DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY SR-79/11
June 1979

TRANSMISSION GRATING EFFICIENCIES IN THE 50 Å TO 250 Å RANGE

by

P. Predehl

Max-Planck-Institut für Physik und Astrophysik
Institut für Extraterrestrische Physik
8046 Garching b. München

R.-P. Haelbich

Deutsches Elektronen-Synchrotron DESY, Hamburg
and
Institut für Experimentalphysik der Universität Hamburg

H. Bräuninger

Max-Planck-Institut für Physik und Astrophysik
Institut für Extraterrestrische Physik
8046 Garching b. München

NOTKESTRASSE 85 · 2 HAMBURG 52

To be sure that your preprints are promptly included in the
HIGH ENERGY PHYSICS INDEX ,
send them to the following address (if possible by air mail) :

DESY
Bibliothek
Notkestrasse 85
2 Hamburg 52
Germany

TRANSMISSION GRATING EFFICIENCIES IN THE 50 Å TO 250 Å RANGE

P. Predehl[1)], R.-P. Haelbich[2)], H. Bräuninger[1)]

1) Max-Planck-Institut für Physik und Astrophysik
Institut für Extraterrestrische Physik
8046 Garching b. München, Germany

2) Deutsches Elektronen-Synchrotron DESY
and Institut für Experimentalphysik der Universität Hamburg
2000 Hamburg 52, Germany

April 1979

The freestanding gold transmission grating behind a grazing incidence telescope permits sensitive spectroscopic studies of cosmic X-ray sources with $\lambda/\Delta\lambda$ of the order of 100[1,2].

The observed efficiencies of diffraction orders strongly depend on wavelength, since the gold is partially transmitting to X-rays near gold absorption edges. Schnopper et al.[4] have studied the properties of a grating, which showed effects of partial transparency near 80 Å. In an earlier paper[3] we have discussed measured efficiencies in the 5.4 Å to 44.8 Å range.

In this investigation, we have studied the optical properties of three transmission gratings in the 50 Å to 250 Å range with different wire thickness. These gratings were replicated from an interferographically produced master with 1 µm period[5]. For our measurements, we used the 7.2 GeV electron accelerator DESY as a synchrotron light source. Monochromasy with a resolution $\lambda/\Delta\lambda$ of about 400 was performed with a grazing incidence monochromator, developed by Dietrich and Kunz[6]. The major advantage of this monochromator over other mountings is the suppression of higher orders. The spectral orders produced by the transmission grating were scanned by moving the detector at constant speed in the direction of dispersion[7]. The detector was an open photomultiplier (Johnston MM1). Beam fluctuations were corrected automatically by a second monitoring photomultiplier. For our model to explain the observations we assumed a trapezoidal wire cross section. This agrees with electron microscope pictures of similar gratings[5]. The model, which is described in more detail by Bräuninger et al.[3], involves the interference of the attenuated and phaseshifted waves coming through the wire and the unattenuated waves coming through the opening. Optical constants of gold were used as given by Hagemann et al.[8], and Aschenbach[9].

Figures I - III show, as data points, the measured efficiencies for the three grating facets. The solid curves represent the theoretical wavelength dependencies of the respective efficiencies for the wire cross section shown in the insert. The parameters of the trapezoidal wire profiles are determined from a best fit to the data points; they are listed in the Table. The fractional obstructing area of the support grid is 0.67 for all gratings.

The influence of the wire thickness on diffraction efficiencies can be seen from the figure. At a thickness of 0.09 µm (grating I), the first order efficiency has an enhancement with a maximum of 20 % at 90 Å, while the zeroth order goes down at the same wavelength. Figure II (the thickness is 0.18 µm) shows an opposite case. The different wavelength dependencies of the first and higher orders are caused by the trapezoidal rather than rectangular cross section. Our model calculations are in excellent agreement with observations. The difference is within 10 % for all values of the zeroth and first order except for three values of grating I and some values of grating II for which the difference is within a factor two as for the higher orders, too. Probably, the reason for this is a misrepresentation of the cross section as a trapezoid. The higher orders are very sensitive to little changes of the wire profile.

The wire thickness does not agree with the specification of the manufacturer. The thickness is about a factor two too low. Uncertainties of the optical constants may be responsible for these discrepancies. Therefore, we plan to calculate the refractive index of gold in the range of anomalous dispersion with the aid of our model, if we shall have determined the wire cross section by electron microscope photographs with sufficient accuracy. The optical constants, determined in this way, promise to be more accurate, because the efficiency gives both phase and amplitude information.

