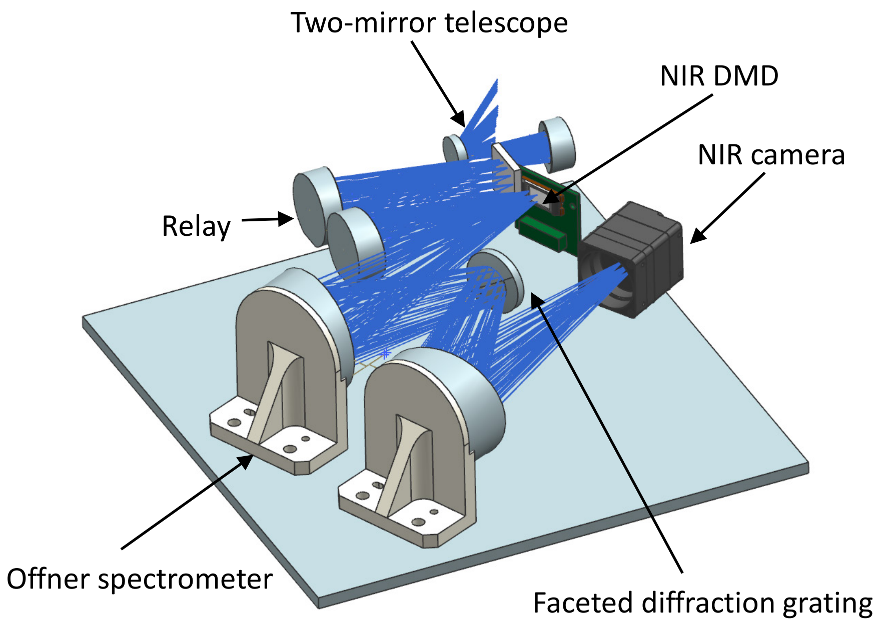


(a) 50 px slit, ~20 sec measurement (b) 29 px slit, ~1 min measurement (c) 10 px slit, ~9 min. measurement

Next Steps

- All-reflective system designed to operate in NIR (1.0-1.7um) wavelengths
- Custom optics improve system F-number, FOV, and spectral range
- Faceted grating for separating the undiffracted (panchromatic) and diffracted (spectral) signals on the detector

1st Order System Properties	
F-number	F/4
FOV	~2.9°
Spectral range	1.0-1.7 µm
Spectral sampling	10 nm
Volume	< 6 U



Optics drawings released
Finished optics ship date: 9/17/20

Thank you

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