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OPTICAL SYSTEMS FOR THE UV

OUTLINE

- Bandpasses and technology
- Consequences to optical designs
- Where are the improvements in each bandpass

UV (NOT AVAILABLE FROM GROUND)

- <550 Å requires either grazing incidence or muiltilayers over small bandpass
- EUV: 550 – 900 Å
- DUV: 900 – 1150 Å
- FUV: 1150 – 2000 Å
- NUV: 2000 – 3200 Å

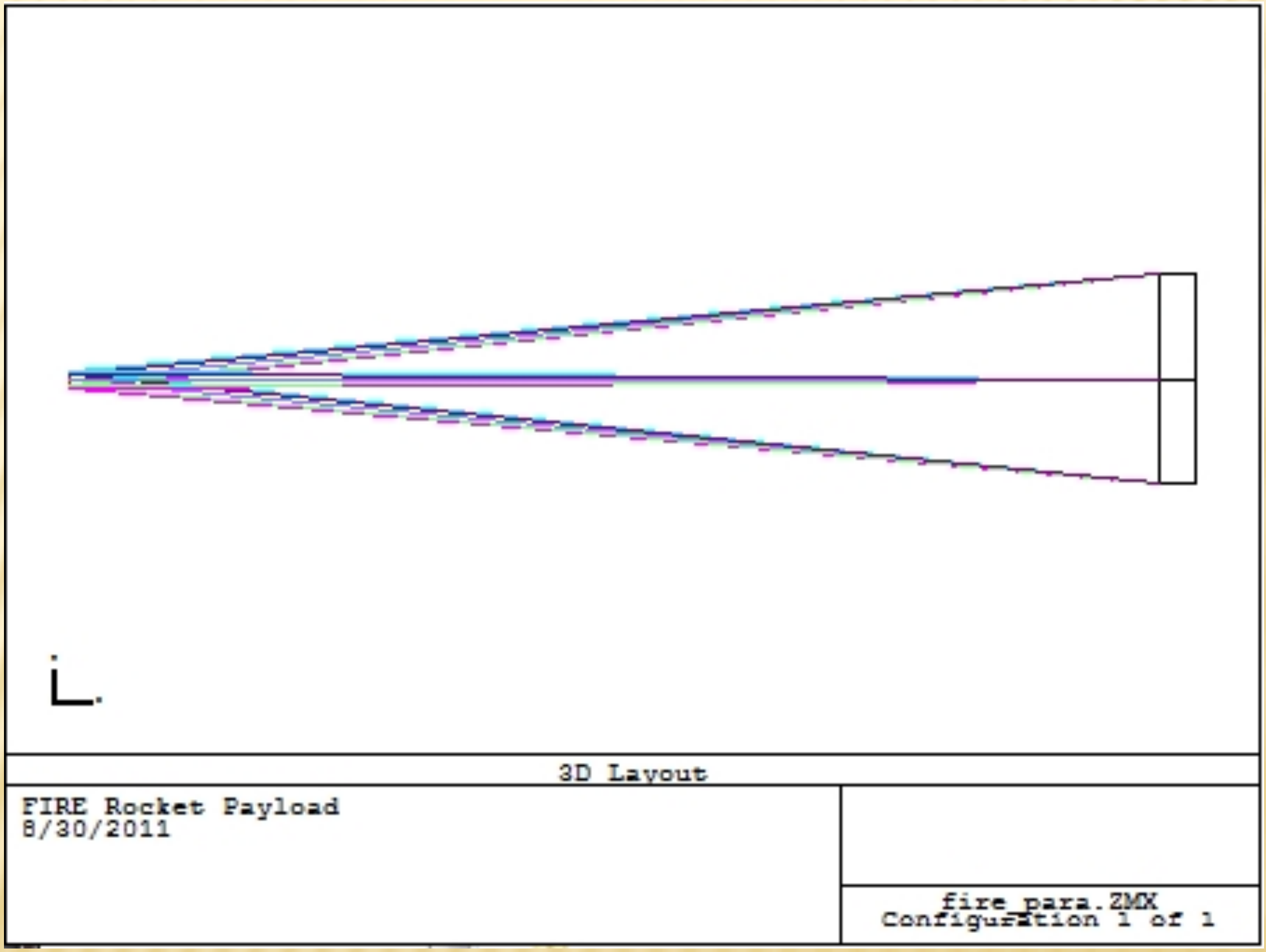
EUV 550 – 900 Å

- EUV currently restricted to in-situ planetary measurements
  - Only a few astrophysical targets in this bandpass
- Architecture completely determined by low reflectivity (~30% broadband SiC, B_4C)
- Missions in this bandpass typically look at bright targets (can be small)
- Thin film metal films are only transmitting materials

