Optical Design of LUVIS for a SMEX mission

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OVERVIEW

We are developing the design for the Lyman-Ultraviolet (LUV) Imaging Spectrograph, LUVIS to propose for a Small Explorer (SMEX) mission. LUVIS will provide true long slit (6 arc minute) imaging spectroscopic capability with large spectral resolving power, R. Minimizing the number of optical components to the required minimum of three enables large spectral throughput. The design uses a two-mirror Cassegrain Ritchey-Chretien Optical Telescope Assembly (OTA), a single optic Rowland-like spectrometer, and a windowless 50 x 127 mm curved Microchannel Plate (MCP). The design is optimized over the 102 to 140 nm spectral range providing spectral imaging at R ~ 20K in a single exposure. Lyman-β enhanced Al + LiF mirror and grating coatings with the LiF protected with an atomic layer deposition (ALD) fluoride encapsulating overcoat provide high throughput over that spectral range. Line-of-sight (LOS) jitter control utilizes time-tag photon arrival to compensate field position jitter by re-registering pixel location in post-processing as well as tip/tilt active control of the secondary mirror of the OTA. This paper will describe the design as well as some of the key design trades that defined the design.

Keywords: Lyman UV (LUV) spectroscopy, Far-UV (FUV) space missions, Long slit imaging spectroscopy

LUVIS Objectives and Summary

LUVIS, if selected, will accomplish priority UV science providing significant contributions to answering many of the key science questions posed in the Astro2020 Decadal Survey. LUVIS consists of a 0.5-m f/24 Cassegrain optical telescope assembly feeding a single instrument – a Lyman-UV/ far-UV single-optic spectrograph. The design form and optical coatings have been selected to optimize the signal in the Lyman ultraviolet while utilizing existing technology. Architecture trades have emphasized a simple design with a minimum of optical elements and mechanisms while using a coating design that optimizes the Lyman UV throughput. We conclude that the mission is feasible on a cost constrained budget.

LUVIS is low risk within the cost constraints of a SMEX budget.

LUVIS Top-Level Requirements and Resulting Block Diagram

LUVIS top level requirements

- Science Sensor mounted on S/C bus
- Science Sensor == OTA plus Spectrometer plus FGS
- OTA
  - D 490 mm clear aperture, f/24: f = 11,760 mm
  - Spatial resolution < 1 arc sec
  - OTA Diffraction-limited in flight @ λ = 1.0 micron
  - SM 3-DoF mechanism: Focus/tip/tilt
    - Focus step size/sensitivity: ± 5.0 micron
- FGS
  - FOV 15 arc min diameter, Focal length = 4.7 m
  - Pixel on sky: 0.010/4693 = 440 mas
    - Resolution 10% of a pixel ~ 44 mas
  - FPA CMOS CIS120 2K x 2K 10 um pixels
- LOS control
  - Body point by bus: Range/jitter 18 arc sec (3 σ)
  - Tip/Tilt OTA SM
    - Control LOS jitter to 60 mas (1 σ) [1/6 of resel]
    - Use FGS error signal
  - SM tip/tilt
    - Range 63 arc sec (3.537*field angle of 18 arc sec)
    - Jitter 210 mas (3.537*field jitter of 60 mas)
    - Maintain SM despace to TBD during tip/tilt
- Spectrometer
  - Single disperser Rowland-like spectrometer
  - FOV: 6 arc min long slit, Slit width = FPA resel (20 um)
  - Resel size on sky: 350 mas
  - λλ: 102 to 139.2 nm
  - Spectral resolving power, λ/Δλ ~ 20K at 139.2 nm (1-resel)
  - FPA: MCP with 20 um resel
    - Photocathode (PC) : CsI/windowless
    - PC usable length 115 mm (from 127 mm total length)
    - PC width 50 mm
  - Photon counting: Time-tagging photons
- Sun exclusion angle: 95 degree
- Viewing angles wrt Earth-Sun line
  - 95 deg to 135 deg
- In-flight Calibration lamps
  - Pt Hollow Cathode Lamp with LiF(TBD) window

