LBNL-40471
UC-410

CONF-9706157--

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Measurement of Diffraction Gratings with a Long Trace Profiler with Application for Synchrotron Beamline Gratings

MASTER

S.C. Irick and W.R. McKinney

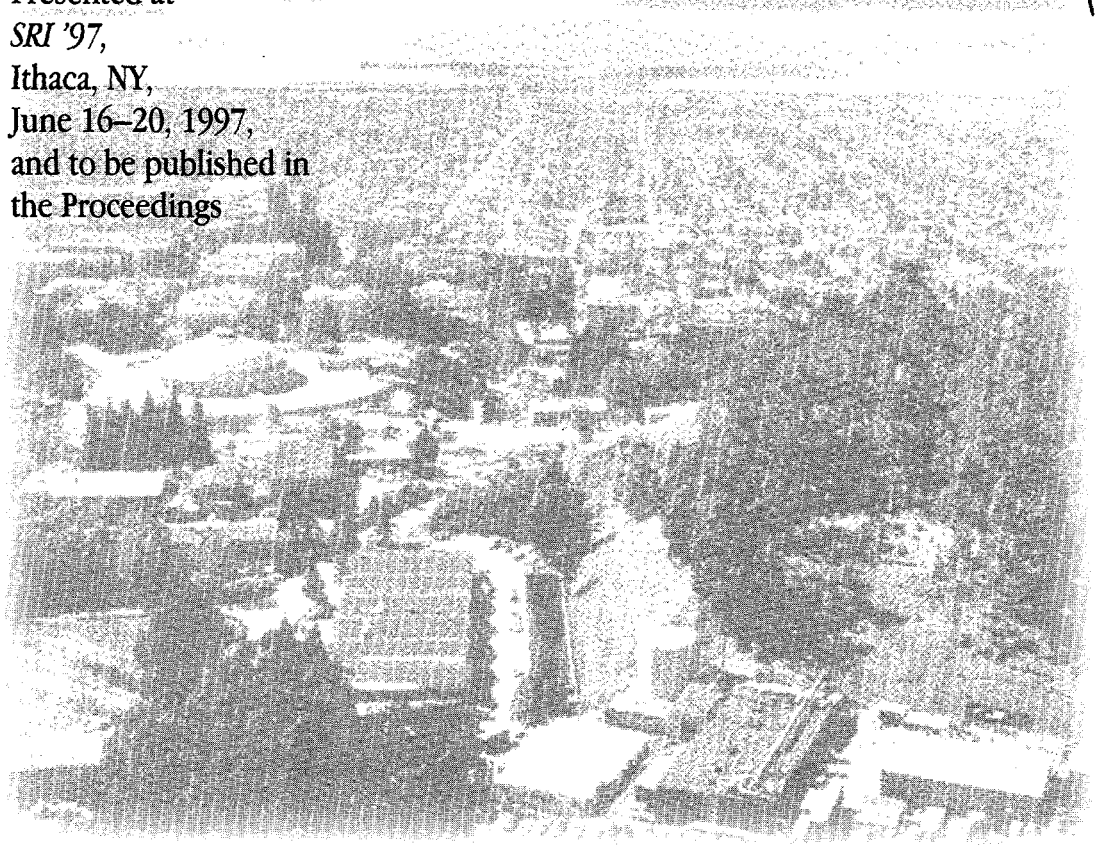
Accelerator and Fusion Research Division

RECEIVED
OCT 08 1997
OSTI

June 1997

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Presented at
SRI '97,
Ithaca, NY,
June 16–20, 1997,
and to be published in
the Proceedings



DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Ernest Orlando Lawrence Berkeley National Laboratory
is an equal opportunity employer.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LBNL-40471
LSBL-394
UC-410

MEASUREMENT OF DIFFRACTION GRATINGS WITH A LONG TRACE PROFILER WITH APPLICATION FOR SYNCHROTRON BEAMLINE GRATINGS

S.C. Irick and W.R. McKinney

Advanced Light Source
Ernest Orlando Lawrence Berkeley National Laboratory
University of California, Berkeley, California 94720