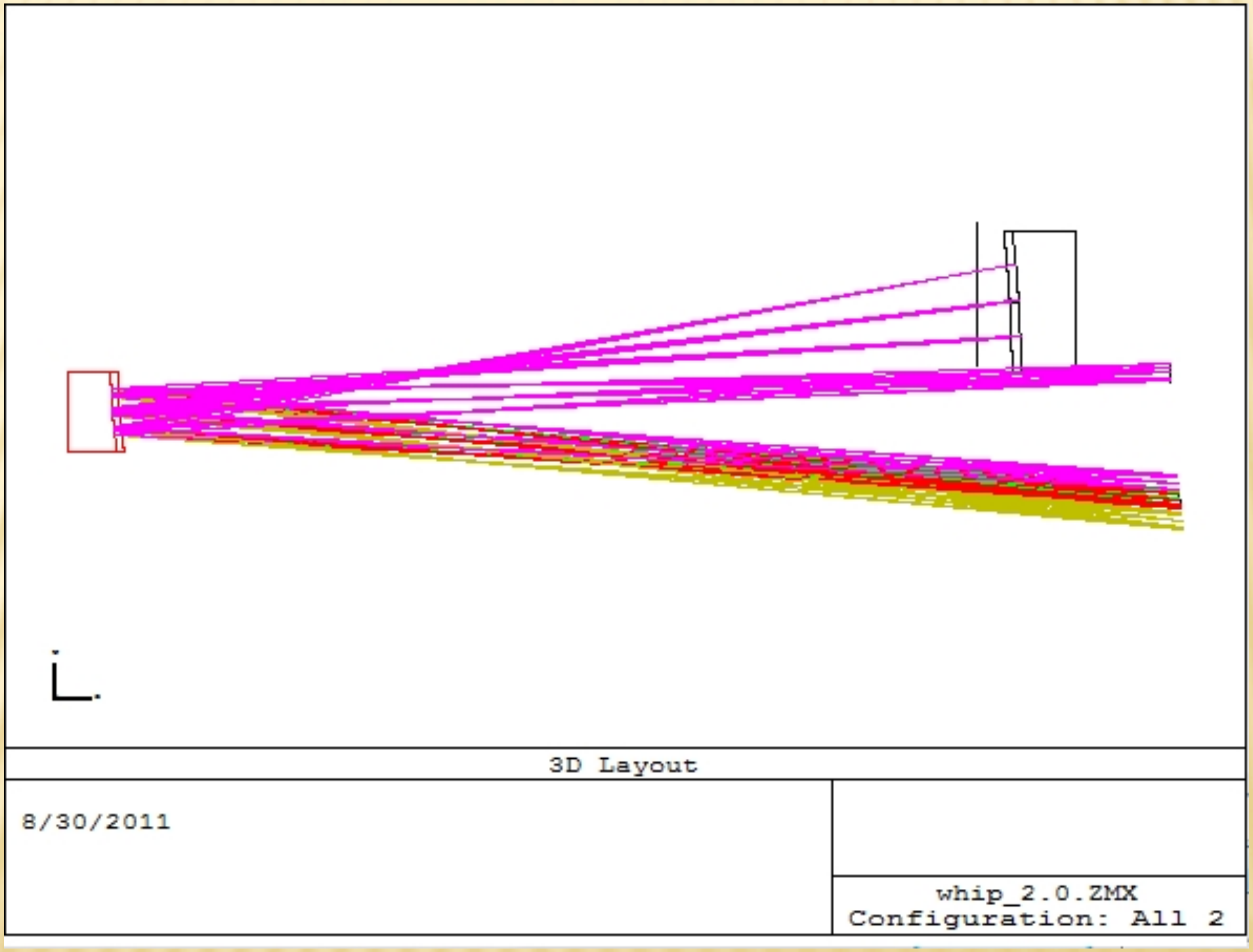
DUV 900 – 1150 Å

- 900 – 1000 Å throughput requires SiC or B_4C (30% reflectivity)
- 1000 – 1150 Å can use LiF/Al for 60% (with good efficiency through optical wavelengths)
- Architecture determined by poor reflectivity
- Thin film metals are only transmitting materials, no lenses

INSTRUMENT FOR DUV (900 – 1000 Å)

