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Informal Report

**OBSERVATION OF COHERENT TRANSITION RADIATION
AT THE ACCELERATOR TEST FACILITY**

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Observation of Coherent Transition Radiation at the Accelerator Test Facility*

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Transition radiation is emitted when a relativistic, charged particle passes between media with different dielectric constants. Most often the transition is between vacuum (unit dielectric constant) and a conductor (infinite dielectric constant). The transition radiation spectrum theoretically extends from DC to extremely short wavelengths determined by the particle energy. In practice, the long wavelengths are cut off in the millimeter or centimeter range by the shielding effect of the vacuum chamber containing the particles.

The intensity of the radiation from a beam of particles is obtained by adding together the electric fields of the radiation produced by the individual particles while properly accounting for the phase difference between the particles. At wavelengths that are much shorter than the bunch length, the phase differences average out and the intensity scales with N , the number of particles in the bunch. At wavelengths that are much longer than the bunch length, the particles act as a single source, the electric fields add coherently, and the intensity scales as N^2 . At intermediate wavelengths, the intensity scales as N times the Fourier transform of the charge distribution in the bunch. Coherent transition radiation was first observed by Hapek, Sievers and Blum at the Cornell 300 MeV linac in 1991.¹

On January 18, 1996 an experiment was performed at the BNL Accelerator Test Facility (ATF) to observe coherent transition radiation produced when a 52 MeV electron beam strikes a copper target. The electrons in the ATF linac are produced by a laser driven RF gun. A single bunch of electrons is accelerated during each linac pulse. The repetition rate of the linac is 1 Hz.

Fig 1. Transition radiation from a rotated target.

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1. Hapek, U., Sievers, A. J., and Blum, E. B., *Phys. Rev. Lett.* **67**, 2962–2965 (1991).

Fig. 2. Experimental apparatus used to detect transition radiation.

The transition radiation target was rotated by 45° from the beam direction to direct the backward scattered radiation away from the electron beam and out of the vacuum chamber through a z-cut, single crystal quartz window in the manner shown in fig 1. The radiation then struck a front surfaced gold mirror, traveled through a 240 cm long brass tube and was focused by a Molelectron Detector, Inc., Model P1-45 pyroelectric detector² by an aluminum cone. A black plastic sheet was used to shield the detector from visible and near IR radiation. The detector was surrounded by lead bricks to shield it from ionizing radiation produced by the electron beam. A schematic diagram of the experimental apparatus is shown in fig. 2.

The signals from the pyroelectric detector were buffered by an LH0002 amplifier and sent to the ATF control room on a shielded, twisted pair cable. A Tektronix 2440 digital oscilloscope, triggered externally by the linac gun laser trigger, was used to measure the detector output. The largest noise component seen was a 2 mV peak to peak, 60 Hz signal. The Tektronix oscilloscope was used to average the signal during successive linac pulses to improve the signal to noise ratio.

The copper target was rotated remotely using a stepping motor. The measured angular distribution is shown in fig. 3. Each point on the vertical axis is the average of the detector output during 16 linac pulses. The horizontal axis shows the angle determined by the step size of the stepping motor (400 steps/revolution). The target was rotated in one direction to avoid backlash. The minimum in the middle of the distribution is characteristic of transition radiation and the $1/\gamma$ half-width (where γ is the Lorentz factor) is expected for relativistic electrons.

2. Molelectron Detector Inc., 7470 S.W. Bridgeport Road, Portland OR 97224.

The number of electrons in the linac bunch was varied by adjusting the energy of the gun laser pulse in order to measure the intensity of the radiation as a function of the charge per bunch. A log-log plot of the result is shown in fig. 4. Each point on the vertical axis represents the average of 8 linac pulses. The bunch current is represented by the peak amplitude from a stripline detector in the linac as measured on a Tektronix TDS series oscilloscope. The signal amplitude varied by less than 5% from pulse to pulse so signal averaging was not used. The solid line in the graph represents a least square fit of the data to the curve $y=ax^2$. The quadratic dependence shows that the radiation is coherent.

The 5 mm opening of the pyroelectric detector determines the longest observable wavelength. This indicates that the bunch length in the ATF linac is less than 5 mm. A Michaelson interferometer will be assembled to measure the spectrum of the coherent transition radiation and determine the charge distribution of the electron bunches.

Fig.3. Angular distribution of the IR radiation.

Fig. 4. Intensity of the IR signal from the pyroelectric detector as
as function of the charge in a bunch.

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