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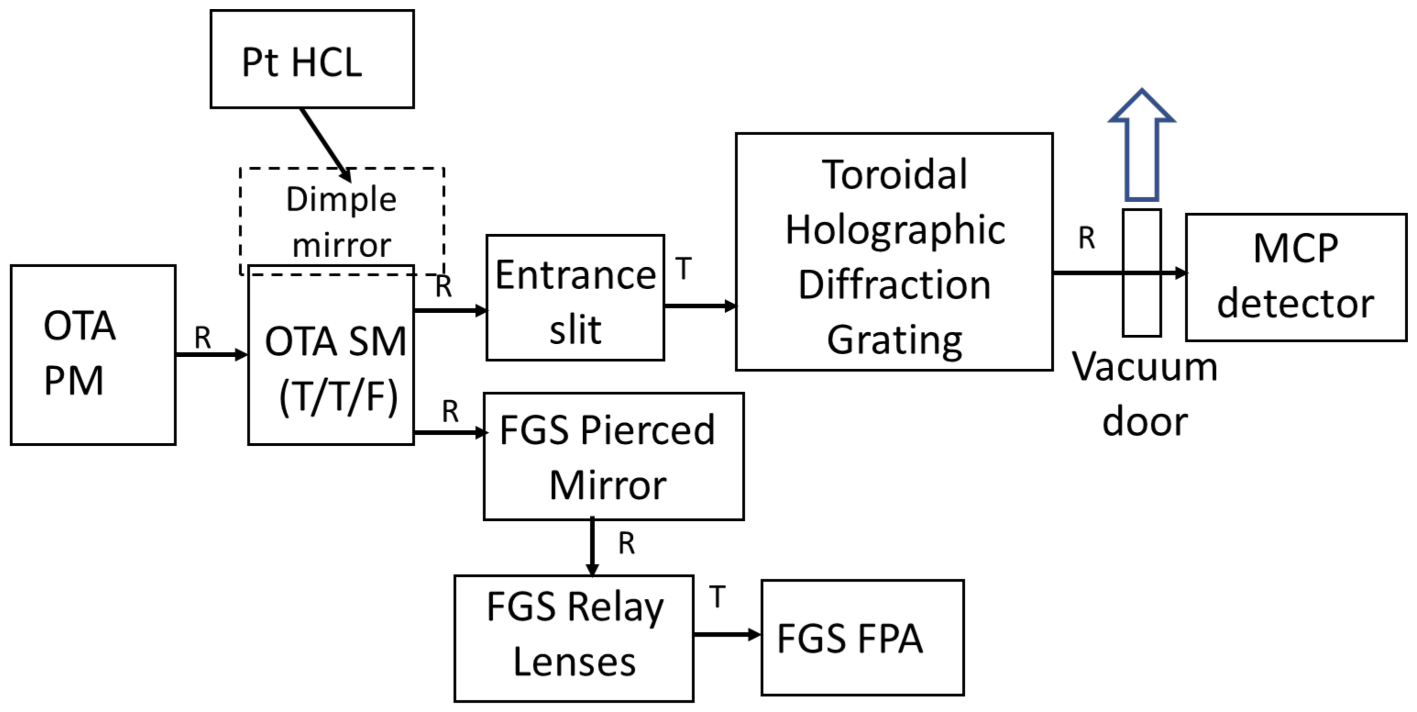
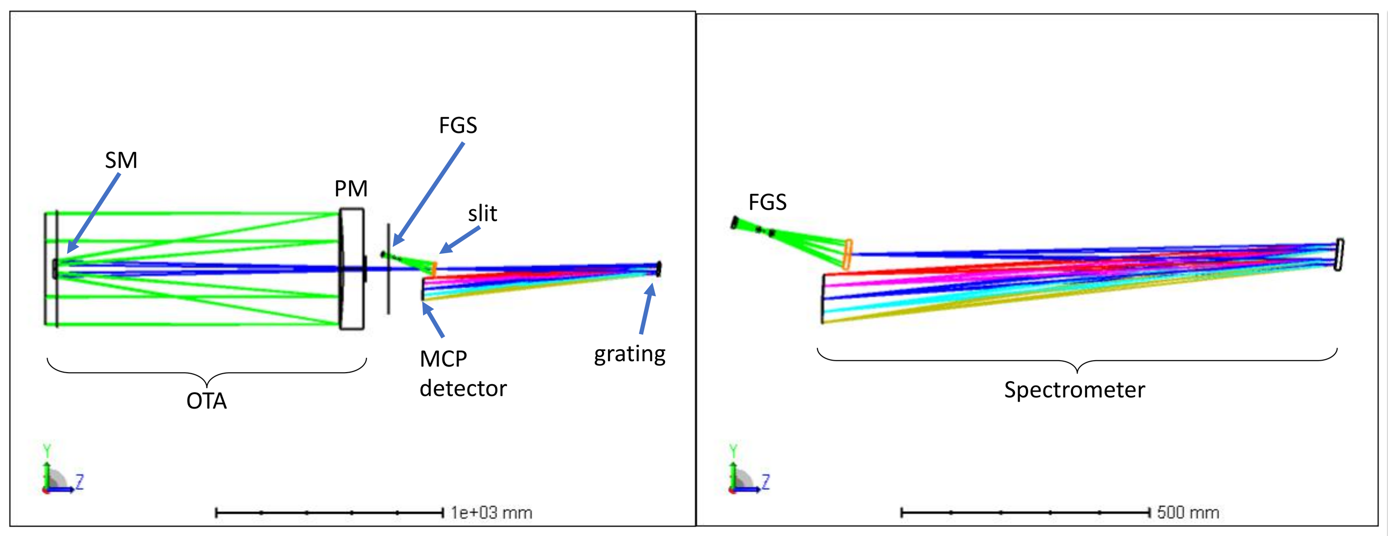