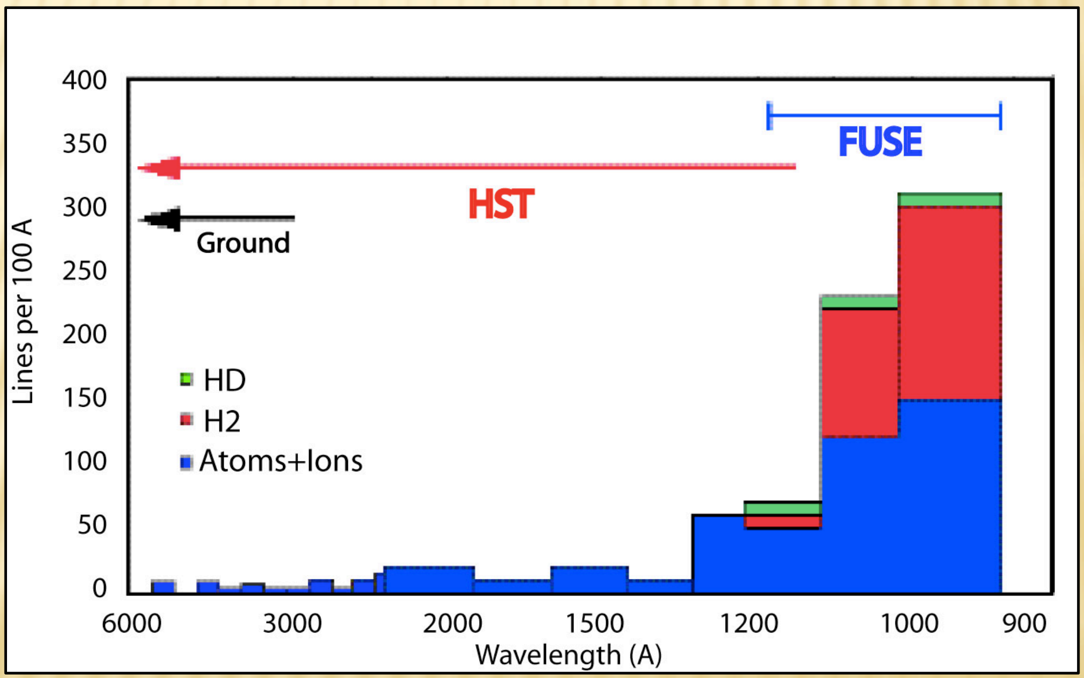


DUV INSTRUMENT (1035 Å)



WHY DUV? WHY WORK SO HARD?

