INITIAL CTR-BASED BUNCH LENGTH MEASUREMENTS OF LINAC BEAMS FOLLOWING THE APS BUNCH COMPRESSOR*

A. H. Lumpkin,† W. J. Berg, M. Borland, J. W. Lewellen and N. S. Sereno
Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439 USA

Abstract

The interest in generation and characterization of ultrabright electron beams for experiments at the Advanced Photon Source (APS) resulted in the installation of a four-dipole chicane bunch compressor within the linac. Both rf thermionic guns and an rf photocathode (PC) gun can be used to generate the electron beams with ps-regime bunch lengths. The bunch compressor can then be used to produce sub-ps bunches. In support of this initiative, a coherent transition radiation (CTR) bunch length monitor based on a far-infrared (FIR) Michelson interferometer was also installed at a location just downstream of the compressor. It used a room-temperature Golay cell as the FIR detector. Processing of the autocorrelation data indicated that structures shorter than 500 fs were being generated.

INTRODUCTION

The generation and characterization of ultrabright electron beams continues to be of interest to the accelerator community. At the Advanced Photon Source (APS) we have addressed these issues in part by the installation of a four-dipole chicane bunch compressor [1] at the 150-MeV point in the linac and in part by the installation of a bunch length monitor based on coherent transition radiation (CTR) techniques [2,3]. In the cases where the rf photocathode (PC) gun and rf thermionic gun generate ps-long bunches, the bunch compressor can be used to shorten the bunch to the sub-ps domain. In this domain a FIR Michelson interferometer has been used to detect radiation in the sub-300-μm-wavelength regime and to perform an autocorrelation of that signal so that profile information can be obtained. These experiments were the first at the APS with the device installed after the chicane. Previous results were reported for a 50-MeV location located after the α-magnet of the thermionic gun [3]. A zero-phasing rf technique was also used with the analyzing magnet at the end of the linac to verify that very short bunches were being generated. Both measurement techniques indicate there is a narrow time spike at the leading edge of the pulse that results in the higher peak current at that point.

EXPERIMENTAL BACKGROUND

These experiments were performed at the APS using beam accelerated by the S-band linac, which is normally used as part of the injector system for the 7-GeV storage ring. We have obtained data with both the PC gun, which generates a single micropulse at 6 Hz, and the thermionic gun with an 8-ns-long macropulse. As seen in Fig. 1 the PC gun beam is at the 150-MeV point at the bunch compressor due to the additional accelerator structure available upstream of the thermionic gun location. The guns and linac are described elsewhere [4,5].

The location of the CTR monitor after the chicane compressor is also seen in Fig. 1. The FIR interferometer

