Wavefront Preserving Mirrors for Free Electron Laser and Diffraction Limited Storage Ring applications

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With the Diffraction Limited storage rings (DLSR) at the horizon and the Free Electron Lasers (FEL) in rapid expansion, the challenge for the optical designers is to achieve a diffraction-limited spot in the experimental chamber and preserve the wavefront along the beamline. Moreover, the demand of working out of focus, preserving the wavefront and the beam homogeneity, poses further challenges. The recent upgrade of the Hard X-ray mirrors at LCLS, briefly presented in this article, have shown the achievability of a uniform beam out of focus. But, this has been reached without heat load induce deformation on the mirrors.

In the presence of a high heat load, the thermal bump prevents from preserving the beam uniformity. The challenges, in cooling the optics are even more severe in the case of FELs. In fact, differently from what happens in the 3^{rd} generation storage rings, the power transported by the beam, is not filtered enough, or not at all, from the monochromators. This implies using cooling schemes on all the optics along the beamline, including bendable mirrors, whenever present.

In October 2016, the Department of Energy, Basic Energy Science, funded a 2-years R&D project, involving the four DOE labs hosting large-scale facilities, SLAC, ANL, BNL and LBNL. It is aimed to find a valid path toward wavefront preservation in the presence of high heat load sources and, on the relative beam characterization (based on wavefront sensor technology). Within this framework, under contract DE-FOA-0001414, a novel cooling scheme, called REAL (Resistive Element Adjustable Length) has been proposed, designed and tested. The idea behind this cooling scheme, is to homogenize power distribution on the mirror, by applying extra heat load outside the area irradiated by the beam. To achieve this, some controllable heaters are directly connected to the cooling circuit of the mirror. Depending on the beam footprint and intensity/power, a sub array of heater is put in operation with a well defined power. Several tests, to asses the feasibility and accuracy of the system, have been successfully performed in the optical metrology laboratory of LCLS/SLAC. They show that it is possible to preserve sub-nm figure accuracy, also in the presence of several watts absorbed by the mirrors.

To implement this cooling scheme on a beamline, it is mandatory to have a feedback system to optimize the mirror shape. For this reason, tests on wavefront sensors are part of the funded R&D project. Preliminary tests on an Hartman sensor realized by Imagine Optic will be presented, showing it has the needed sensitivity to optimize the mirror shape to the level required by DLSR and FELs.

The expected performance of the beamlines for LCLS II will be also presented, including the effect of thermal deformations. It will be shown how the use of the REAL cooling will improve the performance. Nonetheless, a way of mitigating the effect of thermal bump, even without active cooling compensation, will be also presented.