- # of ground state transitions as function of wavelength

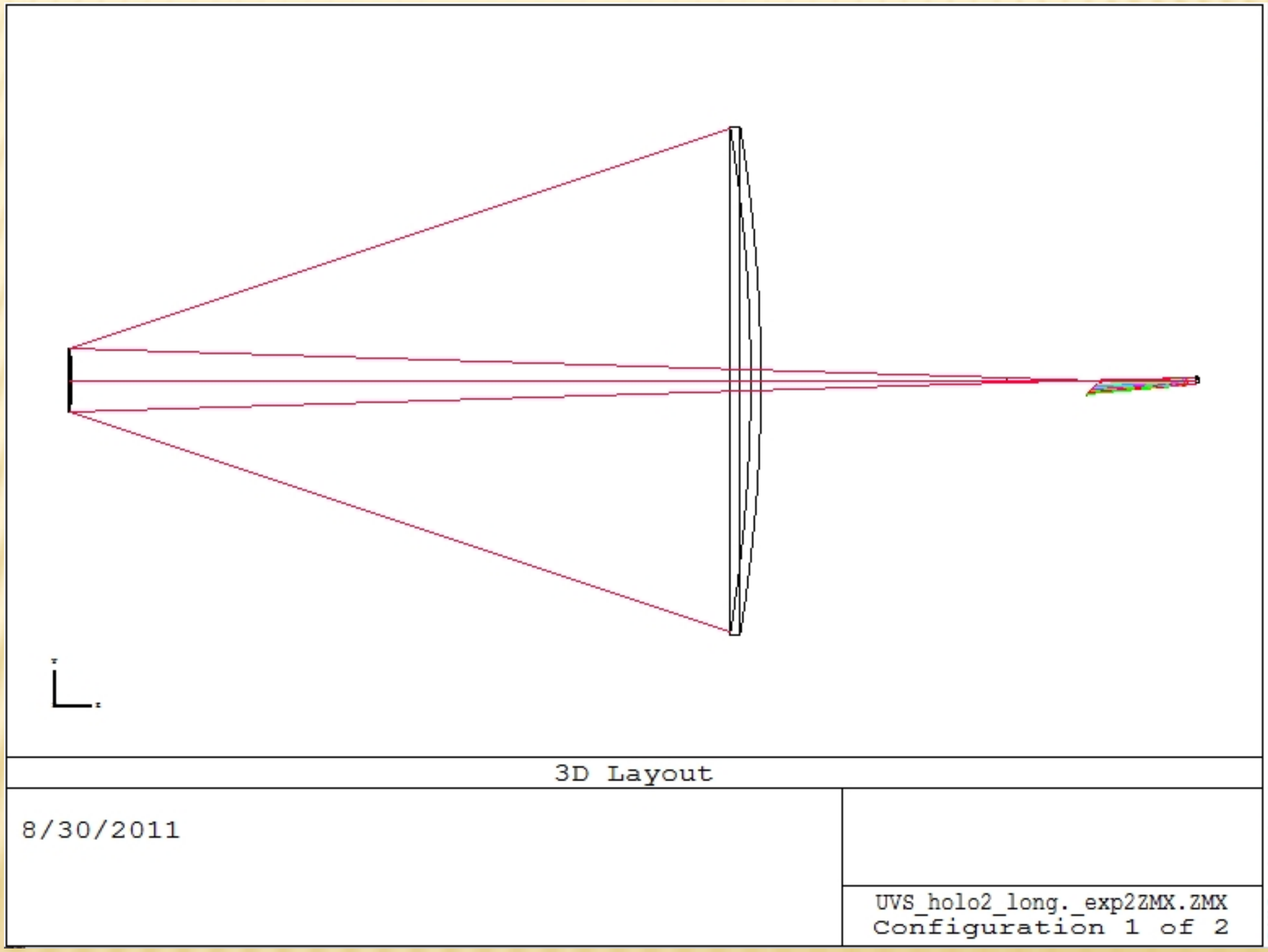


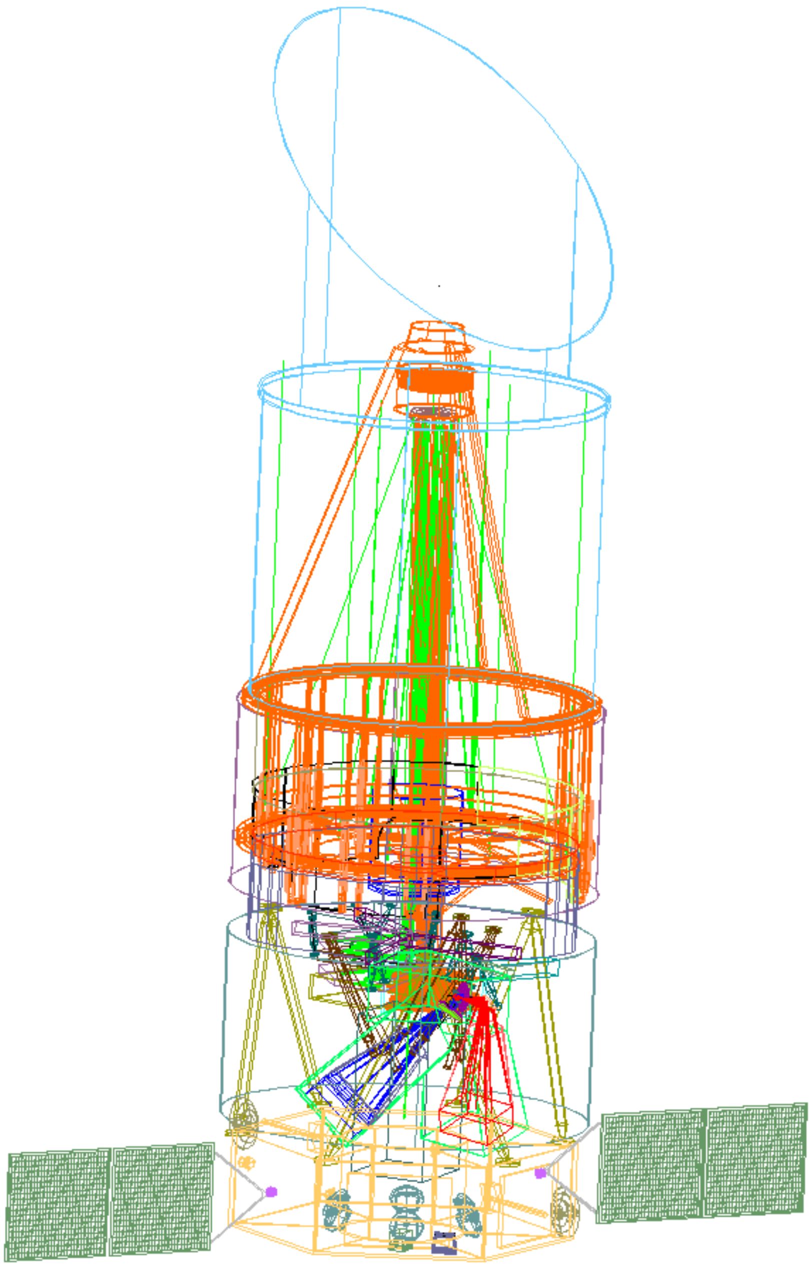
FUV 1150 – 2000 Å

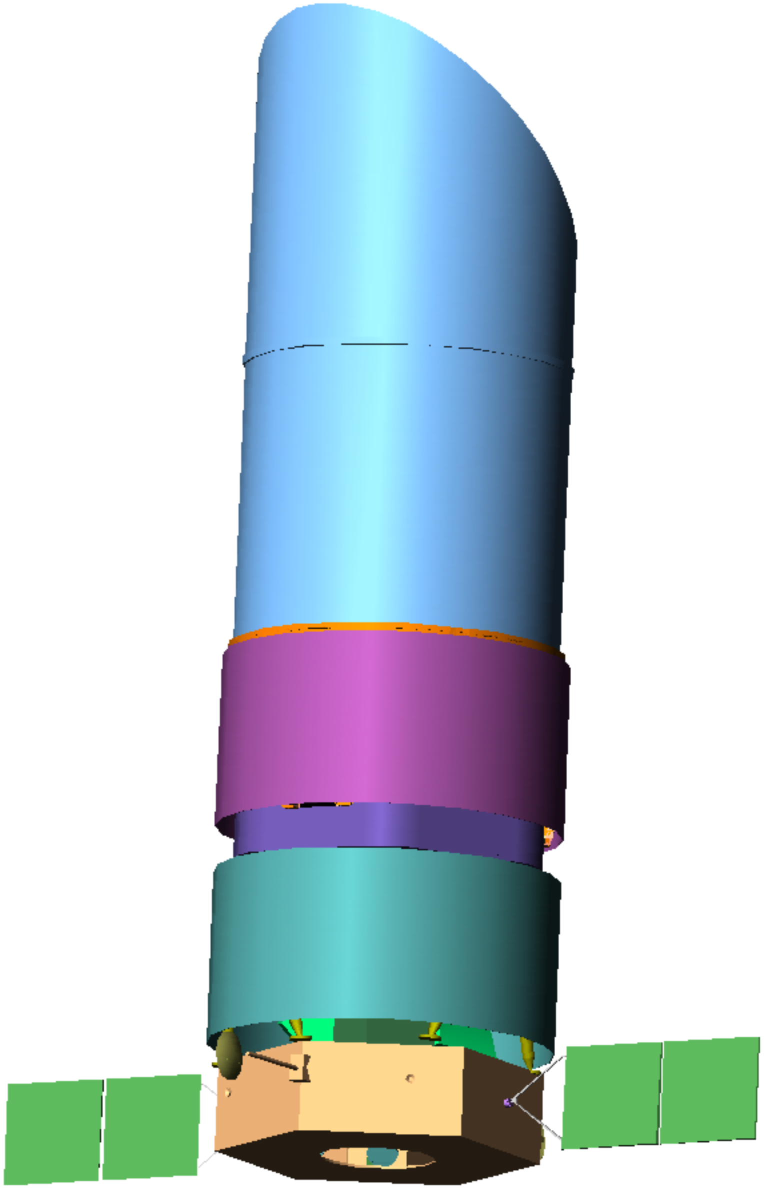
- MgF_2/Al best choice for broadband operation
- 80% reflection allows three optic systems
- Transmitting optics (i.e., lenses) work, albiet poorly
- Good filters would be highly desirable scientifically

HUBBLE FUV

FUV INSTRUMENTS (1000 – 1600 Å)