Table

grating	wire thickness	width at base/top
I	0.09 µm	0.62/0.50 µm
II	0.18 µm	0.63/0.39 µm
III	0.25 µm	0.63/0.30 µm

References

1) H. Gursky, and T. Zehnpfennig, Appl. Opt. 5, 875 (1966)

2) J.H. Dijkstra, L.J. Lantwaard, and C. Timmerman: COSPAR/IAU-Symp. on New Instrumentation for Space Astron., (K. van der Hucht and G.S. Vaiana eds.) (Pergamon Press, Oxford and New York 1976)

3) H. Bräuninger, P. Predehl, and K.P. Beuermann, Appl. Opt. 18, 368 (1979)

4) H.W. Schnopper, L.P. van Speybroeck, J.P. Delvaille, A. Epstein, E. Källne, R.Z. Bachrach, J. Dijkstra, and L. Lantwaard, Appl. Opt. 16, 1088 (1977)

5) H. Bräuninger, H. Kraus, H. Dangschat, K.P. Beuermann, P. Predehl, and J. Trümper, submitted to Appl. Opt.

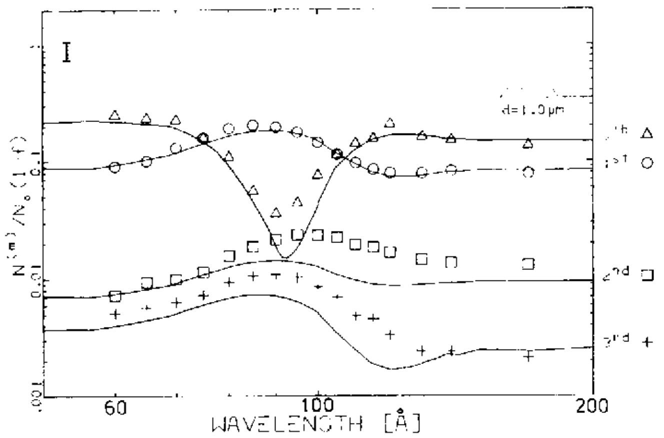
6) H. Dietrich, and C. Kunz, Rev. Sci. Instr. 43, 434 (1972)

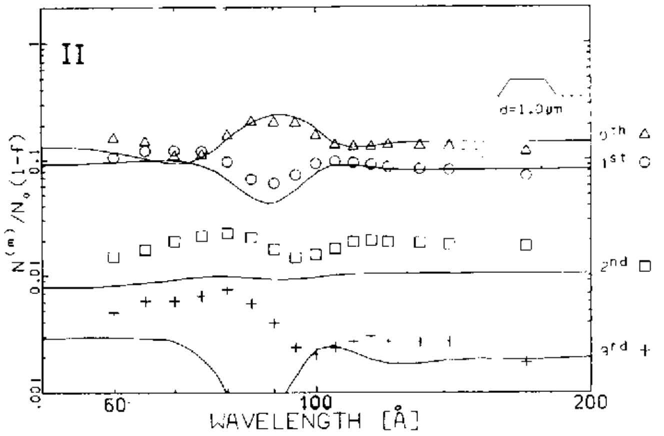
7) R.-P. Haelbich, C. Kunz, D. Rudolph, and G. Schmahl, Nucl. Instr. Methods 152, 127 (1978)

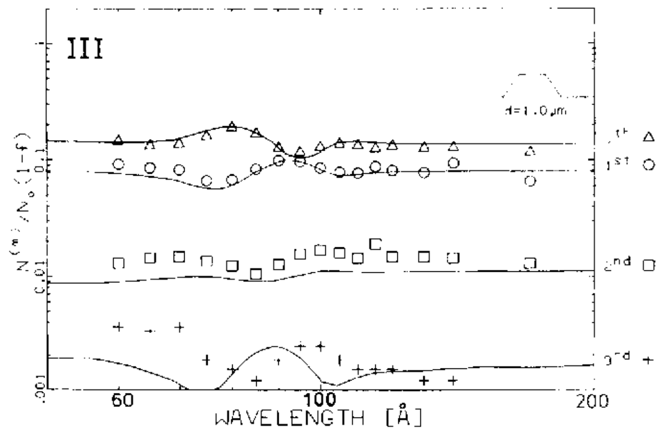
8) H.-J. Hagemann, W. Gudat, and C. Kunz, DESY SR-74/7

9) B. Aschenbach, private communication

Figure: One-side m-th order efficiencies $N^{(m)}/N_0$ (1-f) for the first three and the zeroth diffraction orders. A fractional obstructing area of f = 0.67 is assumed. The triangles, circles, squares and crosses represent the data points, the solid curves are the corresponding theoretical efficiencies. The wire cross section is shown as insert. The scale is 1 µm.


I
d=1.0μm
$N^{(m)}/N_o(1-f)$
.001
0.01
0.1
0th △
1st ○
2nd □
3rd +
60
100
200
WAVELENGTH [Å]


II
d=1.0μm
$N^{(m)}/N_o(1-f)$
.001
0.01
0.1
0th △
1st ○
2nd □
3rd +
60
100
200
WAVELENGTH [Å]


III
d=1.0μm
$N^{(m)}/N_o(1-f)$
.001
0.01
0.1
0th △
1st ○
2nd □
3rd +
60
100
200
WAVELENGTH [Å]