Self-amplified spontaneous emission saturation at the Advanced Photon Source free-electron laser (abstract) (invited)[a)]

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Today, many bright photon beams in the ultraviolet and x-ray wavelength range are produced by insertion devices installed in specially designed third-generation storage rings. There is the possibility of producing photon beams that are orders of magnitude brighter than presently achieved at synchrotron sources, by using self-amplified spontaneous emission (SASE). At the Advanced Photon Source (APS), the low-energy undulator test line (LEUTL) free-electron laser (FEL) project was built to explore the SASE process in the visible through vacuum ultraviolet wavelength range. While the understanding gained in these experiments will guide future work to extend SASE FELs to shorter wavelengths, the APS FEL itself will become a continuously tunable, bright light source. Measurements of the SASE process to saturation have been made at 530 and 385 nm. A number of quantities were measured to confirm our understanding of the SASE process and to verify that saturation was reached. The intensity of the FEL light was measured versus distance along the FEL, and was found to flatten out at saturation. The statistical variation of the light intensity was found to be wide in the exponential gain region where the intensity is expected to be noisy, and narrower once saturation was reached. Absolute power measurements compare well with GINGER simulations. The FEL light spectrum at different distances along the undulator line was measured with a high-resolution spectrometer, and the many sharp spectral spikes at the beginning of the SASE process coalesce into a single peak at saturation. The energy spread in the electron beam widens markedly after saturation due to the number of electrons that transfer a significant amount of energy to the photon beam. Coherent transition radiation measurements of the electron beam as it strikes a foil provide additional confirmation of the microbunching of the electron beam. The quantities measured confirm that saturation was indeed reached. Details are given in Milton *et al.*, Science **292**, 2037 (2001) (also online at www.sciencexpress.org as 10.1126/science. 1059955, 17 May 2001), and Lewellen *et al.*, ''Present Status and Recent Results from the APS SASE FEL,'' to be published in the Proceedings of the 23rd International Free-Electron Laser Conference, Darmstadt, Germany, 20–24 August 2001.
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