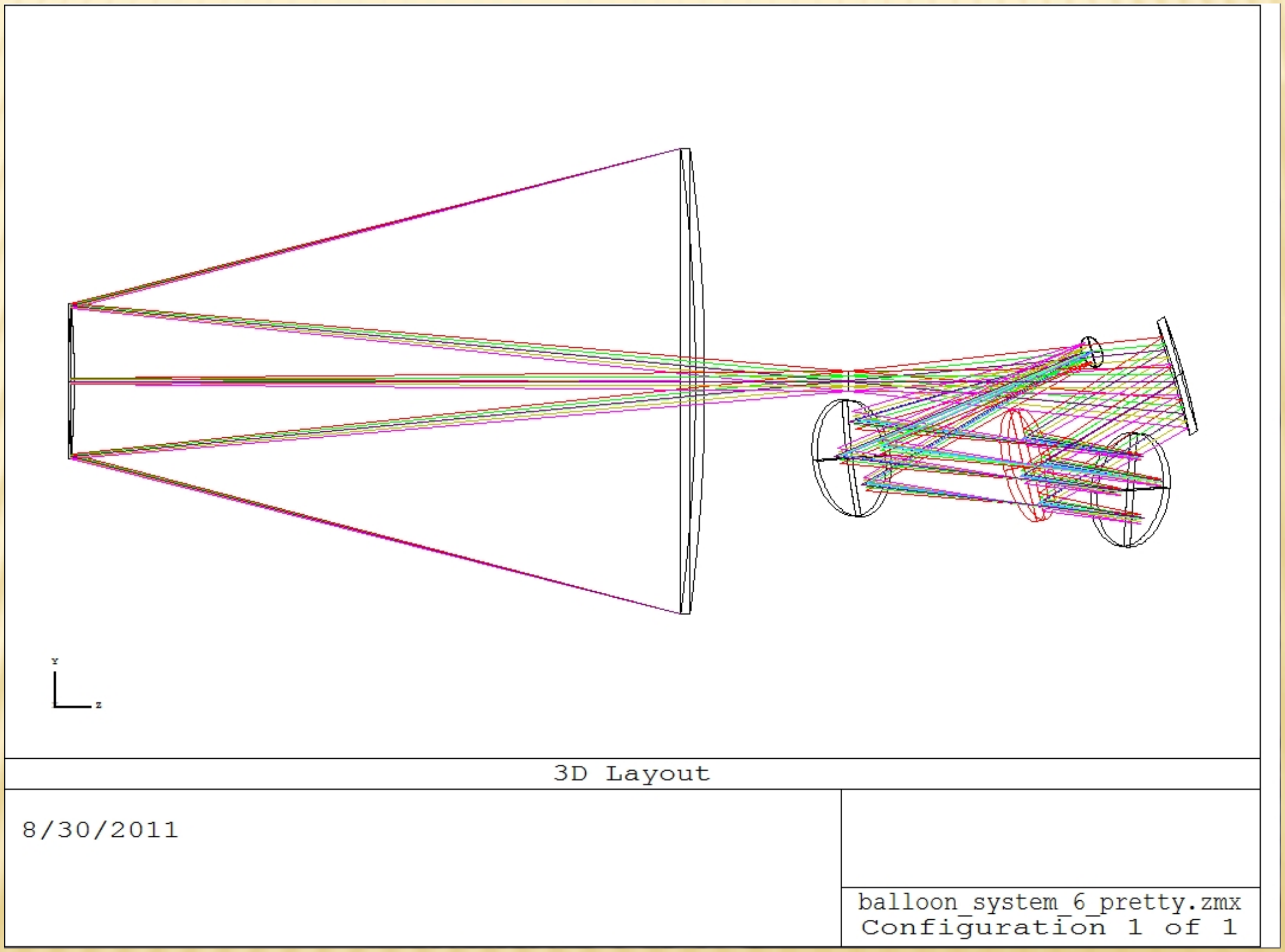




NUV 2000 – 3200 Å

- Excellent efficiency >85% from high quality MgF_2, mirror coatings not driver for architecture
- Good optical quality, decreasing scatter issues, low airglow
- Detectors have room for improvement
- Conventional filters leave something to be desired, but work

NUV INSTRUMENT



BROADBAND COATINGS

- Bare metal has been used (iridium, osmium), but low (~15%) reflectivity compromises performance
- Evaporated MgF_2/Al, LiF/Al, SiC, B_4C.
  - Represent advancements over bare high-Z metals in the UV (30 – 60%)

CURRENT COATINGS

- However, the MgF_2/Al and LiF/Al are simply to protect the native aluminum reflectivity and suffer short wave cutoff due to the crystal becoming opaque.
- Improvements on the way

OPTICAL FABRICATION ISSUES

- Diffraction limit costly to achieve with NUV/FUV optics due to testing issues
- Holographic diffraction gratings limited in figure quality, typically have little impact on systems

SCATTER

- Highly polished glass (< 10 Å rms) excellent
  - New metal optics acceptable in DUV (nickel clad aluminum)
- Gratings
  - Holographic in photoresist
    - VERY LOW (< $5x10^{-7}$)
  - Holographic Ion Etched
    - Low (< 1×10^{-5})
  - Ruled (via diamond)
    - Can be high
  - Exotics
    - Silicon Lithography – probably low
    - Photonic material – low, may have other effects

FILTERS (AND DICHROICS)

- EUV – thin film metal filters and multi-layer reflective systems provide modest filter capacity
- DUV – thin film filters have been used. Nothing approaching narrowband (R~10 is the best I'm aware of)
- FUV – conventional filters becoming available, but throughput is low and resolution is modest (compared to optical wavelengths), reflection filters better
- NUV – Selections of materials is improving, better filters, reflective filters still competitive

DETECTORS

- EUV – detectors (silicon/MCP based) work well, DQE is high (>60% dropping as wavelengths get long, especially for silicon)
- DUV – MCPs (or other photocathode based) have good DQE (~50%), Silicon ~30%
- FUV – MCPs (or other photocathode) best at short wavelengths, Silicon potentially better at long wavelengths
- NUV – silicon devices currently best, MCPs with GaN may be competitive

