AN ULTRAVIOLET MICROMIRROR IMAGING SPECTROGRAPH CONCEPT STUDY. R.N. Schindhelm[1], A. R. Hendrix[2], B. Fleming[3], D. Vorobiev[3]. [1]Ball Aerospace, Boulder, CA, [2]Planetary Science Institute, Tuscon, AZ, [3]LASP, University of Colorado, Boulder, CO

Introduction: Ultraviolet spectroscopy is a critical element of planetary science missions, enabling the study of both planetary surfaces and atmospheres. UV spectroscopy serves as an excellent complement to infrared spectroscopy and visible imaging because unique molecular absorptions (by atmospheric/plume gases and solid surfaces) and gaseous atomic emissions can be measured exclusively in the UV; in surfaces, unique mineralogical and compositional information is contained in the UV spectral region (e.g. [8]). We present a technology concept for a future planetary science UV multi-object imaging spectrograph, the Ultraviolet Micromirror Imaging Spectrograph (UMIS). UMIS is an integral field spectrograph (IFS) that utilizes analog micromirror arrays (AMDs) and advanced mirror coatings to enable efficient, adaptive target selection in a two-dimensional field-of-view. For example, the large, adaptable UMIS field of view would allow for simultaneous observation of large regions of a plume and surface of an Ocean World, including potentially simultaneous stellar occultations by different regions of a plume (Figure 1). A PICASSO grant has been awarded to PSI, LASP, and Ball for a breadboard demonstration of UMIS, along with an instrument/science trade study to determine optimal instrument parameters for different targets.

Technology Advances: New advances in UV instrument component technologies enable more complex instruments than the state of the industry (e.g. SwRI's Alice/UVS line, LASP's UVIS/IUVS line: single long-slit imaging spectrographs) while minimizing size, weight, and power. These advances allow inclusion of AMDs to reconfigure more of the image plane into an imaging spectrograph.

UV detectors are being demonstrated with higher performance and size. Atomic layer deposition activation of borosilicate microchannel plates minimizes gain sag [1] and allows larger format plates, while cross-strip anodes and Application Specific Integrated Circuit (ASIC) readouts enable larger formats at high spatial resolution with lower power [2]. New MCP photocathodes (e.g. GaN) offer potential for higher quantum efficiency (QE) [3].

Advanced optical coating techniques enable higher throughput for FUV instrumentation. Coating groups have measured reflectivities for LiF, and MgF_2 with a new Physical Vapor Deposition process allowing several more reflections in instrument without

Figure 1. *UMIS vastly improves on the capabilities of scanning-slit UV instruments. Upper panel: Simulation of Enceladus surface + plume signal using a scanning slit. The slit FOV (shown in red at left) must be scanned across the field of regard to make an image. Lower panel: Enceladus simulation using UMIS-like system. Both simulations use Cassini UVIS data folded through the UMIS effective area curve (Hansen et al., 2006; Hendrix et al; 2010). Simultaneous features of interest can be accessed across the telescope field of view.*

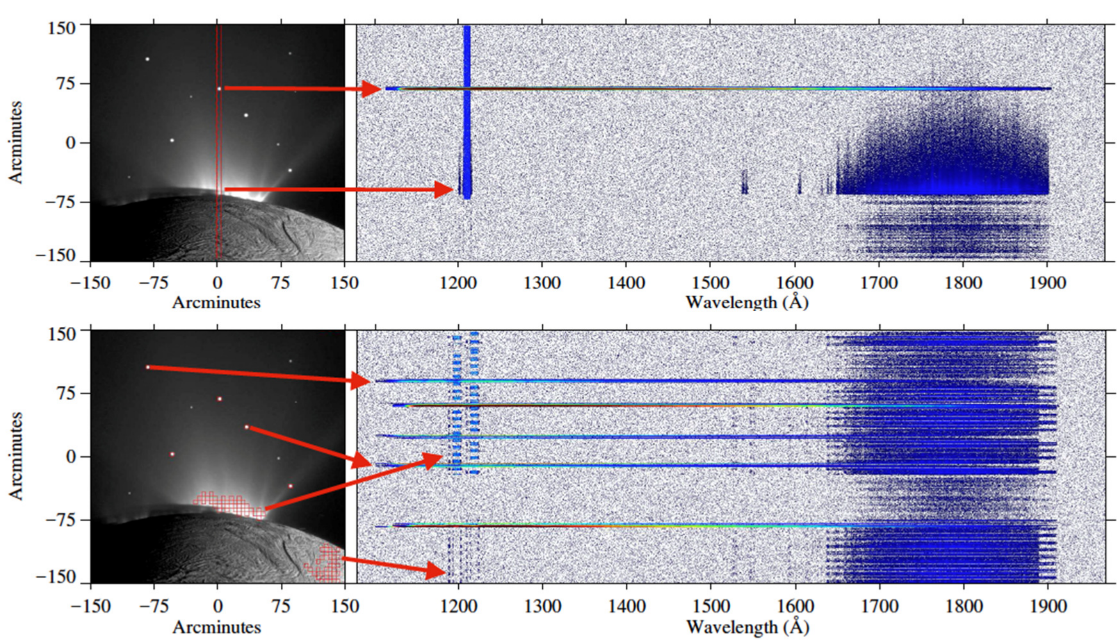
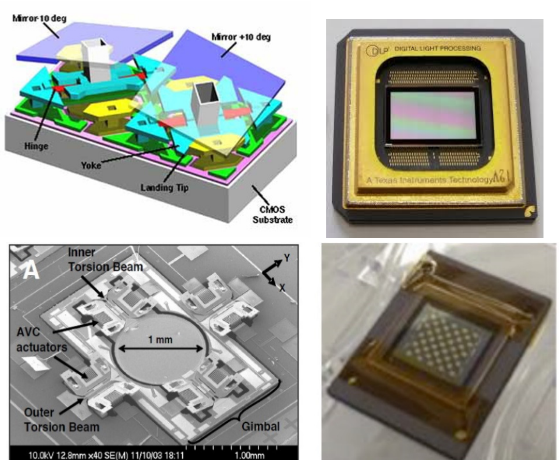