Detailed LUVIS Design and projected performance



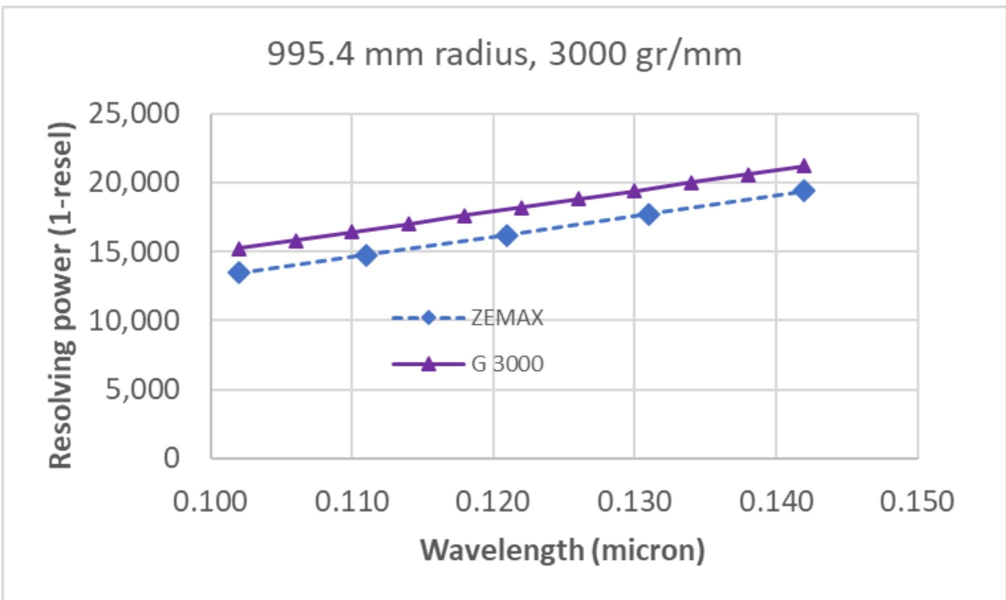


Image at MCP: Two wavelengths separated by 0.076 Å

Over 360 arc sec FOV (X-dispersion)

N.B. Improved correction @ 111.0 and 131.0 nm

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Box = 50 micron = 0.88 arc sec