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High Gradient Cryo-RF Enabled Hard X-ray Free-electron Laser for Chip Metrology

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Recently, muc work has been directed at R&D a ultra-compact X-ray FEL (UC-XFEL) based on rapidly emerging techniques in high field cryogenic acceleration, attendant dramatic improvements in beam brightness, and state-of-the-art concepts in beam dynamics, magnetic undulators, and X-ray optics. A full conceptual design of a 1 nm XFEL with a length and cost over an order of magnitude below current XFELs has been developed. This instrument has been conceived with an emphasis on permitting exploratory scientific research in a university setting. Concurrently, compact FELs are undergoing rapid development for use in next-generation chip manufacturing as a high flux, few-nm lithography source. This new role suggests consideration of XFELs to address urgent demands in this sector, as identified by recent national need studies, for new radiation sources aimed at chip manufacturing: a coherent hard X-ray source which enables frontier metrology methods. Indeed, it has been shown that one may use coherent X-rays to perform few nm-resolution surveys of macroscopic structures using ptychographic tomography. As the XFEL is an extremely promising candidate for realizing such methods, we present here an analysis of the issues and likely solutions associated with extending the UC-XFEL to X-rays above 7 keV, much higher fluxes, and methods of applying such a source to ptychographic tomography for micro-electronic device measurements. We discuss the development path to move the concept to rapid realization.

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