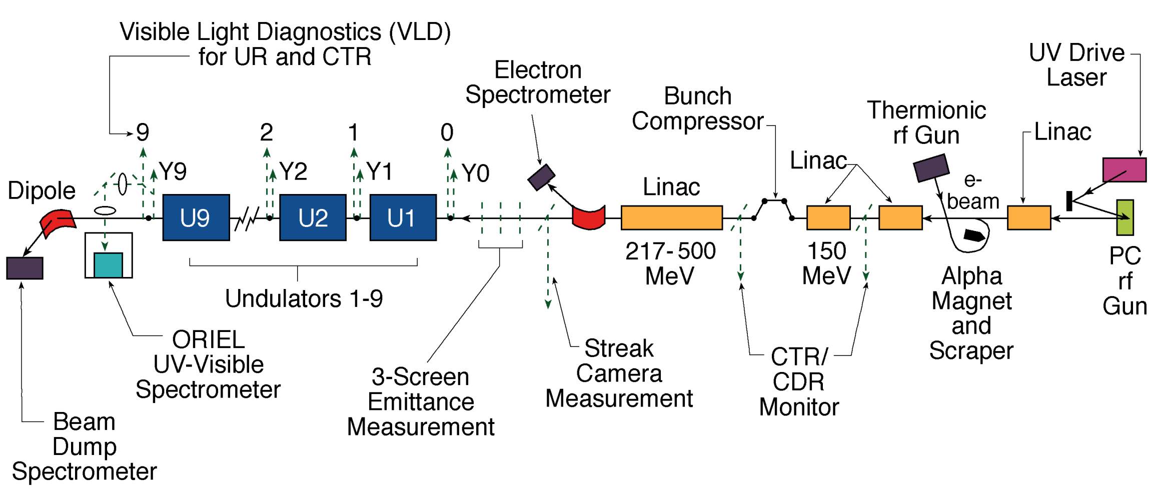

Figure 1: A schematic of the APS linac with bunch compressor, CTR monitor locations, and electron spectrometer indicated.

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†lumpkin@aps.anl.gov

was described in [3]. It is based on the autocorrelation of FIR CTR generated as the charged-particle beam strikes a metal mirror oriented at 45° to the beam direction. This particular interferometer has a novel, compact design using an Inconel-coated beam splitter. A Golay cell, model OAD-7 from QMC Ltd., is used as the FIR detector. Its entrance window transmits well from 20 μm to 1 mm. The moveable arm of the interferometer and the data acquisition are handled via EPICS. The bunch profile was calculated using a fast Fourier transform (FFT) of the autocorrelation followed by an application of the minimal phase approximation of Lai and Sievers [6]. Complementary bunch length measurement information is available at the end of the linac using the rf zero-phasing technique combined with the electron spectrometer (see Fig. 1).

EXPERIMENTAL RESULTS

The electron beam was transported through the bunch compressor with the phasing of the accelerating structure just before the chicane adjusted for the desired energy-time correlation in the beam.

PC rf Gun Results

Without compression the beam was measured using the zero-phasing technique to have a bunch length of ~ 3ps (FWHM). For a charge of 200 pC, the beam compression was increased so that the bunch was shorter at ~ 1 ps. Then the compression was further optimized, and the CTR interferometer scan was performed. The processed autocorrelation results indicate a 300-fs FWHM, as seen in Fig. 2. A rephasing of rf was done to lengthen the pulse, and the result is shown in Fig. 3. The intensity profile has shifted out towards the 500-fs regime. The gun was reoptimized at 300 pC and at good compression. Under these conditions another autocorrelation was obtained and processed as shown in Fig. 4. The beam was then transported to the rf zero-phasing test location at the end of the linac, and the bunch length of 0.45 ± 0.02 ps was determined using maximum power in the last accelerating structure. After rephasing the beam to be on rf crest in L2 (before the compressor) the measured bunch length was 2.2 ± 0.3 ps (rms), but no CTR signal was detected at this longer bunch length.

Thermionic rf Gun Results

We operated with about 1 nC in 24 bunches from the thermionic gun. This corresponds to about 42 pC/bunch. Two CTR scans were taken, and the shortest result was 290 fs (FWHM). This would imply about 140 A peak current. Figure 5 shows the processed autocorrelation that provides the time profile. The leading edge spike is present as in the data for the PC gun. There appears to be a measurable difference in this spike width from the two gun sources. The data with the single micropulse is narrower than the average of 24 micropulses.

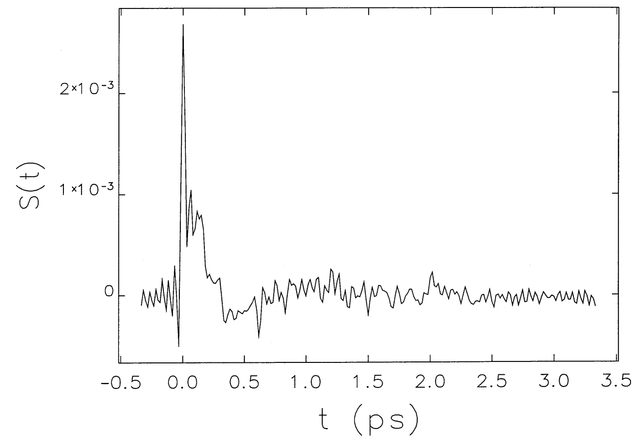

Figure 2: The derived longitudinal bunch profile using the CTR data for the compressed PC gun beam at 200 pC.