Figure 2. *DMDs (top) and AMDs (bottom) enable advanced spectral selection and multiplexing.*



significant loss in throughput [4,5]. MgF_2 has peak reflectivity ~93% and is generally 85-90% for most of FUV.

Finally, microelectromechanical systems (MEMS) technology enable advanced spectral selection and multiplexing through micromirror arrays (Figure 2). Digital micromirror arrays (DMDs) are bi-state arrays where the mirrors tip/tilt between two positions and have been demonstrated and proposed for ground/space-based instruments [6] that allow a larger field of regard without slewing the spacecraft and act as a selectable slit. Analog micromirror devices (AMDs) achieve a range of angles in two dimensions to dissect the image plane more freely. These arrays are made for telecom but could enable an IFS in the far-UV [7].

UMIS Concept and Science Potential: In its full implementation UMIS utilizes a 2-axis AMD at the image plane to direct portions of the field of view (FOV) to either an imaging channel or a spectrograph channel. In the spectrograph channel, a second 2-axis DMA is required to parallelize the beams from AMD1 before the grating. ~25% of the image plane can be fit onto the spectrograph detector at one time, so observing algorithms that leverage the imaging channel are implemented to optimize observing efficiency.

AMD1 covers a 5ºx5º FOV in the telescope image plane, with 50x50 mirror elements. The mirrors in AMD2 are arranged in 3 lines to spread the image plane elements in the spatial dimension. A 100 mm x 100 mm cross-strip microchannel plate detector is assumed for the spectrograph channel. Ball raytraces of a 2-mirror telescope provide imaging quality over 3-5 degree FOV for ~0.1ºx0.1º size mirror elements in a 20 x 45 cm volume.

For the PICASSO effort we will align a breadboard of the spectrograph channel of UMIS to demonstrate the feasibility of a 2-AMD imaging spectrogram. The CU raytrace (Figure 3) traces path from mirrors in AMD1, to mirrors in AMD2, off a grating and camera optic to distribution in the spatial dimension on detector. Multiple paths exist between a single AMD1 mirror and the detector that maintain sufficient spatial and spectral resolution. A follow-up effort would coordinate with a MEMS foundry to fabricate a more ideal AMD for UMIS prototype than the telecom array that will be used in the breadboard

UMIS stands to improve upon current UV imaging spectrographs by greatly increasing spectral multiplexing efficiency. This is parameterized by the product of the instrument effective area and the number of spectra observed simultaneously. The increased field of view and reconfigurable image plane, coupled with intelligent algorithms for observing and onboard data reduction, open the possibility for greatly increased scientific return from remote exploration missions.

Acknowledgements: The UMIS demonstration is funded under NASA contract #80MSFC19C0042.

References: [1] Ertley et al. 2016, SPIE [2] Vallerga et al. 2016, SPIE [3] Siegmund et al. 2005, SPIE [4] Quijada et al. 2015, SPIE [5] Fleming et al. 2016, SPIE [6] Travinsky et al. 2017, JATIS [7] Fleming et al. 2018, SPIE [8] Wagner, J. et al. (1987) ---

Figure 3. *A raytrace schematic of the testbed system*