CONTAMINATION CONTROL

- Increasingly strict the shorter the wavelength due to hydrocarbon absorption of light
- Can be a cost driver for LiF/Al optics
  - Will result in cost increases over the entire mission for any UV instrument

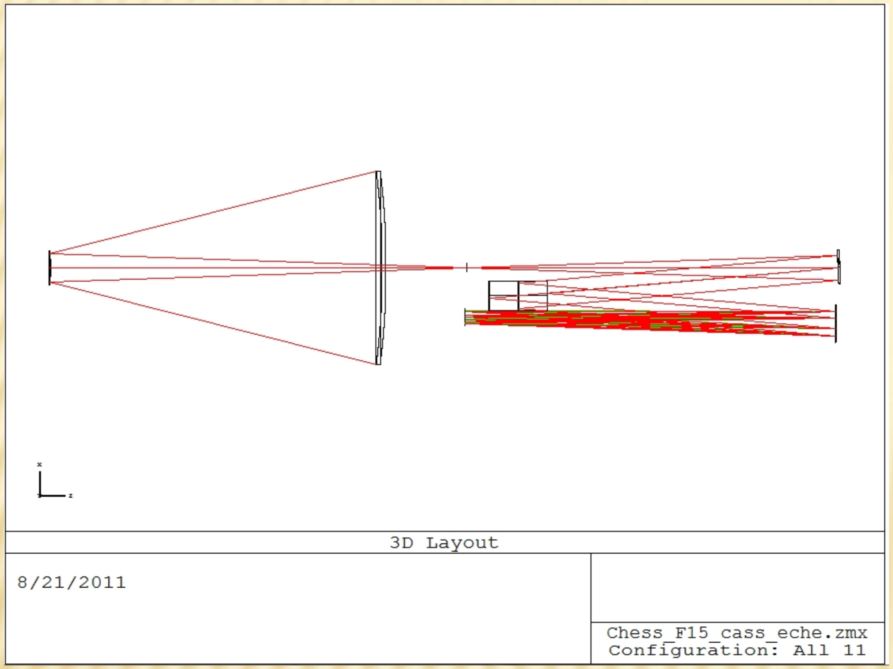
AIRGLOW

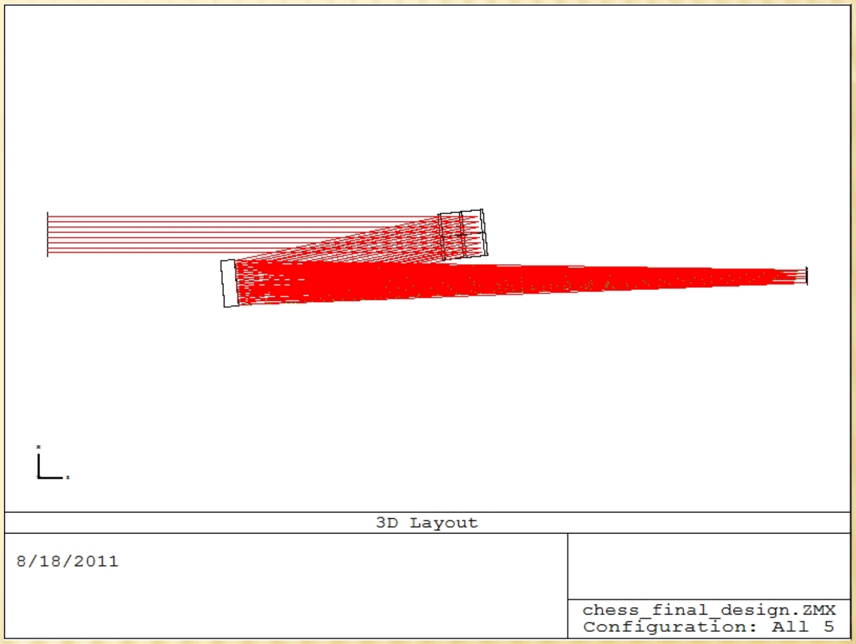
- EUV, DUV, FUV – bright geocoronal airglow force some sort of control into instrument design
  - In situ planetary missions consider the airglow "science"
- NUV – airlglow not a significant issue

IMPROVEMENT

- DUV has substantial (and more profound increases in capability) available at low cost with a straightforward development path
- Other UV bands have improvement paths
  - Detectors are being worked on (several groups here)
  - Filters, etc

