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Memorandum

To: D. Chemla, Z. Hussain, H. Padmore, and D. Robin

From: Michael C. Martin, John Byrd, and Wayne McKinney

Subj: **Interesting Far IR Bursts Measured at BL 1.4.2**

Last week we performed the first measurements at the ALS of coherent far-IR bursts coming from instabilities within a high-current single electron bunch. This is the first experiment in our funded LDRD research on coherent far-IR from accelerators. The results are summarized here, with three figures attached in PDF format.

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 used one accelerator physics shift to make measurements with a well-controlled setup as well as additional measurements during normal 2-bunch operations. Two previous investigations (at the NSLS and Maxlab) 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 a first preliminary 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. The output of the detector was recorded by a digitizing oscilloscope borrowed from the control room. 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 time of the bursts was detector limited, while the fall time was approximately exponential with a time constant of ~310 microseconds, as is seen in the top trace in Fig. 1. This corresponds to less than 3 synchrotron oscillation periods, therefore the damping mechanism may not be inferred immediately. The threshold for the onset of 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.

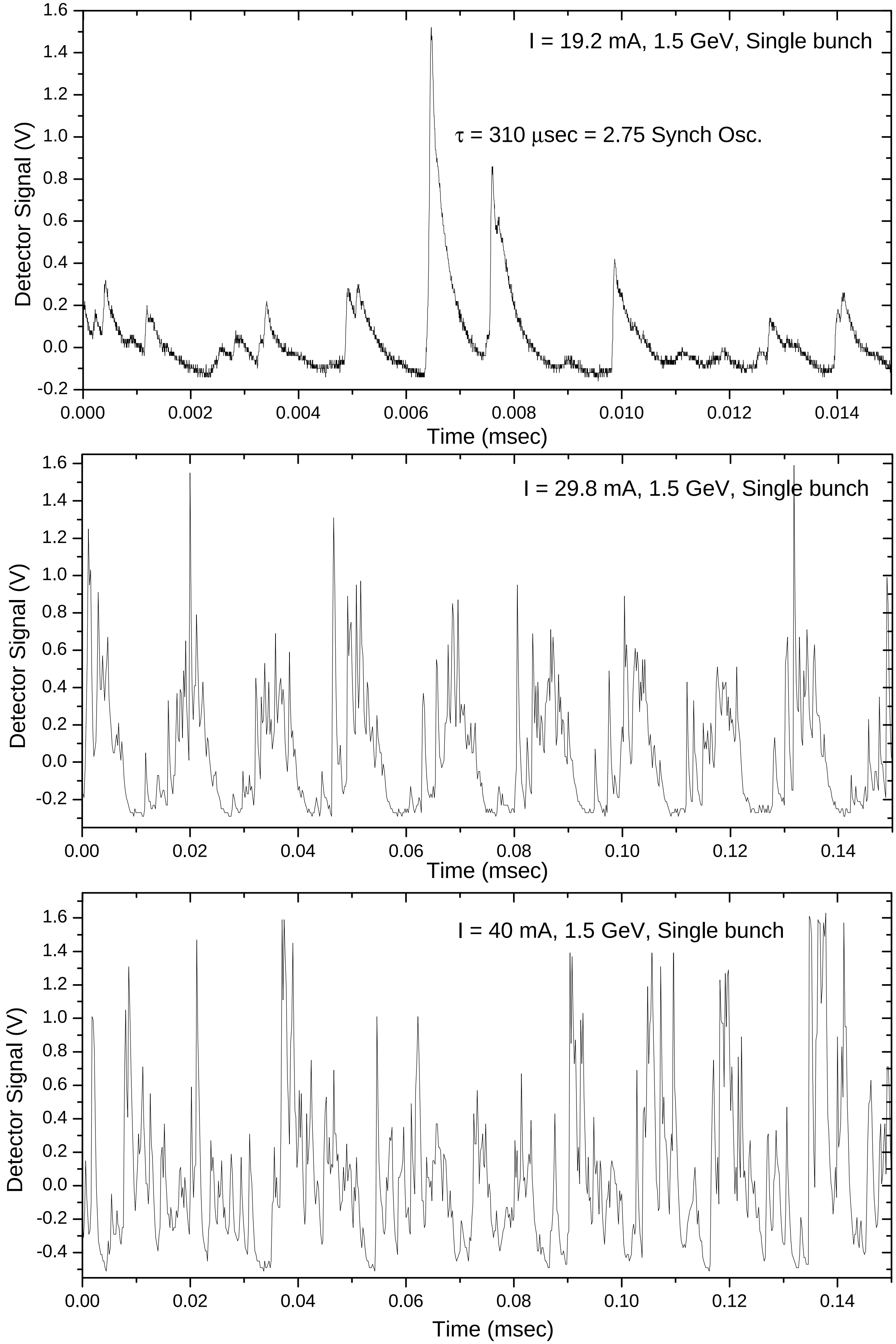
Since the bursts seem to be related to high peak currents within a bunch, reducing the RF power will lengthen the bunch and therefore cause the bursts to stop. At 14 mA and 1.9 GeV, the bursts go away by reducing the RF power from 120 to 90 KW; returning to 120 KW causes the bursts to reappear. At 1.5 GeV and 14 mA, the bursts can be stopped by dropping the RF power from 120 KW 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. The onset is now resolved and noticeably slower, and the decay no longer appears to be a simple exponential.

