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Signatures of Misalignment in X-Ray Cavities of Cavity-Based X-Ray Free-Electron Lasers

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Cavity-based x-ray free-electron lasers (CBXFEL) will allow use of optical cavity feedback to support generation of fully coherent x-rays of high brilliance and stability by electrons in undulators. CBXFEL optical cavities comprise Bragg-reflecting flat crystal mirrors, which ensure x-rays circulation on a closed orbit, and x-ray refractive lenses, which stabilize the orbit and refocus the x-rays back on the electrons in the undulator. Depending on the cavity design, there are tens of degrees of freedom of the optical elements, which can never be perfectly aligned. Here [1], we study signatures of misalignment of the optical components and of the undulator source with the purposes of understanding the effects of misalignment on x-ray beam dynamics, understanding misalignment tolerances, and developing cavity alignment procedures. Betatron oscillations of the x-ray beam trajectory are one of the characteristic signatures of cavity misalignment. The oscillation period is in the general case a non-integer number of round-trip passes of x-rays in the cavity. This period (unlike the amplitude and offset of the oscillations) is independent of the type of misalignment and is defined by cavity parameters. The studies are performed on an example of a four-crystal rectangular cavity [2] using analytical and numerical wave optics as well as ray-tracing techniques.

References:
[1]. Peng Qi and Yuri Shvyd'ko, *Phys. Rev. Accel. Beams*, **25** (2022) 050701
[2]. G. Marcus, et al., CBXFEL R&D: A Joint Argonne National Laboratory and SLAC National Laboratory Collaboration, *FEL2019, doi:10.18429/JACoW-FEL2019-TUD04*

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