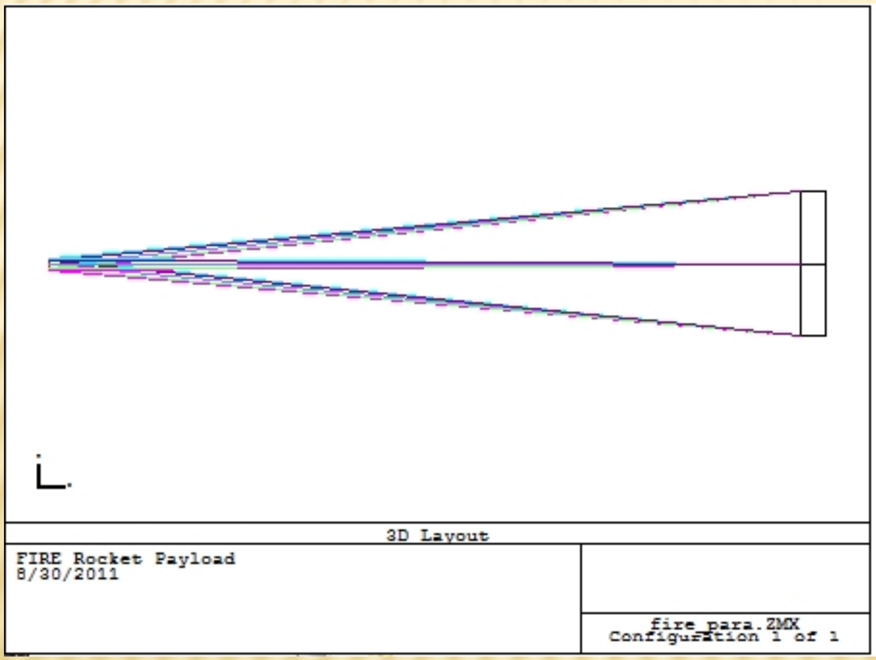
CHESS ROCKET PAYLOAD (DUV/FUV)

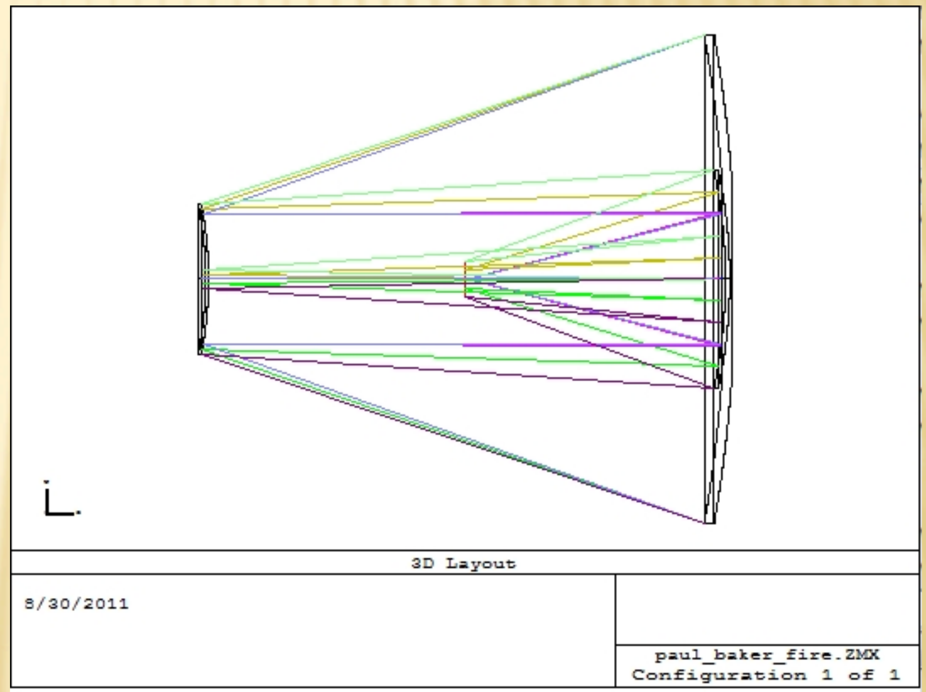




These echelle systems are roughly equivalent (resolution, bandpass). The design on the left is a BETTER design.

DUV SYSTEMS


3D Layout
FIRE Rocket Payload
8/30/2011
fire_para.ZMX
Configuration 1 of 1


3D Layout
8/30/2011
paul_baker_fire.ZMX
Configuration 1 of 1

UPGRADE PRIORITIES

- EUV/DUV
  1. Reflective coatings
  2. Gratings
  3. Detectors
- FUV
  1. Gratings/ Filters
  2. Detectors
  3. Reflective Coatings
- NUV
  1. Detectors
  2. Gratings/ Filters
  3. Reflective Coatings

ASTROPHYSICAL MISSION CONCEPTS

- Three-mirror anastigmat architecture good candidate for UVOIR instrument
- Unless operations below 1150 Å required, three mirrors not a significant impact for FUV
- DUV systems would require more exotic designs to integrate UV/ Optical (and performance compromises)
- UV-only mission could make these trades