Spectral Measurements.

By using a combination of filters with the above setup we determined the spectral content of the bursts was primarily below 100 cm-1 (wavelengths longer than 100 microns). To make this more quantitative, we used the 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 signal 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.

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 also plan to collaborate with researchers at Jefferson Laboratory to measure the coherent far-IR emitted from a bend magnet in their energy-recovery linear accelerator based infrared free electron laser. Electron bunches at JLab are typically a few hundred microns in length which should be emitting coherent far-IR.



I = 19.2 mA, 1.5 GeV, Single bunch
τ = 310 μsec = 2.75 Synch Osc.
Detector Signal (V)
Time (msec)
I = 29.8 mA, 1.5 GeV, Single bunch
Detector Signal (V)
Time (msec)
I = 40 mA, 1.5 GeV, Single bunch
Detector Signal (V)
Time (msec)

Figure 1

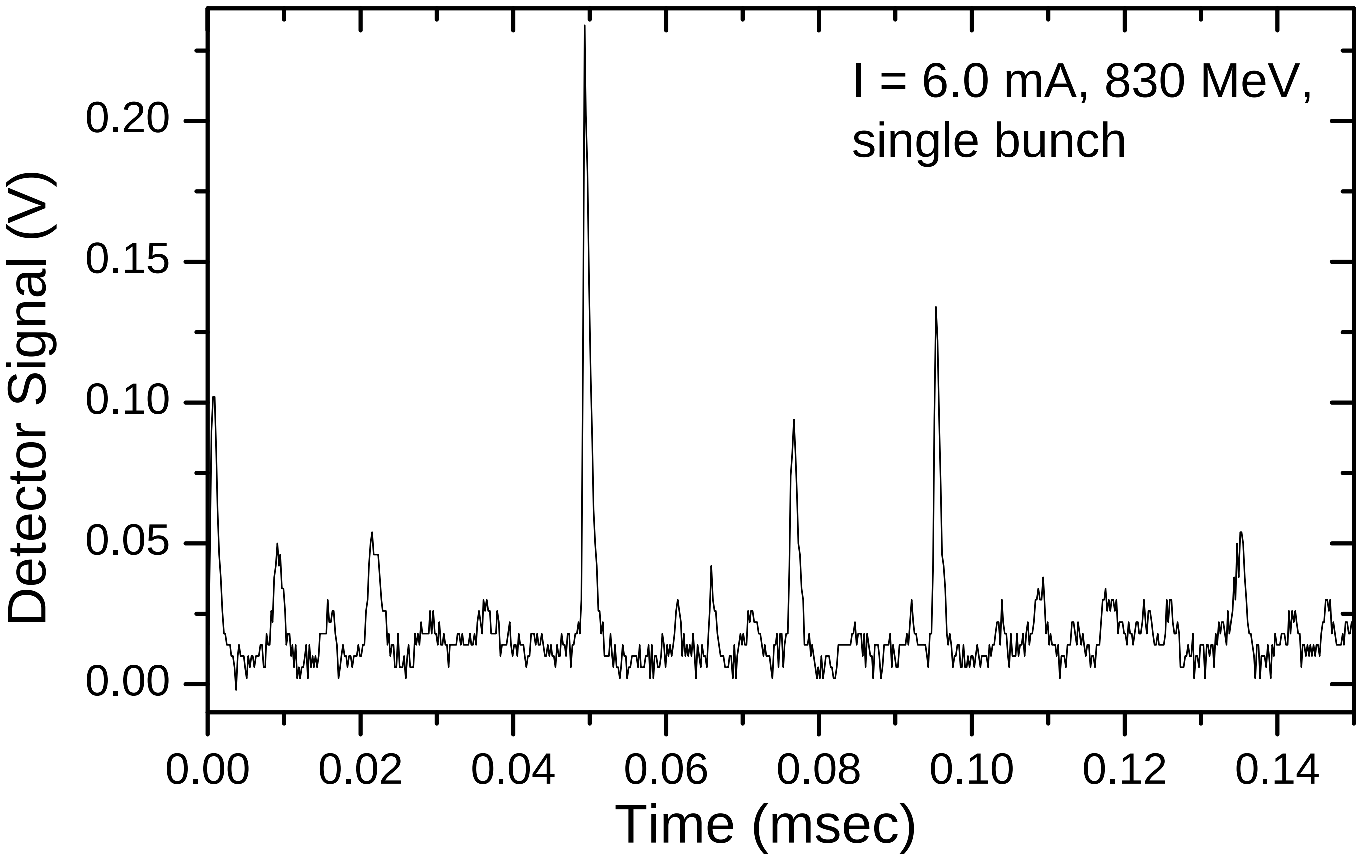
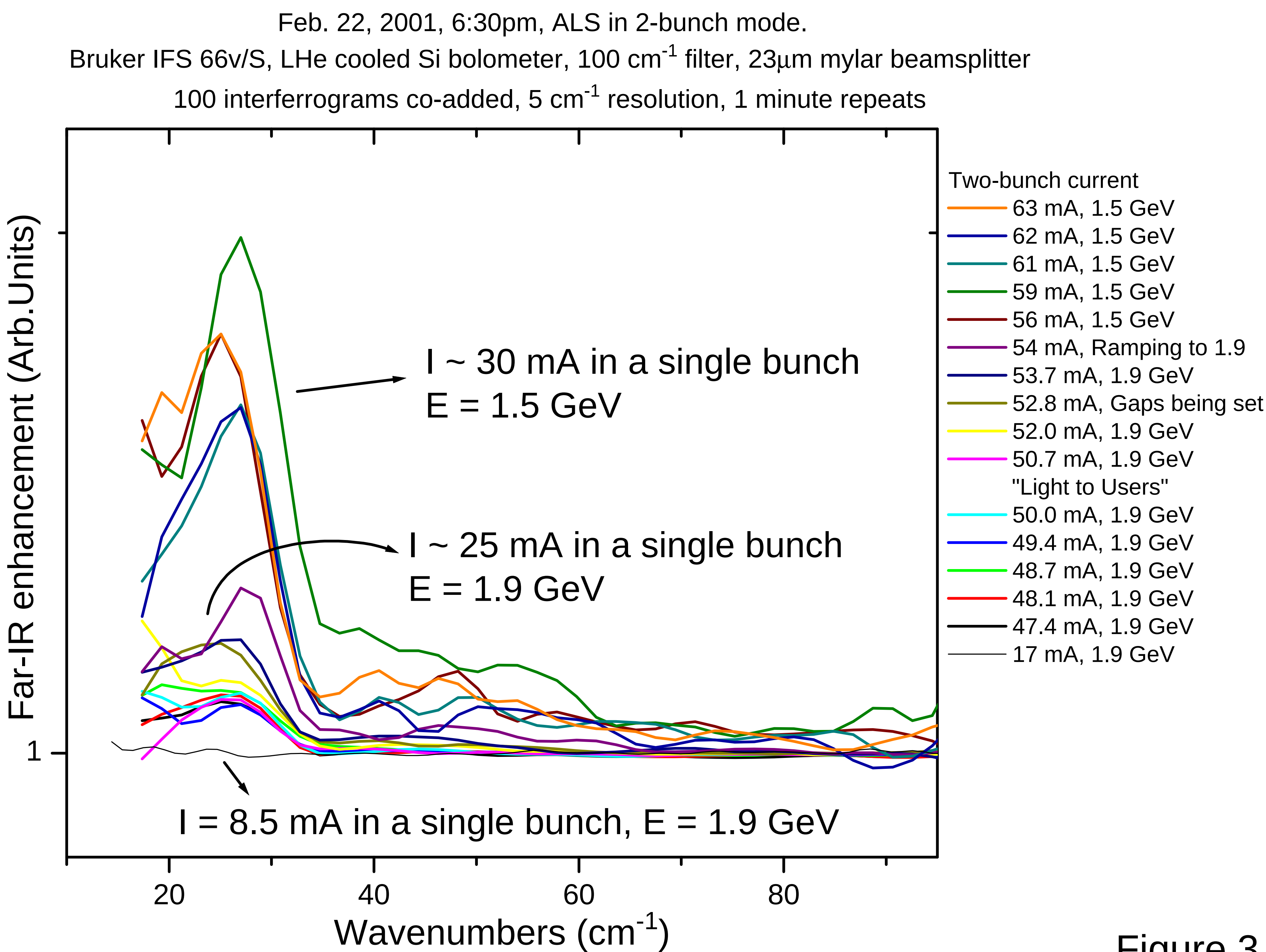