*This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division, of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

Measurement of diffraction gratings with a Long Trace Profiler with application for synchrotron beamline gratings

S. C. Irick and W. R. McKinney
University of California,
Lawrence Berkeley National Laboratory
Advanced Light Source
Berkeley, CA 94720, USA

Abstract

The Long Trace Profiler (LTP) is used primarily for measuring the figure of long synchrotron beamline mirrors. The LTP has also been used for measuring the figure of the substrate of beamline gratings. We propose a method for measuring the effective figure that comes from the grating groove pattern on the substrate of long beamline gratings. Analysis of grating groove patterns can be useful in determining cause of poor imaging of the diffracted light, but requires investigation of small changes of the groove frequency over the entire clear aperture of the grating.

A diffraction grating that is small enough to be measured by a general purpose six inch aperture interferometer is measured by both this interferometer and the LTP, so that results for two different instruments may be compared. The height profile of the substrate light (m = 0) measurement is subtracted from the height profile of the diffracted light (m = 1) measurement, and the result is the effect of only the diffraction from the grooves along the entire surface. This procedure is also used for a diffraction grating that is too long to be measured by the general purpose interferometer, but is easily measured by the LTP.

Introduction

Focusing X-rays onto a small spot has placed difficult requirements on production of optical components in synchrotron beamlines. These requirements have spawned new instrumentation over the last few years. One of these instruments is the Long Trace Profiler[1,2,3,4], which is able to characterize the slope profile over the length of a mirror. The slope profile s(x) may be integrated with respect to the measurement direction x, in order to get a height profile h(x) which can be compared to results from other height-measuring instruments. However, the slope profile is often retained for a more direct analysis of mirror imaging performance. In other words, if the light source is a simple geometric shape (e.g. a point), then the image will be a distribution of light that is directly related to the slope function of the imaging mirror.

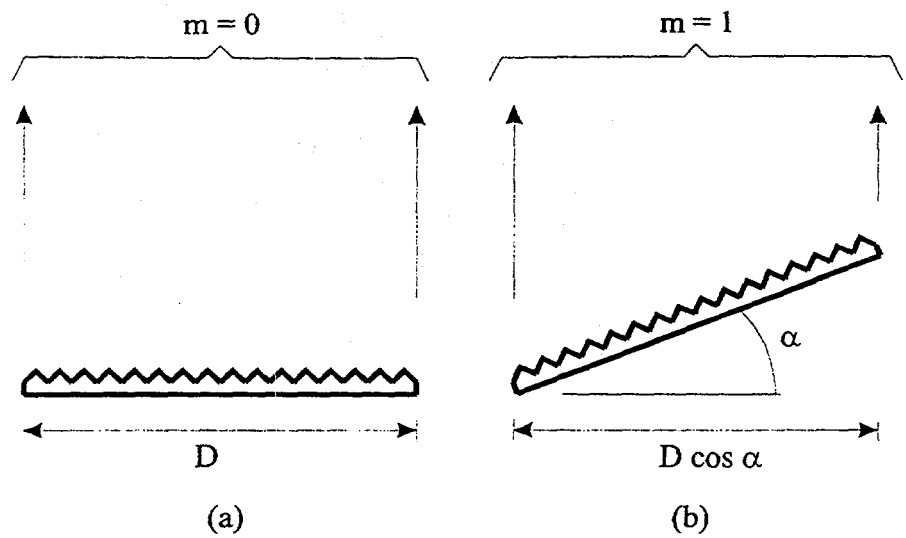


Figure 1. Rays of specular reflection (a) and rays of first order diffraction (b) returning to the measuring instrument.

$\Delta x_1 = 0.9157$ mm. This ensures that there will be the same number of data points in each measurement, and the measurements may easily be compared. Figure 2 gives results of those LTP measurements as slope profiles.

