Coherent Far IR Bursts Measured at BL 1.4.2

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INTRODUCTION

We have performed the first measurements at the ALS of coherent far-IR bursts coming from instabilities within a high-current single electron bunch.

The 2-bunch mode operations of the ALS afforded us the opportunity to use the machine while it was tuned for high currents in individual electron bunches. We have used a number of accelerator physics shifts to make measurements with well-controlled setups as well as additional measurements during normal 2-bunch operations. Recent investigations at other light sources [1-6] have observed far-IR bursting at high bunch currents. We want to investigate these bursts more carefully towards the goal of understanding how to make use of high-intensity coherent far-IR synchrotron light as a new source of far-IR that is many orders of magnitude brighter than the best presently available sources.

TIME DOMAIN MEASUREMENTS

As an initial investigation into coherent far-infrared synchrotron radiation we placed a liquid He cooled Silicon Bolometer with integrated pre-amplifiers just outside a 20 mm diameter diamond window mounted in the 'switchyard' at Beamline 1.4. A single extra mirror was inserted in the switchyard to direct the collimated beam through this window into the bolometer without disturbing the alignment of the IR beamlines. A digitizing oscilloscope recorded the output of the detector. We observed large intensity bursts when the single bunch current was very high. Fig. 1 shows time traces of the bolometer output voltage for three different beam currents in single bunch operation. Although the bursts seemed to be quasi-random, at certain currents the bursts occurred within a periodic envelope, as evidenced by the middle trace in Fig. 1. The rise and fall times of the bursts were detector limited, therefore the damping mechanism may not be inferred immediately. The single bunch current threshold for the onset of

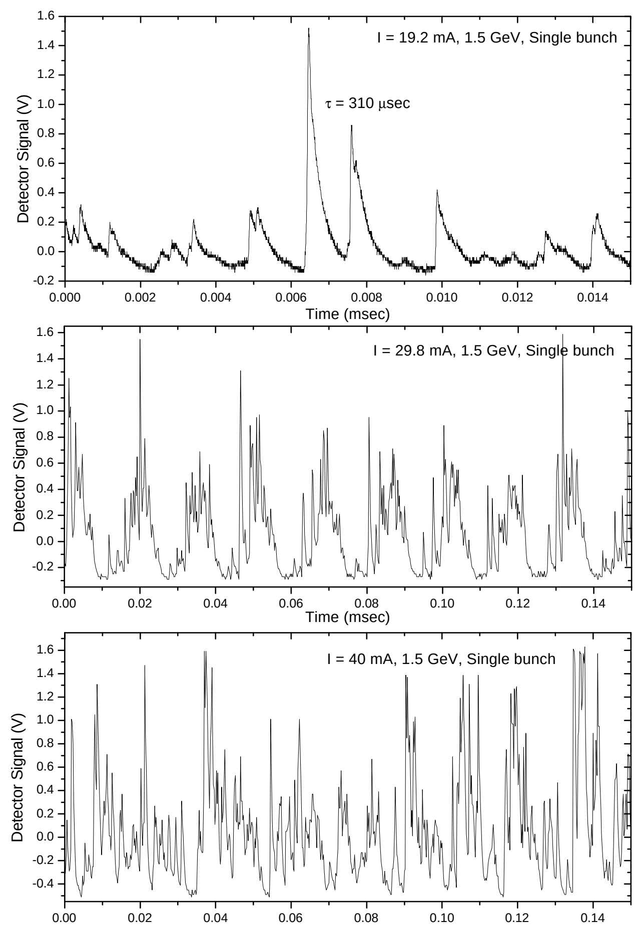

Figure 1. Far-IR detector signal vs time for three different beam currents. Note the expanded time scale for the top panel.

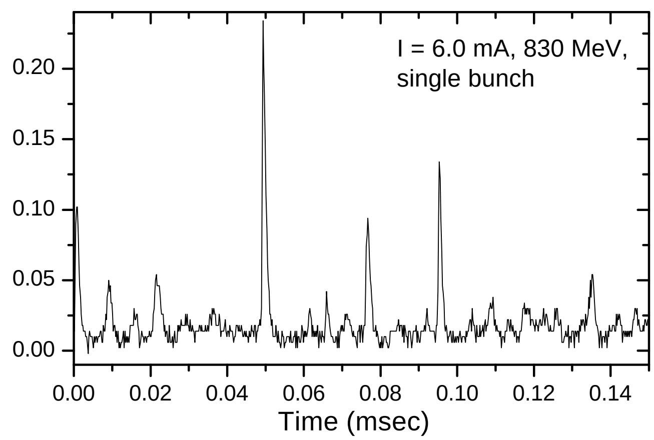

Figure 2. Bursting observed at 830 MeV which shows a quite different time envelope.

bursts is approximately 7 mA at 1.5 GeV. The transition to bunching of the bursts within a super period occurs at about 27 mA at 1.5 GeV.

