Direct measurement of the time structure of ultrashort x-ray pulses

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Introduction

The x-ray pulse timing structure of the storage ring at the Advanced Photon Source has been measured. A simple and straightforward detector system was employed to capture and record the x-ray pulses while the storage ring operated in the 6 + 25 triplets mode. In this mode the dense x-ray pulse structure was clearly resolved with respect to the inter-pulse spacing and pulse position. The pulse profiles are presented clearly detailing the time structure of the storage ring.

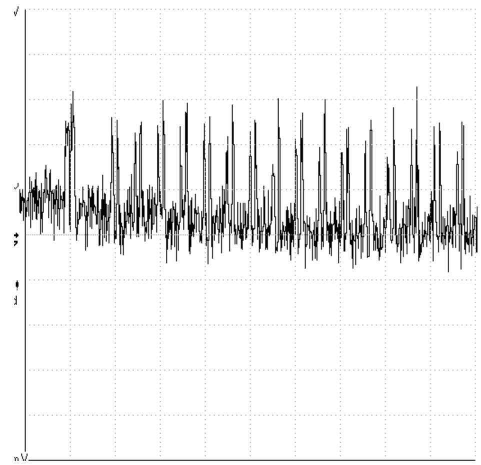

Figure 1 BPM and beginning of triplets pattern

Methods and Materials

A biplanar vacuum photodiode was used to produce electronic replicas of the incident x-ray pulses [1]. A 90%-transmission brass mesh was used as the anode. A 1-μm thick CsI coating was deposited onto the polished aluminum cathode to enhance the quantum efficiency near 10 keV. The detector was operated at a 300-V bias provided by a Canberra Model 31020. To preclude plasma arcing between the cathode and anode, the diode was operated at a pressure of 10^{-5} torr.
The detector was used to measure the x-ray pulse structure of the Advanced Photon Source. The beam dimensions were .2 x .2 mm^2. The undulator gap was 18 mm, corresponding to a photon energy of 7.7 keV. The photocurrent from the diode was amplified using two cascaded broadband amplifiers (Picosecond Pulse Labs). The signal was recorded with a digital sampling oscilloscope (Tektronix). Through the use of a sampling head, the scope had a bandwidth of 20 GHz. The oscilloscope was triggered by a timing reference synchronized to the RF bunch clock [2].

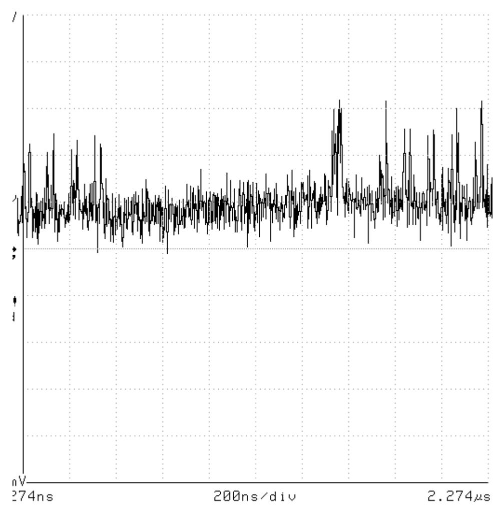

Figure 2 End of triplets pattern, 1017 ns gap, and beginning of pattern.

Results

During these runs, the synchrotron was operating in triplets mode. The triplets bunch pattern has two bunch sequences: the triplets sequence and the bunch train required for proper beam position monitoring (BPM). The BPM sequence contains six consecutive bunches which are 2.8 ns apart. The triplets sequence is comprised of 25 groups of three consecutive filled buckets repeating every 102 ns. The stored positron beam current intensity was typically 85-95 mA.

First, the bunch train was investigated. Since the acquisition speed of the oscilloscope was too high to view the entire 81 pulses simultaneously, we viewed the beginning and end of the bunch train. The BPM train and the beginning of the triplets pattern, 190 ns later, can be seen in Figure 1. The end of the triplets pattern, the trailing 1017 ns gap followed by the beginning of the next BPM train is in Fig 2. Next, the BPM pattern was isolated. Typical data are shown Figure 3 which shows the six pulses, spaced by 2.8 ns.

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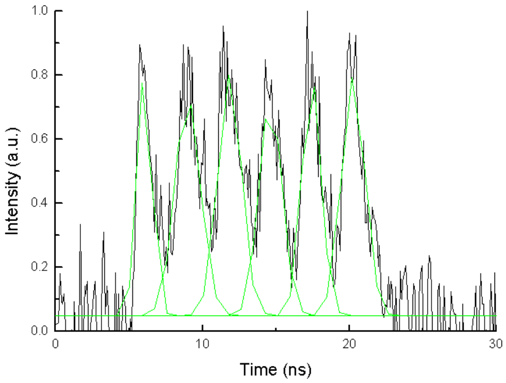

Figure 3 BPM sequence

The triplets pattern was then investigated as shown below in Figure 4.

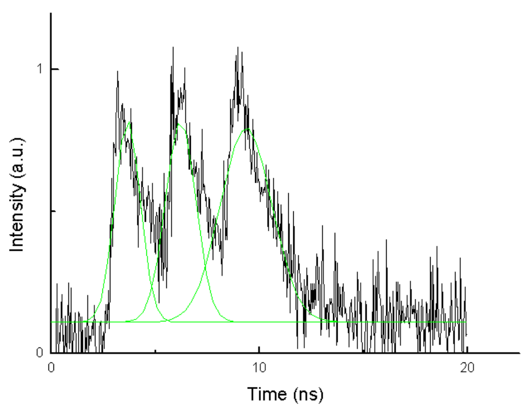

Figure 4 Triplets sequence

Discussion

To analyze the time characteristics, the BPM pattern and the triplets sequence were fitted with Gaussians. As seen in Figures 3 and 4, the pulse-to-pulse spacing was 2.8 ns. The average measured pulse width was about 1.5 ns, limited by the resolution of the detector.

To determine the time response of the detector, the triplets pattern was analyzed. The 10%-90% rise determined to be 450 ps. The 10%-90% fall time was 2.5 ns. We believe that this long trailing edge was due to the propagation delay of electrons that originate below the surface of the deposited CsI film. This is currently under investigation.

The ability to use synchrotron pulses for time-resolved x-ray experiments will in part depend on how well the pulse can be captured and measured. We have presented measurements of closely spaced x-ray pulses using a relatively simple laboratory detector. The pulse train for the APS storage ring operating in the standard mode consisting of 25 triplets was recorded and analyzed with respect to position and conformance to the RF template. It is immediately determined that the detector can time resolve successive pulses separated by a mere 2.8 ns. Using the detector the background to peak ratio is approximately 5:1 demonstrating a more than required SNR. We are currently working to further improve the temporal characteristics of this detector.

Acknowledgments

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References

[1] Adams, F., Ng, A., Gazit, Y. (1987) Rev. Sci. Instrum 58(6): 1130-1132.
[2] Lenkszus, F., Laird, R. (1997). Proceedings of Particle Accelerator Conference.