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PUBLICATION
F. Wang, D. Cheever, M. Farkhondeh, W. Franklin, E. Ihloff, J. van der Laan, B. McAllister, R. Milner, C. Tschalaer, D. Wang, D.F. Wang, A. Zolfaghari, T. Zwart, G.L. Carr, B. Podobedov, and F. Sannibale, "Coherent THz Synchrotron Radiation from a Storage Ring with High Frequency RF System," *Phys. Rev. Lett.*, **96**, 064801 (2006).

FUNDING
U.S. Department of Energy; Massachusetts Institute of Technology

FOR MORE INFORMATION
Fuhua Wang
MIT-Bates Linear Accel. Center
fwang@mit.edu

COHERENT THZ SYNCHROTRON RADIATION FROM A STORAGE RING WITH HIGH FREQUENCY RF SYSTEM

F. Wang[1], D. Cheever[1], M. Farkhondeh[1], W. Franklin[1], E. Ihloff[1], J. van der Laan[1], B. McAllister[1], R. Milner[1], C. Tschalaer[1], D. Wang[1], D.F. Wang[1], A. Zolfaghari[1], T. Zwart[1], G.L. Carr[2], B. Podobedov[2], and F. Sannibale[3]

[1]MIT-Bates Linear Accelerator Center; [2]National Synchrotron Light Source, Brookhaven National Laboratory; [3]Lawrence Berkeley National Laboratory

Coherent synchrotron radiation (CSR) generated in an electron storage ring is a promising source for stable, high-intensity terahertz (THz) radiation. The achievable CSR power and spectrum depend strongly on ring radiofrequency (RF) system parameters, mainly RF frequency and gap voltage. We report the initial results of CSR generation in the MIT-Bates South Hall storage ring (SHR), which is equipped with a unique high-frequency S-band RF system. The CSR enhancement is 10,000 times above background for wave numbers near 3 cm^{-1} with a bunch current of 1.1 μA. Suppressing beam instabilities emerged as the first challenge in pursuing a very brilliant ring-based THz source, with further investigations underway.

The THz region of the electromagnetic spectrum lies between the infrared and the microwave. Only over the past decade has this region become more available for scientific research and applications as moderate intensity sources have emerged. Accelerator-based CSR provides a category of broadband THz sources with much higher power. The stability of radiation flux, familiar to many synchrotron radiation users in synchrotron light sources, is also a distinguishing characteristic of the CSR obtained from a ring-based THz source.

Source research efforts in past years predict that the achievable stable CSR power and spectrum of a ring-based source are strongly dependent on ring RF frequency and gap voltage. At present, the RF frequencies employed in light-source storage rings are 500 MHz and below for practical reasons. For example, the BESSY II storage ring, at this frequency, has demonstrated CSR in the THz region. The MIT-Bates SHR is the only storage ring that is equipped with an S-band (2.856 GHz) RF system. The system was originally designed to facilitate uniform pulse stretching operation for nuclear physics. However, it has also been successfully operated in a storage mode for years with this RF system. This provides us with an excellent opportunity to investigate the potential of a ring-based source at its technical limits.

Authors (labeled 1-12, respectively): Fuhua Wang, Ernie Ihloff, Wilbur Franklin, Defa Wang, Larry Carr, Chris Tschalaer, Jan van der Lann, Boris Podobedov, Richard G. Milner, Abbi Zolfaghari, Manouchehr Farkhondeh, and Dong Wang

To attain short electron bunch length (~ 1 mm, rms), the SHR optics were turned into a low-momentum compaction (α) lattice, in which electrons with different momenta would have smaller path-length differences. As expected with the higher RF frequency, a bunch length of about 1mm rms was attained with a moderate α value of 0.0006, which is favorable for stable operation.

The CSR radiation was extracted through a 6-mm-thick fused quartz view port followed by two parabolic reflectors that collected the light and matched it to a spectrometer. The spectrometer was a modified commercial Nicolet Magna 860 Fourier Transform Infrared (FTIR) Spectroscopy interferometer with a liquid-helium-cooled silicon composite bolometer as the detector. The spectrometer could sense CSR to wave numbers as low as 1 cm^{-1}. The spectrometer assembly was carefully tuned and tested at the NSLS. Strong CSR signals were detected in the sub-THz region. The enhancement of CSR compared to the 300 K blackbody radiation background was 10,000 times, peaked near a wave number of 3 cm^{-1}, and had a very low electron bunch current of 1.1μA. Most of the 1812 RF buckets of the ring were filled, as it was the only available SHR injection mode at the time. The signal of the incoherent THz radiation with a few mA circulating beam was below the detection limit. The coherency tests of the radiation included dependency of the spectrum intensity on the bunch current and bunch length. The CSR radiation spectra from electron bunches with different bunch lengths, and the quadratic dependency of intensity on bunch current, are shown in **Figure 1** and **Figure 2**.

Beam longitudinal instabilities were observed in both the radiation spectrum and time domain signals as well as in the beam longitudinal profile measurements. The instabilities limited the maximum bunch current that could be used for the tests and resulted in deteriorated radiation coherency at higher bunch intensities. Preparation for further tests is underway to address the technical challenges uncovered here.

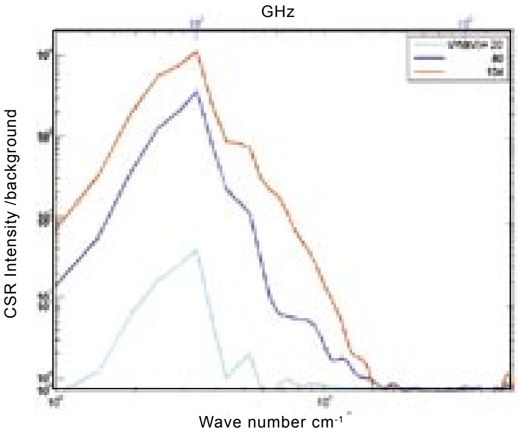

Figure 1. Intensity ratio of CSR to background for different bunch lengths. Total stored current I = 2 mA. Measured rms bunch length (ps): 7.6, 4.4, 4.0, corresponding to the RF peak voltage V_{RF} (kV) of 20, 80, and 134.

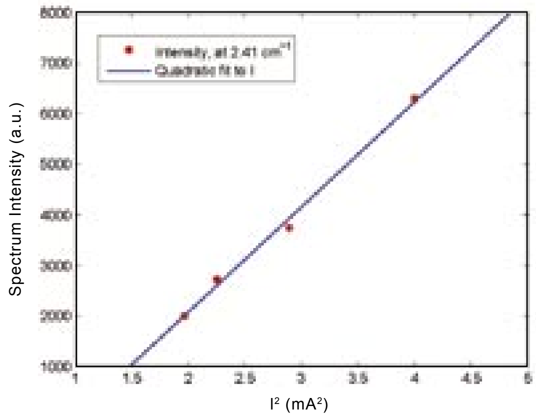

Figure 2. Quadratic dependency of spectrum intensity of CSR to beam current.