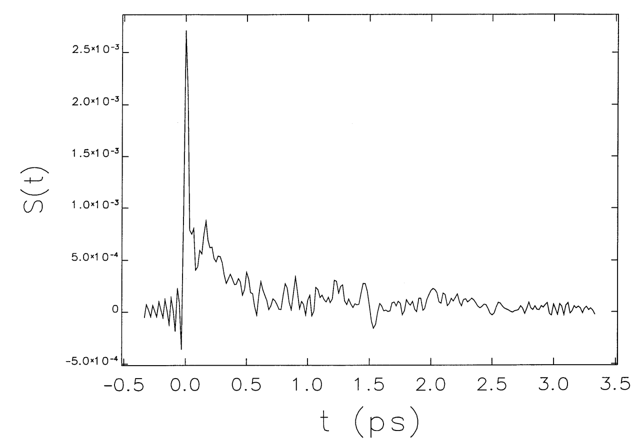

Figure 3: The derived longitudinal bunch profile using the CTR data for the partly dephased beam. Note the increased intensity near 500 fs compared to Fig. 2.

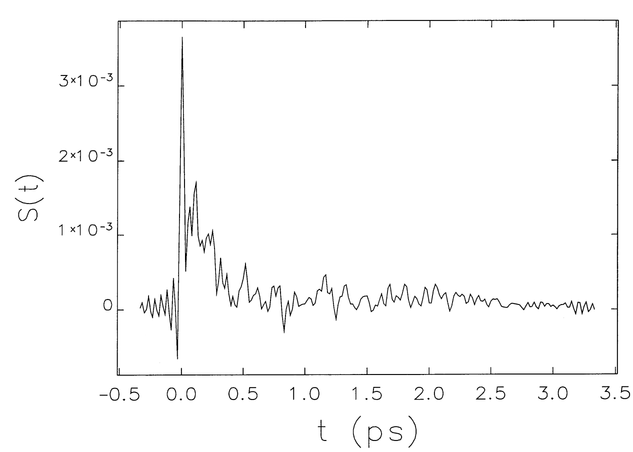

Figure 4: The derived longitudinal bunch profile using the CTR data for the PC gun beam at 300 pC.

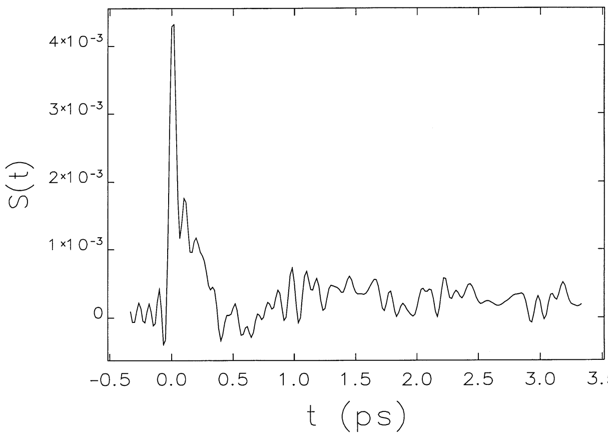

Figure 5: The derived longitudinal bunch profile using the CTR data for the thermionic gun beam.

SUMMARY

In summary we have obtained our initial measurements of the beam following the chicane bunch compressor. Two different gun sources were assessed by the FIR CTR interferometer. The compressed PC gun beam was subsequently used for a number of self-amplified spontaneous emission free-electron laser experiments. A more complete assessment of the CTR system detector efficiencies for various bunch lengths is still warranted.

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