Design of wavefront sensors for the Advanced Light Source Upgrade (ALS-U)

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The advent of fourth-generation light sources such as Diffraction Limited Storage Rings (DLSR) and FELs [1] enables a dramatic increase in brightness and coherent flux, provided that beamlines can maintain diffraction-limited performance [2]. In October 2016, the Department of Energy, Basic Energy Science, funded a 2-years long R&D project, to define a valid path toward wavefront preservation, and we are focusing our wavefront sensor design efforts on existing and proposed, high-coherent-flux beamlines.

We describe a set of design guidelines for the emerging class of wavefront sensors planned for diffraction-limited soft x-ray (SXR) and tender x-ray (TXR) beamlines, where nanometer-scale mirror surface imperfections, including contamination, misalignments, and time-varying thermal and mechanical distortions all conspire to degrade the wavefront quality [3]. A wide variety of wavefront sensors currently provide accurate and detailed wavefront shape feedback in many fields of advanced optics, including short-wavelength applications. Wavefront information is essential for assessment, alignment, and correction, including the available alignment degrees of freedom and active, adaptive elements.

Our studies concentrate on grating-based lateral shearing interferometry (LSI, [4]) and Hartmann wavefront sensors (HWS, [5]). These two techniques share similar hardware and detector requirements; both enable rapid, one- and two-dimensional wavefront measurements without the need for scanning elements. Our approach seeks to identify designs that satisfy a number of pragmatic constraints, including the number and density of fringes, the shear magnitude (for LSI), and beamlet diffraction/overlapping (for HWS), among other factors. Millimeter-scale beam widths and low numerical aperture values (e.g. 500 μrad) are among the significant challenges, and we apply our methodology on a notional beamline of the proposed upgrade of the Advanced Light Source (ALS-U) to derive workable designs.

In addition, the measurement signal-to-noise ratio must be high enough to sense wavefront errors imparted by sub-nm mirror figure error, and slope errors lower than 50 nrad. Sensitivity depends strongly on the design geometries: we provide figures of merit derived from numerical simulations, and discuss ways to adjust the performance to suit the measurement needs dynamically. This work is supported under DOE contract DE-FOA- 0001414 and DE-AC02-05CH11231

References

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