Title

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21st Century Metrology for Synchrotron Radiation Optics – Understanding How to Specify and Characterize Optics

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As early as 1989 [1,2], E. Church and P. Takacs presented a systematic theoretical foundation for characterization of X-ray optics in terms of imaging system performance, accounting for surface figure and finish errors. Physically, the distinction between figure and finish errors reflects two regimes of scattering, specular and diffuse scattering. In Refs. [1,2], both figure and finish of a mirror surface were treated statistically based on the power spectral density (PSD) distribution for the surface profile. Such an approach naturally leads to specification and characterization of figure and finish of X-ray optics in the terms of slope variation (rms) and roughness (rms), respectively. In the present work, we demonstrate the limitations of specification, characterization, and performance evaluation based on the totally statistical approach. The limitations arise due to the fundamentally deterministic character of the surface profile data at lower spatial frequency measured for a specific mirror. Due to the deterministic character of the mirror figure, detrending and windowing procedures usually applied to the measured profile before estimating the PSD distributions, can significantly effect the estimated PSD distributions. This in turn gives rise to uncertainty while evaluating system performance based on the PSD distribution. An example of a figure leading to a fatal performance violation is a two-facetted mirror surface. For such a surface the image intensity distribution consists of two peaks. To overcome these problems, we suggest an extension of the approach developed in Refs. [1,2]. The deterministic character of the surface finish is accounted for by a direct specular scattering calculation. In the simplest case, such a calculation can be performed with a ray-tracing code. For each ray-trace, image variation due to the finish errors are still treated statistically based on the PSD distribution measured at higher special frequencies. As a result, the image intensity distribution is estimated and compared with the parameters specified for the system. The effectiveness of the approach is demonstrated with a number of examples. We also propose a systematic method for the integration of our ideas into the development of a new level of 0.1 μrad optics for 3rd and 4th generation sources, including new and more accurate Long Trace Profilers, and the establishment of International standards for evaluation of the PSD at specific frequencies. This work was supported by the U. S. Department of Energy under contract number DE- AC02-05CH11231.

Keywords: X-ray optics metrology, power spectral density, X-ray optics specification

[1] E. L. Church and P. Z. Takacs, *Specification of surface figure and finish in terms of system performance*, Applied Optics 32(19), 3344-53 (1993).
[2] E. L. Church and P. Z. Takacs, *Specification of glancing- and normal-incidence X-ray mirrors*, Optical Engineering 34(2), 353-60 (1995).