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Ultra-intense sub-10 nm focusing at a hard X-ray FELs

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X-ray mirrors are essential for transporting and focusing X-rays in synchrotron radiation beamlines, thanks to their high reflectivity and minimal chromatic aberration. Recent progress in ultra-precise surface finishing and testing techniques [1-3] has enabled the creation of mirrors with accuracies reaching the 1-nm level. This has made it possible to achieve focusing down to 50-30 nm using Kirkpatrick–Baez (KB) geometry. However, sub-10 nm focusing at X-ray free-electron laser (XFEL) sources remains a significant challenge due to comatic aberration in KB geometry and unavoidable source pointing/angular jitter, which degrade the focusing conditions. Past methods used a secondary source slit to precisely define the source position, but this resulted in substantial photon loss, undermining the high-peak-brilliance characteristics of XFELs.
In this study, advanced KB (AKB) mirrors were utilized to achieve sub-10 nm XFEL beam focusing. These AKB mirrors, consisting of one-dimensional Wolter mirrors, reduce comatic aberration by satisfying Abbe's sine condition, ensuring stable nanofocusing with greater tolerance to incident angle errors. Building on mirror characteristics and tuning strategies from previous developments in full-field imaging [4,5], we designed multilayer-coated advanced KB nanofocusing mirrors based on Wolter-type III geometry. The mirrors have been fabricated by a wavefront correction method [6,7] and achieved an accuracy of less than λ/15 in root-mean-square. Consequently, the ultra-intense XFEL sub-10 nm focusing system without the secondary source slits has been established at SACLA. The achieved focus, evaluated by the ptychography, indicated the spot size of 7 × 7 nm2 which corresponds to an XFEL intensity of 1.45 × 1022 W/cm2, representing the highest XFEL intensity ever recorded [8].
The presentation will showcase the AKB mirror development results, specifically the design and fabrication of sub-10 nm XFEL focusing mirrors, along with demonstrations of their reliable focusing performance.
References:
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