

A Quick Note on the Possible Usefulness of Coherent Microbunching as a Diagnostic in the Early Stages of the LCLS Undulator

William Fawley – LBNL – 21 January 2004

Following the discussion Tuesday afternoon on the difficulty of picking up the coherent (FEL) signal out of the spontaneous emission, I quickly looked on my laptop for an example of a GINGER LCLS SASE run which would illustrate my claim that the coherent bunching in a narrow bandwidth quickly comes out of the general noise background. Fortunately, I had such an example of the Linux side of my beast and after rerunning the post-processor to get the bunching spectrum, I think my assertion is well-founded.

The example comes from a run I did a few years ago for the then standard LCLS with a drift-free FODO lattice, 1.2 mm-mrad normalized emittance. As shown in Fig. 1 the FEL power saturates in about 85 m at a level of 20 GW and has a gain length of ~ 4.4 m. In Fig. 2, the time-averaged microbunching is plotted versus z and one sees that the peak is about 0.37.

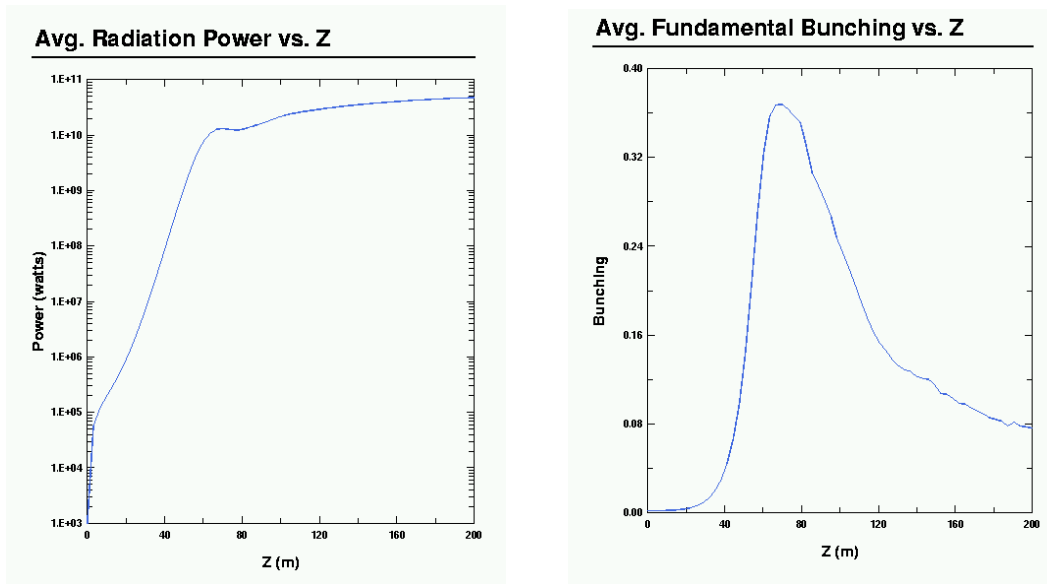


Fig. 1 & 2: Time-averaged radiation power and microbunching vs. z .

A couple years ago I implemented a diagnostic within GINGER which would calculate the spectrum of the instantaneous microbunching $b(\omega)$ at a given z . This is possible because GINGER diagnoses both the amplitude and phase of the instantaneous bunching $b(t)$. At visible wavelengths, the emitted intensity of coherent optical transition radiation will be proportional to $b^2(\omega)$. Figures 3-5 below plot $b(\omega)$ on a linear scale; to reduce the noise level, I have averaged the spectra over four bins (which is still much smaller than the RMS bandwidth). One sees that by the 9.5 m position the bunching in a 1% bandwidth is nearly double the incoherent bunching and by 15.7 m the coherent signal to noise ratio in

a 0.6% bandwidth is better than 10:1. So, all the collective we need to do is figure out a robust (and inexpensive way) to measure the bunching in a narrow bandwidth at x-ray wavelengths without significant problems arising from the incoherent spontaneous radiation.

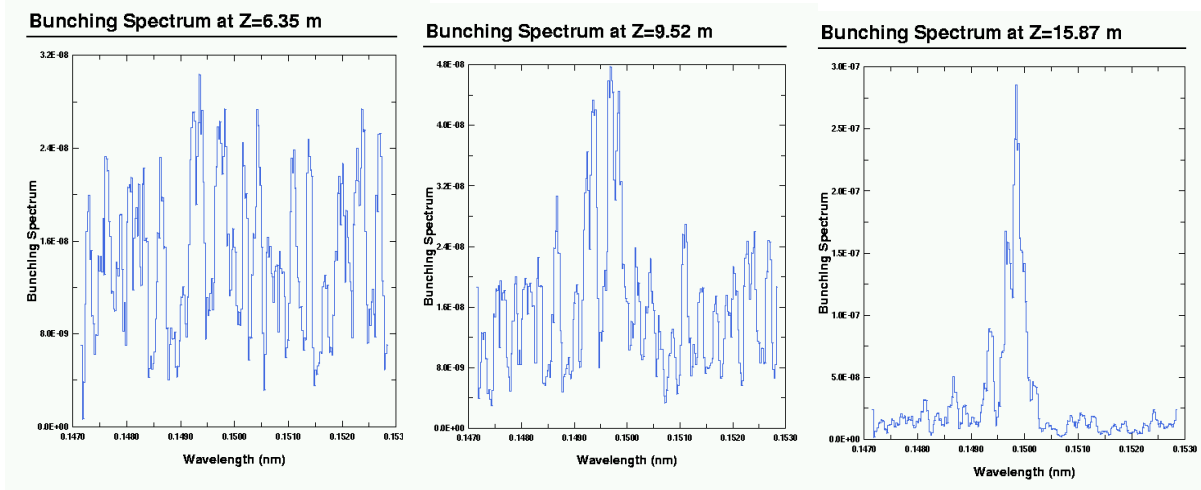


Fig. 3 – Microbunching spectra at three locations in the early part of the undulator.

Analytically, one can predict the relative growth of the microbunching by employing the dispersion relation for the various modes which predicts a growing mode, a decaying mode, and a purely oscillatory mode. At one gain length in the power, the enhancement in COTR is $(2 \cosh(0.5) + 1)^2 / 9 = 1.18$. At two gain lengths, the enhancement is 1.85. At three and four gain lengths is 3.6 and 8.1, respectively. So presuming we can pick an appropriate bandpass and do some shot-to-shot averaging, in “theory” one should pick up the enhanced COTR by two gain lengths in power from the beginning of the undulator.