Likewise, care must be used when measuring the grating for both orders with the Zygo GPI. Just before the grating is measured for m = 0, the Zygo system is calibrated for lateral length. The outside dimensions of the grating are known accurately, so this may be used as a calibration standard. Just before the grating is measured for m = 1, the Zygo system is zoomed to a magnification of $M = 1 / \cos \alpha$, and the calibration is not changed. This ensures a constant correspondence between the measurement points for m = 0 and m = 1.

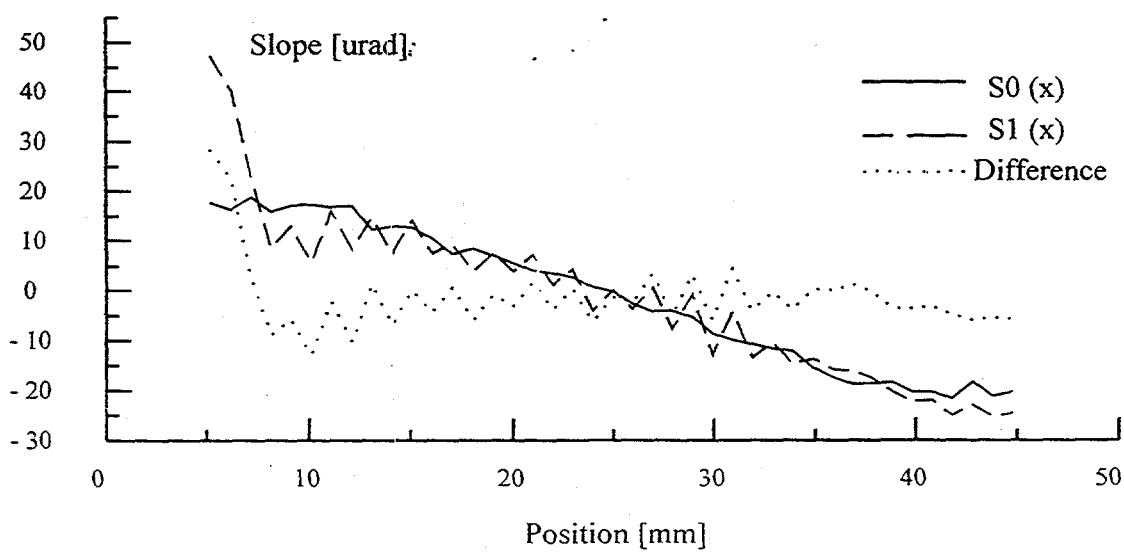


Figure 2. Slope measurements from the LTP.

Measurement of a long beamline grating

Many commercial profiling instruments are inappropriate for measuring X-ray beamline components, not only because the instrument aperture is too small but also because the fringes of high-curvature surfaces cannot be resolved. This is the case for the diffraction grating from the ALS beamline 7.3.1. The grating clear aperture is 217 mm long, and the grating's substrate has a specified radius of curvature of R = 250 meters. For the LTP, however, this is a routine measurement.

Again, to measure the m = 1 diffracted order the grating is tilted by an angle α in order to give a Littrow condition. Figure 4 shows height profiles of a center trace of the grating. Although the two measurements are almost on top of each other (dashed and dotted lines in Figure 4), their difference gives the effect of the grating grooves alone. This grating groove effect (solid line in Figure 4) has a convex height profile. The radius of curvature of this convex profile is 16000 m, so the grating's substrate curvature (R = 250 m) is effectively reduced by a small amount.

As mentioned earlier, it is often more instructive to retain the measurement results as slope profiles. Figure 5 shows the slope function $s(x) = s_1(x) - s_0(x)$. The maximum and minimum slope values can then be used to determine the amount of groove spacing change. The optical arrangement is the Littrow condition, but the incident angle is constant; only the diffracted angle β changes with groove frequency f change.