I = 6.0 mA, 830 MeV,
single bunch
Detector Signal (V)
0.00
0.05
0.10
0.15
0.20
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Time (msec)

Figure 2



Feb. 22, 2001, 6:30pm, ALS in 2-bunch mode.
Bruker IFS 66v/S, LHe cooled Si bolometer, 100 cm-1 filter, 23µm mylar beamsplitter
100 interferrograms co-added, 5 cm-1 resolution, 1 minute repeats
Far-IR enhancement (Arb.Units)
Wavenumbers (cm-1)
1
20
40
60
80
I ~ 30 mA in a single bunch
E = 1.5 GeV
I ~ 25 mA in a single bunch
E = 1.9 GeV
I = 8.5 mA in a single bunch, E = 1.9 GeV
Two-bunch current
63 mA, 1.5 GeV
62 mA, 1.5 GeV
61 mA, 1.5 GeV
59 mA, 1.5 GeV
56 mA, 1.5 GeV
54 mA, Ramping to 1.9
53.7 mA, 1.9 GeV
52.8 mA, Gaps being set
52.0 mA, 1.9 GeV
50.7 mA, 1.9 GeV
"Light to Users"
50.0 mA, 1.9 GeV
49.4 mA, 1.9 GeV
48.7 mA, 1.9 GeV
48.1 mA, 1.9 GeV
47.4 mA, 1.9 GeV
17 mA, 1.9 GeV

Figure 3