Since the bursts seem to be related to high peak currents within a bunch, reducing the RF power will lengthen the bunch and therefore cause the bursts to stop. At 14 mA and 1.9 GeV, the bursts go away by reducing the RF power from 120 to 90 KW; returning to 120 KW causes the bursts to reappear. At 1.5 GeV and 14 mA, the bursts can be stopped by dropping the RF power from 120 to 1.5 KW.

A measurement of the bursting at 830 MeV electron energy at 6 mA single bunch current showed distinctly different time behavior as shown in Fig. 2.

SPECTRAL MEASUREMENTS

By using a combination of filters with the above setup we determined the spectral content of the bursts was below 100 cm^{-1} (wavelengths longer than 100 microns). To make this more quantitative, we used the Bruker 66v/S FTIR spectrometer on BL 1.4.2 to measure the bursts that occur at the very top of the fill during regular 2-bunch mode operations. By quickly averaging 100 interferograms over 50 seconds we integrated long enough to demonstrate the average spectral content of the bursts. Shown in Fig. 3 is the measured intensity of the bursts as a function of wavelength, ratioed to the incoherent synchrotron signal measured at low beam current. The bursts are peaked at ~27 cm^{-1}. This indicates a microbunching within the electron bunch having a period on the order of 400 microns (or approximately 30 times smaller than the normal ALS bunch length). The bursting was clearly dependent on the beam energy, with higher intensity at 1.5 GeV. This is to be expected, as the bunch length is proportional to $E^{3/2}$, implying higher peak currents at 1.5 GeV than 1.9 GeV, and therefore a greater tendency for instabilities and hence microbunching. Overall, the burst intensity dropped with decreasing beam current, with the spectral content remaining essentially unchanged.

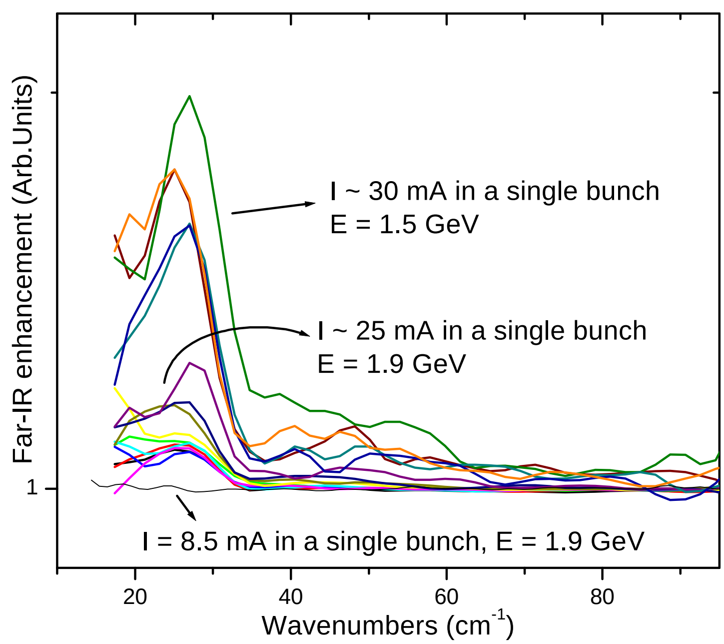

Figure 3. Spectrum of coherent far-IR bursts measured at Bl1.4.2 as the current was decaying.

We are continuing these measurements to gain a greater understanding into coherent synchrotron emission both from instabilities (as measured here) and hopefully in a stable manner. In the near future, we will make additional measurements using femtosecond sliced electron bunches (in collaboration with the femtosecond x-ray team at LBNL) which will allow a clean study of coherent emission from a well known transient short bunch. Because this will be a laser pumped measurement with synchronized optical detection, electron beam instabilities and oscillations will not be a factor. We have also collaborated with researchers at Brookhaven National Laboratory and Thomas Jefferson National Laboratory to measure the coherent far-IR emitted from a bend magnet in their energy-recovery linear accelerator based infrared free electron laser [7] (reported in a separate compendium abstract).

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