Advanced Intraundulator Electron Beam Diagnostics Using COTR Techniques*

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Abstract. A significant advance in intraundulator electron-beam diagnostics has recently been demonstrated based on coherent optical transition radiation (COTR) imaging. We find signal strengths from a microbunched beam in a UV-visible free-electron laser to be several orders of magnitude higher than that of incoherent optical transition radiation. In addition we report that the far-field images of COTR interferograms carry information about beam size and asymmetry, divergence, and pointing.

INTRODUCTION

One of the standard means of imaging electron beams is the use of optical transition radiation (OTR) as the conversion mechanism [1-4]. Its inherently good spatial resolution and ultrafast time response must be balanced with its lower conversion efficiency in some applications with bright beams. However, in the case of microbunched electron beams, we report a significant advance in intraundulator diagnostics based on the signal enhancements and structure observed in coherent optical transition radiation (COTR). Longitudinal microbunching of the electron beam occurs as it copropagates with the emitted synchrotron radiation within the undulator. The density modulation develops at the fundamental wavelength of the light, which leads to a growing fraction of electrons emitting in phase, or coherently. A favorable instability results in an exponential growth of the light generation in a self-amplified spontaneous emission (SASE) free-electron laser (FEL) [5-8]. The signal strength now goes as the square of the number of particles involved $(b_n N)^2$, where b_n is the amplitude of the Fourier component of the electron distribution with spatial frequency k_n, and N is the total number of particles. We have routinely had to use neutral density (ND) filters providing attenuation factors of 10^4 to 10^5 (!) for COTR from 200-pC electron beams that have been microbunched. This would be an unheard of scenario with OTR imaging, and the light yield exceeds most scintillators.

In the case of the Advanced Photon Source (APS) FEL operating in the UV-visible regime, we have used standard CCD imaging cameras to obtain near-field, far-field, and spectral information on the COTR [9-12]. In addition to the unprecedented signal

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