NORTHROP GRUMMAN

Design of a High Resolution X-ray Reflection Grating Demonstration

T. Johnson[1,*], L. S. Casement[1], D. Henderson[1], C. Lillie[1]
Randall L. McEntaffer[2], Webster Cash[3]
[1]Northrop Grumman Corporation, [2]University of Iowa,
[3]University of Colorado
*tim.p.johnson@ngc.com; One Space Park, MS 201A/5127, Redondo Beach, CA 90278

Abstract

The International X-ray Observatory (IXO) has baselined a soft x-ray grating spectrometer as part of its instrument complement to provide spectral resolution (R) of >1250 over the 0.3 – 1 keV band. Current generations of reflection gratings have demonstrated R of a few hundred with very small telescopes. The same basic technology can be used with a higher resolution telescope such as IXO to provide R of up to 3000 with only small modifications. We have developed a test article which will be placed in the X-ray beamline facility at GSFC using a mirror pair developed as a technology demonstration for IXO. The test article will demonstrate the current baseline requirement for resolution. We present test data (as available) and performance predictions, as well as an approach to get to R~3000, well in excess of IXO requirements.

- High performance X-ray telescope mirrors at GSFC have measured spatial resolution of 15 arcsec

- Used with test grating of groove density 4500 gr/mm (and other parameters of set-up) we should measure spectral resolution R~200 before applying subaperture

- Applying subaperture to telescope will increase spectral resolution (R) by decreasing blur at detector

- Because R is a strong function of telescope resolution (see below), this should increase measured R to upwards of 3000

- Only tradeoff of subaperturing is that it also decreases light through system thus lower signal to noise ratio (SNR) at detector

- Thus as we increase telescope resolution the tradeoff is a reduction in SNR

- Note: detector pixels are smaller than blur size thus does not limit measurement

Spectral Resolution or Resolving Power (R = λ/Δλ) is a strong function of Mirror Spatial Resolution.

Conical Diffraction Grating Equation [2]

$$\frac{n\lambda}{d} = \sin\gamma(\sin\alpha + \sin\beta),$$

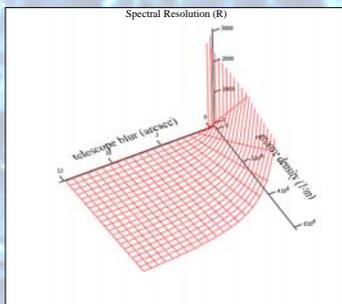$$R = \frac{(\sin\alpha + \sin\beta)\sin\gamma}{B\cos\beta}$$
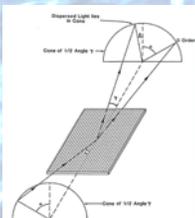

Test Facility at GSFC showing IXO Mirrors inside Vacuum Chamber

Similar Test Facility at University of Colorado showing Grating, Stages, and Detector

	2003 Test at CU	2009 Test at GSFC
Grating groove density	4245 gr/mm	4500 gr/mm
Telescope Resolution	180 arcsec	15 arcsec
Measured R	200	TBD
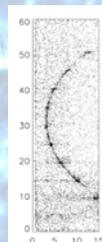
Example detector plot. Grating orders from Cu-L line. R can be calculated using spot width and distance between orders. [1]
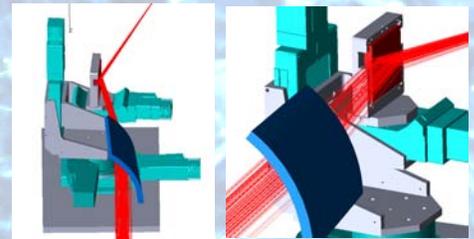
References

1. *Off-plane grating performance for Constellation-X* by Steve Osterman, Randall L. McEntaffer, Webster Cash, Ann Shipley. Proc. of SPIE Vol. 5488, 2004

2. *X-ray optics 2: A technique for high resolution* by Webster Cash. APPLIED OPTICS Vol. 30, No. 13, 1 May 1991

Source   Telescope   Grating   Detector

Basic Test Layout
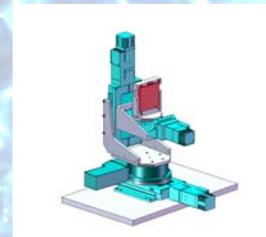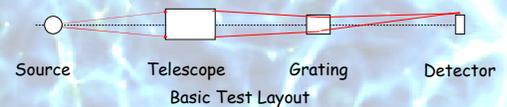
Stage Assembly Holding Grating

Degrees of Freedom Provided by Stage Assembly		
	purpose of DOF	motion provided by
X	aligns grating to beam	linear stage, horiz
Y	aligns grating to beam	linear stage, vert
Z	aligns grating to beam	manual, slide on rails
θx	static	none
θy	controls angle of incidence (γ)	rotational stage
θz	controls diffraction input angle (α)	goniometer stage

Raytrace of Grating (mounting to Stage Assembly) and simplified X-ray Mirror

Rendering of the Cosmic Web courtesy of Matthew Hall (NCSA) and Brian O'Shea (LANL)