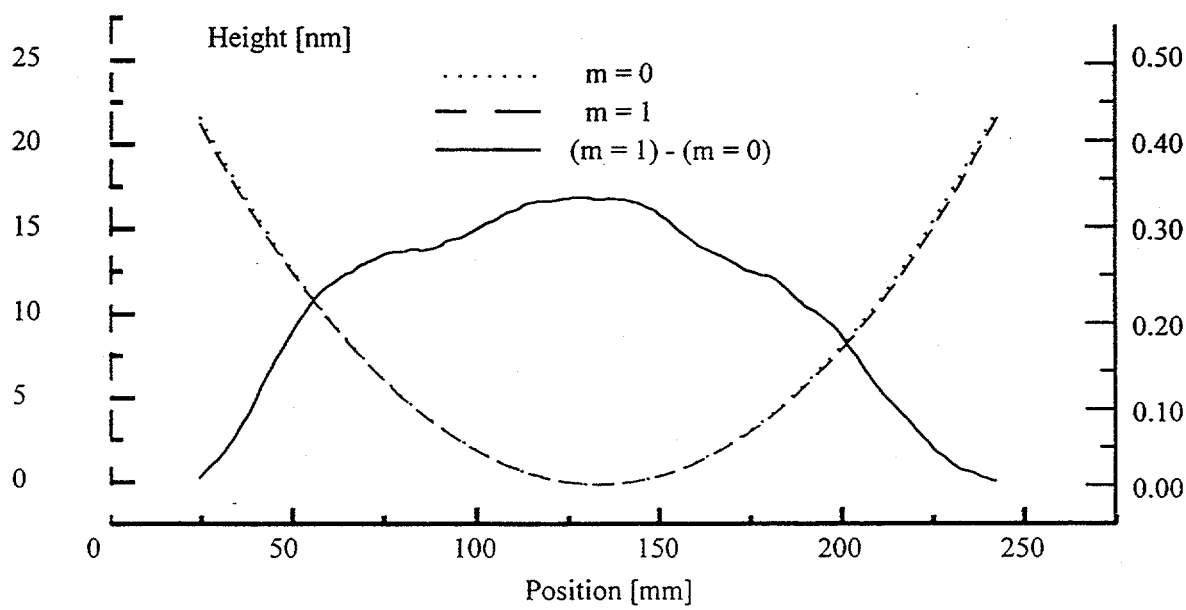


Figure 4. Measurements of the beamline 7.3.1 grating.

To check this value of $\Delta f / f$, it was suggested to measure the grating with an atomic force microscope (AFM). The BL 7.3.1 grating was measured by the AFM at the positions corresponding to approximately x = 40 and x = 220 in Figure 5, where the largest slope variations occur. At each of those positions an area of 75 μm x 75 μm was scanned with a resolution of 256 x 256 points. A rough measurement of groove frequency was obtained by determining the distance between cursors in the analysis section of the AFM program. A much more accurate way of determining groove frequency was to take the Fourier transform of a height profile along a line perpendicular to the grooves. This was done for 1) several orders of the transform at the center of each measurement and for 2) the +1 and -1 orders of the transform at several places in each measurement. Table 1 shows the results of the AFM measurement of the grating.

Method	Position : x = 40	x = 220	$\Delta f / f$
Average 12 orders of center of area	200.70347	201.06363	0.0018
Average +1, -1 orders at five places in area	193.424	193.461	0.000185

Table 1. AFM measurements on the BL 7.3.1 grating. Values are for f [grooves/mm].

If both methods of determining groove frequency in Table 1 are valid, then a huge error bar of 1000% must be placed on this measurement. If the measurement of the first method (averaging many orders) is influenced too much by higher frequency noise, then the second method should be more believable. Clearly this analysis points out the difficulty in quantifying AFM lateral measurements. Of more importance is the direction of frequency change. For both methods the frequency is greater at x = 220. In Figure 1(b) the diffracted ray at the left will be inclined away (clockwise) from a ray of m = 0. This corresponds to a lower slope value, which agrees with a lower slope value at x = 220 in Figure 5.

Conclusion

Using a LTP has shown to be a useful and valid method for measuring the diffracting surface of a long beamline grating. Measurements of a small grating show good agreement between the LTP and Zygo large aperture interferometer. Many long beamline gratings can be measured only on the LTP.