Penning source for calibration of x-ray and EUV optics and spectrometers at wavelengths as short as 56 A

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ABSTRACT

We report on the development and evaluation of a redesigned version of the Penning gas discharge source of x-ray and EUV radiation previously described by Finley et al.[1] The most significant new features are the use of stronger permanent magnets and spill-proof quick-disconnect water cooling line fittings. Using aluminum cathodes and Ar discharge gas, and with a 0.5 mm by 5 mm exit aperture on the source, we obtained an absolute flux in the bright Al IV line at 129.73 A of order 5 x 10^{11} s^{-1} sr^{-1}, and of order 5 x 10^{9} s^{-1} sr^{-1} for the Ar I line at 56 A. Detailed spectral analysis of the lines near 56 A is reported. The application of this source to the prelaunch calibration of the AXAF x-ray astronomy observatory is discussed, with emphasis on use of the narrow line at 56 A for calibrating the spectral resolution of the AXAF transmission grating spectrometers.

1. INTRODUCTION

Penning sources of various designs have been used to provide EUV illumination for over three decades[2,3,4]. A relatively recent report on design and performance of such a source for use in calibrating the EUVE satellite telescopes was given by Finley et al.[5], in which they showed a spectrum of the source using an aluminum cathode with argon gas in the chamber. This spectrum clearly demonstrated that there are many lines, with the strongest being at about 130 A. Work by Hettrick et al.[6] showed that this line (which is actually a doublet) is extremely narrow, with a FWHM of about 0.010 A, and so can be used for calibrating the resolution of spectrometers. We are planning to use this and other nearby lines to calibrate the spectral resolution of the Low Energy Transmission Grating (LETG) of AXAF.

The two other gratings on AXAF, the Medium Energy Grating (MEG) and the High Energy Grating (HEG), will be calibrated using characteristic x-ray emission lines from an electron impact source, using various anodes. Below about 1 keV, however, electron impact lines are unacceptably broad ($\Delta E/E > 0.001$) because the energy levels involved are spread out into a band structure by interaction with neighboring atoms' valence electrons. This is not a problem for calibrating the HEG, which will not be used below 1 keV, but the MEG will be used at energies as low as 400 eV, or even 200 eV.

For low-energy calibration of the MEG, we therefore require some other narrow-line source. In the spectrum reported by Finley et al., an Ar I line was observed at 56 A (221 eV), but the instrumental resolution of their spectrometer was rather poor at that wavelength. We report here on a measurement of the width of that 56 A line, showing that it is indeed narrow enough to be used for calibrating the MEG resolution. Figures 1 and 2 show a spectrum of the Penning source output in the vicinity of the 56 A line, obtained with the Hettrick HIREFS grazing incidence spectrometer being installed at the AXAF X-ray Calibration Facility at Marshall Space Flight Center. The width of the line is no greater than about 0.04 A, corresponding to $\lambda/\Delta\lambda$ =1400, which is close to the resolving power limit of the HIREFS spectrometer. (The surprisingly narrow feature at 55.98 A is probably spurious.) On theoretical grounds, we expect this line to be even narrower than measured, but in any case, it will serve very well for calibrating the MEG resolution.

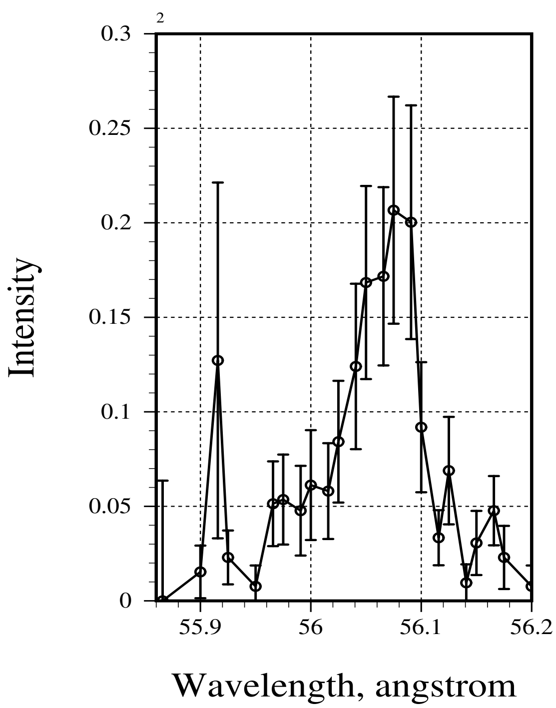

Figure 1. Spectrum of the Penning source with 0.02A bins. HIREFS entrance slit width 20 µm, exit slit width 10 µm.

The intensity in the 56 A main peak has been measured at SAO to be about 5 x 10^9 s^{-1} sr^{-1}. Using a thin filter to prevent contamination of downstream optics by sputtered Al atoms, the source should provide about 1 photon $s^{-1}cm^{-2}$ at the entrance to the AXAF optic, the High Resolution Mirror Assembly (HRMA). Since the HRMA has an effective area of about 700 cm^2 at that wavelength, this works out to about 700 photons s^{-1} striking the MEG. The first order efficiency of MEG/detector combination is relatively low at that wavelength, but even so, the net detected counting rate will be of order 100 counts s^{-1}. Such a counting rate will easily provide a measurement with high statistical precision in a reasonable amount of time.

2. ACKNOWLEDGMENTS

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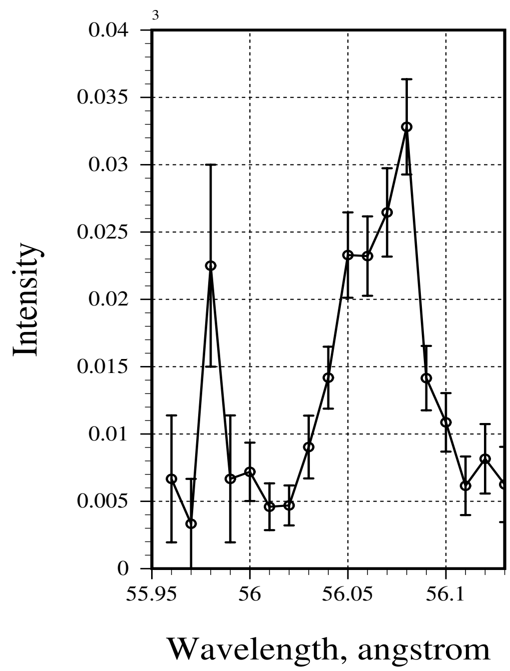

Figure 2. Spectrum of the Penning source with 0.02A bins. Entrance slit width, 10 µm, exit slit width 5 µm.

3. REFERENCES

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