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Final Report for FUSE/Lyman Grant

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We have studied a variety of options for a short wavelength spectrometer for the Lyman telescope, and have identified the optimum configuration for this instrument. In this spectrometer option study we have assumed (consistent with performance goals outlined by the project) that the instrument, whose prime spectral domain is 900-1200Å, will incorporate a grazing incidence telescope which will maintain good collecting efficiency down to 100Å. In particular we have assumed that the telescope will have an effective focal length of 10 meters, an image quality of 1.5" and will provide a diverging f/10 beam. We have analyzed designs compatible with this telescope, and determined that a two-element grazing incidence spectrometer using as its first optic an ellipsoid to re-focus the beam and a varied line-space plane diffraction grating to disperse the light is the best overall design. This spectrometer could be fed by a small pick-off mirror located just behind the prime focus of the telescope and would clear the light path when not in use. We have undertaken a test of the diffraction efficiency of a low blaze angle grating, which is the only technical uncertainty in the spectrometer design.

In addition to identifying the optical elements required for the optimal design, we have generated a number of specific spectrographs, the parameters for each tailored to match slightly different design assumptions. Each spectrograph design was optimized using analytical formulae, then numerically ray-traced to verify resolution performance and to determine off-axis aberrations. Our design discussed in the attached paper, "A Grazing Incidence Extreme Ultraviolet Spectrometer for Use with a Diverging Beam," resulted from an optimization process with a minimum number of constraints, with no restrictions placed on the particular location of the various optical elements. This design yields a spectral

(NASA-CR-180024) FUSE/LYMAN GRANT Final Report (California Univ.) 3 p CSCL 20F N87-14972

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resolution of from ~350 to ~750 across the 100 to 350Å bandpass, assuming a 1.5″slit, and a resolution up to ~1050 for a 1″slit. The parameters were tweaked slightly to produce a spectrograph which could provide coverage from 80 to ~950Å with two interchangeable gratings, and which fit well within the envelope of the prime Rowland spectrograph. This design could just as well be implemented with a single grating, covering a factor of λ to $3.5\times\lambda$ for any specific range desired in the EUV. It is this design which is discussed in Section V (D) of the Lyman Proposal to presented to NASA Code EZ.

Most recently, we designed yet another EUV spectrograph, this time in response to a request from the European community. The Europeans envisioned an Echelle spectrograph for the prime bandpass and urged us to modify the EUV instrument to fit within the much smaller physical envelope provided by the Echelle. In order to achieve a resolution in excess of 300 at all wavelengths between 100 and 350Å within this smaller envelope a slit size of 1″is required. The details of this design were sent to G. Tondello in September of 1986.

The technical feasibility of the spectrographs we propose is in general quite good: the required detector performance can readily be met with EUVE-type microchannel plate wedge-and-strip detectors, and the single non-flat optic could be produced with diamond turning techniques with much less difficulty than the fabrication of the telescope mirrors themselves. A question has been raised, however, about the diffraction efficiency achievable with a low blaze-angle grating, which is required for the spectrograph. Conflicting reports from grating manufacturers has encouraged us to investigate the issue at Berkeley, and we have obtained a very low blaze angle grating (1.7°) which will be tested at EUV wavelengths in our grating test facility.

Project Summary

We have shown that an EUV spectrograph consisting of a grazing incidence ellipsoidal mirror, a plane varied line-space grating, and flat microchannel plate detectors with standard wedge-and-strip readout systems can provide a spectral resolution in excess of 300 over a factor of 3.5 in wavelength across the EUV. The specific parameters of the design can be modified to fit any reasonable physical envelope allotted to the instrument. The efficiency of the spectrograph will be extremely high due to its small number of grazing incidence reflections. The technical difficulties of this design are minimal, and the single potentially difficult task, production of a high-efficiency low blaze angle grating, is being addressed in our lab.