Name: James Wiley
Research Advisor: Dr. Brian Fleming
Research Field: Optical Coatings for the far ultraviolet
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Automated vacuum ultraviolet reflectivity chamber for characterization of broadband mirror coatings in the far ultraviolet

Figure 1: A rendering of the experimental setup.

Prospectus:

Advances in coating processes for ultraviolet optimized optics for astronomy have led to the potential for higher throughput in the Lyman UV Bandpass (LUV, 912-1216 Å). [1, 2, 3] Current and previous space observatories such as the *Hubble Space Telescope*, which consists of mirrors coated with aluminum (Al) overcoated with magnesium fluoride (MgF_2), and the *Far Ultraviolet Spectroscopic Explorer*, which utilized a two-bounce optical system with Al overcoated with lithium fluoride (LiF) mirrors, had low reflectivities in the LUV. New physical vapor deposition (PVD) techniques developed at NASA's Goddard Space Flight Center (GSFC) give rise to the possibility of enhanced reflectivities from LiF+Al (eLiF) optics, potentially extending the bandpass of future UV-sensitive observatories. [1, 2, 4]

LiF+Al provides a lower wavelength cut off compared to other dielectrics such as MgF_2 or Aluminum Fluoride (AlF_3)[5], but LiF is hygroscopic and loses reflectivity over time with exposure to humidity. Atomic layer deposition (ALD) of a very thin MgF_2 or AlF_3 layer could protect the LiF layer from moisture exposure without decreasing reflectivity or raising the short wavelength cut off. The end goal is reflectivities > 80% and a band pass cut off ≤ 102 nm to support future flagship missions such as LUVOIR and HabEx.

Qualifying these state of the art coatings requires high cadence reflectivity testing to optimize the coating prescription and determine the durability of the coating over time. Environmental constraints inherent to the Far Ultraviolet (FUV, 122–200 Å) such as having to take measurements at vacuum and working in a clean environment vastly increase testing times. For these reasons, I have designed an automated vacuum reflectivity chamber designed to increase efficiency and decrease user oversight for taking high accuracy, high cadence reflectivity measurements in support of qualifying these state of the art optics.[6]

Previous experience with reflectance chambers influenced the design of the experimental setup. [2, 7, 8] An optics plate is at the center of the chamber, mounted to a Newport URM-150PP rotation stage. Mirror samples and an arm for guiding cables are mounted to the optics plate. An OptoDiode Corp AXUV100G photodiode with a McPherson 671MX Vacuum Preamplifier is mounted opposite the samples to observe the reflected beam. The stage rotates to place the diode in the incident position, and then rotates to three reflected positions. The chamber has a flange that leads to a Leybold 450ix Turbomolecular pump and an Agilent IDP-15 Dry Scroll pump and operates at pressures $< 10^{-5}$ torr.

A Resonance LTD EUV-XL-L Flow Lamp, attached to an Acton (Princeton Instruments) VM-502 monochromator and a collimator serves as the light source for the experiment. The lamp uses hydrogen-argon gas to produce wavelengths needed for testing, but is compatible with multiple gas sources. Monochromatic light is sent into the collimator where it reflects off an off-axis parabolic mirror mounted on a Newport 8821-UHV Picomotor. The Picomotor enables steering of the collimated beam for detector peak-ups and flexibility for future experiments. The monochromator has a flange that leads to the high vacuum pumping system, while the lamp is pumped only by the IDP-15 rough pump.

The system is computer controlled by an interface I programmed in LabVIEW. The computer uses USB, RS-232, and GPIB interfaces to communicate with the controllers and measurement devices. The LabVIEW program performs automatic routines such as detector peak ups by moving the collimator, and moving between reflected and incident positions. The software continuously logs use and pressures in the system in case of error, as well as records data and calculates the reflectivity curve. Future work will be done to increase the autonomy of taking measurements.

I am currently in the process of calibrating the system and my research group is in possession of eLiF, AlF_3 and MgF_2 protected eLiF, and AlF_3+Al mirror samples that are in storage in an N_2 purge environment. Once the chamber is fully operational, the samples will be characterized and then aged in humidity chambers[2] and then measured periodically for over one year to track degradation. My thesis will focus on the characterization of the optics and the design and theory of operation for the reflectivity chamber. I plan on including data taken in my chamber to compare the degradations of the different eLiF coatings and compare those to a non eLiF coating. My reflectivity chamber will increase efficiency and reliability of these degradation measurements in support of developing next generation coatings.

Timeline:

TABLE 1 Timeline

Oct 2017	Finish putting together setup; Calibrate System; Get first measurements
Nov 2017	Work more on computer program and possible additions to system to increase automation; Characterize mirror coatings
Dec 2017	Begin getting measurements for coatings; continue working on increasing efficiency
Jan 2018	Begin writing honor's thesis; Continue reflectivity measurements; optimize efficiency
Feb 2018	Work on thesis; Continue measurements
Mar 2018	Finalize thesis; Continue getting data;
Apr 2018	Defend thesis; submit thesis

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