Ex situ metrology of x-ray diffraction gratings

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The idea of measurements of groove density distribution of diffraction gratings suggested and first realized in Ref. [1] consists of determination of the spatial frequency of the first harmonic peak appearing in the power spectral density (PSD) distribution of the grating surface profile observed with a microscope. Using a MicroMap™-570 interferometric microscope, it was experimentally proven that this technique is capable for high precision measurements with x-ray gratings with groove density of about 250 grooves/mm varying along the grating by ±5%.

In the present work, we provide analytical and experimental backgrounds for reliable application of PSD characterization of groove density of diffraction gratings.

We analyzed the shape of the first harmonic peak and derive an analytical fitting function suitable for fitting of the PSD peaks obtained with gratings with a variety of groove shapes. In the case of a gratings with an rectangular groove shape, a reliable fitting function with a limited number of parameters is

$$Fit(f) = A + B \cdot Log\left[\left((f - f_1)^2 + \eta \cdot (w/2)^2\right) \Big/ \left((f - f_1)^2 + (w/2)^2\right)^2\right] + C \cdot (f - f_1), \quad (1)$$

where f is the spatial frequency, and fitting parameters are the peak position f_1, the peak width w, and the constants η, A, B, and C.

Figure 1 presents a result of fitting with the function (1) of a PSD peak profile of a diffraction grating with 300 grooves/mm, measured with a ZYGO™ NewView-7300 interferometric microscope at 20× magnification. The estimated accuracy for the best-fit

value of the spatial frequency of the peak in Fig. 1 is 0.2 grooves/mm.

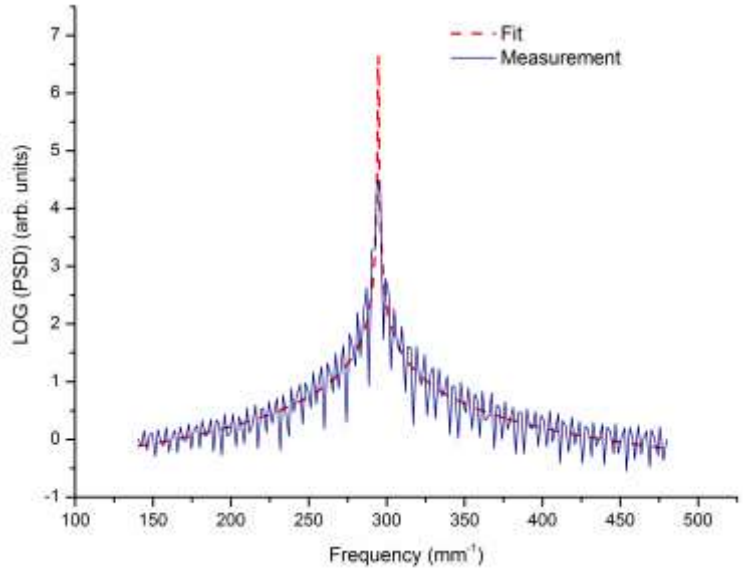

Figure 1: Blue solid line corresponds to the profile of the first harmonic peak in the PSD distribution obtained from surface profile measurements with a grating with 300 grooves/mm. Red dashed line reproduces the result of fitting with the function (1).

Equation (1) is derived assuming a large number of spatial frequency points across the measured PSD intensity peak. In the case when the number of points per one grating period is just a few, the PSD measurements strongly depend on the mutual alignment of the grating groove phase with respect to the pixel grid of the detector CCD camera. The closer the spatial frequency of the grating to the Nyquist frequency of the microscope, the larger the perturbation of the peak shape that is observed. This and other sources of peak shape perturbation are discussed throughout the work.

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REFERENCES

[1] V. V. Yashchuk, A. D. Franck, S. C. Irick, M. R. Howells, A. A. MacDowell, W. R. McKinney, *Two dimensional power spectral density measurements of X-ray optics with the Micromap interferometric microscope*, Proc. SPIE **5858**, 58580A/1-12 (2005).

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