Title
A Method for Measuring the Time Structure of Synchrotron X-Ray Beams

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Publication Date
1989-08-01

LBL-27581

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Presented at the 7th Synchrotron Radiation Instrumentation Conference, Berkeley, CA, August 7–10, 1989, and to be published in Nuclear Instruments and Methods in Physics Research A

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August 1989

Donner Laboratory

Biology & Medicine Division

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

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A Method for Measuring the Time Structure of Synchrotron X-Ray Beams

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August 6, 1989

Abstract

We describe a method employing a plastic scintillator coupled to a fast photomultiplier tube to generate a timing pulse from the x-ray bursts emitted from a synchrotron radiation source. This technique is useful for performing synchrotron experiments where detailed knowledge of the timing distribution is necessary, such as time resolved spectroscopy or fluorescence lifetime experiments. By digitizing the time difference between the timing signal generated on one beam crossing with the timing signal generated on the next beam crossing, the time structure of a synchrotron beam can be analyzed. Using this technique, we have investigated the single bunch time structure at the National Synchrotron Light Source (NSLS) during pilot runs in January, 1989, and found that the majority of the beam (96%) is contained in one rf bucket, while the remainder of the beam (4%) is contained in satellite rf buckets preceeding and following the main rf bucket by 19 ns.

In order to perform timing experiments such as time resolved spectroscopy or fluorescence lifetime measurements at synchrotron radiation facilities, it is necessary to obtain a timing signal that is accurately synchronized to the incident beam. The most common method for obtaining this timing signal is to sample the radio-frequency (rf) signal that powers the synchrotron's accelerating cavities with a zero-crossing discriminator. As the rf cavities and associated power supplies are usually located many meters away from the experimental area, a long cable is required to carry the timing signal to the experimental area, frequently resulting in electrical noise and subsequent timing jitter because of ground loops and antenna effects. In addition, the time difference between the rf crossover and the arrival of the x-ray beam into the experimental area is unknown, and can vary during a run as the accelerator orbits are changed.

Therefore, we have devised a method the uses the x-ray beam itself to generate a timing pulse. The device, shown in Fig. 1 consists of a thin (0.043 in. thick × 0.375 in. wide × 1.0 in. long) piece of Pilot U plastic scintillator coupled with Dow Corning 3140 RTV to a fast (2.3 ns rise time, 1.6 ns transit time spread) Hamamatsu R647-01 photomultiplier tube that is powered by a Hamamatsu E849-02 base. The plastic scintillator is wrapped with a reflective coating of aluminum foil, and the entire assembly is wrapped with black tape to block ambient light. When the scintillator is placed in the path of the x-ray beam, the x-rays excite the scintillator and cause the photomultiplier tube to fire. An Ortec 473A constant fraction discriminator converts the photomultiplier tube output into a timing signal that is accurately synchronized to the leading edge of the synchrotron x-ray beam.

The intrinsic timing resolution of this device is measured by constructing two such devices, supplying -1100 V to each of their bases, and placing a positron emitting ^{68}Ge source between them. The back-to-back pair of 511-keV photons resulting from positron annihilation excites the two devices simultaneously, and the difference between the arrival times of the two pulses is measured with an Ortec 457 time to amplitude converter and digitized with a LeCroy 3512 analog to digital converter. The resulting distribution, shown in Fig. 2, has a full width at half maximum (FWHM) of 1.5 ns, which implies that the time resolution of a single device has a FWHM of 1.2 ns.

This device is usually placed to one side of our sample in a portion of the incident x-ray beam that is not being used to irradiate the sample. In this configuration, it can be used with x-ray energies as low as a few keV, limited by the x-ray beam attenuation in the aluminum foil and black tape surrounding the scintillator. A minimum total energy deposit in the scintillator of approximately 100 keV is necessary to form a good timing pulse. Using this value and the mass absorption cross section for aluminum [1], Fig. 3 shows the minimum flux necessary to form a good timing signal, in units of number of x-rays per bunch incident on the detector, as a function of the incident x-ray energy. At 5 keV incident energy, an incident flux of approximately 340 photons per bunch is necessary.

As the x-ray energy increases, their penetrating power increases to the point where most of the x-rays pass through the scintillator without interacting. Fig. 3 also shows the fraction of the incident x-ray beam that passes unaltered through the device as a function of energy. Less than 50% of the incident beam flux of x-rays above 10 keV is absorbed in the scintillator and aluminum coating. Therefore the device can be placed in the x-ray beam in front of the sample without significantly affecting the beam, and the minimum incident flux is determined not by absorption in the protective wrapping but by the x-ray flux stopped in the scintillator. This minimum flux necessary to have sufficient radiation absorbed by the scintillator is a slowly varying function of the x-ray energy, and is approximately 100 photons per bunch impinging on the device for x-ray energies above 6 keV.

We used this device to investigate the beam timing structure with monochromatic 22 keV x-ray radiation from beamline X23-A2 at the National Synchrotron Light Source (NSLS) during pilot single bunch runs in January, 1989. The time difference between timing signals generated by our device for successive bunch crossings is digitized with the same equipment used to measure the intrinsic timing resolution of the device, and the resulting distribution is shown in Fig. 4. The majority of the beam (96%) is contained in one rf bucket, while the remainder of the beam (4%) is distributed into two satellite rf buckets located 19 ns preceeding and following the main rf bucket. When the effect of the intrinsic timing resolution of our device is subtracted from the 2.3 ns FWHM of the central peak, we measure a 1.9 ns FWHM variation in the bunch rotation period.

In conclusion, we have constructed a simple device based on a photomultiplier tube and plastic scintillator that provides a timing pulse synchronized within 1.2 ns of the arrival time of an x-ray pulse. The device is useful for x-ray energies above a few keV, and can operate with fluxes as low as a few tens to hundreds of x-rays impinging on the device. In addition to providing a timing pulse for fluorescence lifetime or time resolved spectroscopy measurements, it can be used to measure the synchrotron x-ray beam time structure.

We would like to thank John Cahoon of Lawrence Berkeley Laboratory for invaluable technical support, as well as Dr. Chuck Bouldin of the National Bureau of Standards for use of Beam Line X23-A2 at NSLS.

This work was supported in part by the Director, Office of Energy Research, Office of Health and Environmental Research of the U.S. Department of Energy, under contract No. DE-AC03-76SF00098, and in part by Public Health Service Grant Numbers P01 HL25840 and R01 CA38086 awarded by the National Heart, Lung, and Blood Institute and the National Cancer Institute of the U.S. Department of Health and Human Services. The research was carried out in part at the National Synchrotron Light Source, Brookhaven National Laboratory, which is supported by the U.S. Department of Energy, Division of Materials Sciences and Division of Chemical Sciences, under contract No. DE-AC02-76CH00016.

References

[1] B.L. Henke, J.C. Davis, E.M. Gullikson, and R.C.C. Perera, *A Preliminary Report on X-Ray Photoabsorption Coefficients and Atomic Scattering Factors for 92 Elements in the 10–10,000 eV Region*, Lawrence Berkeley Laboratory report LBL-26259, (1988).

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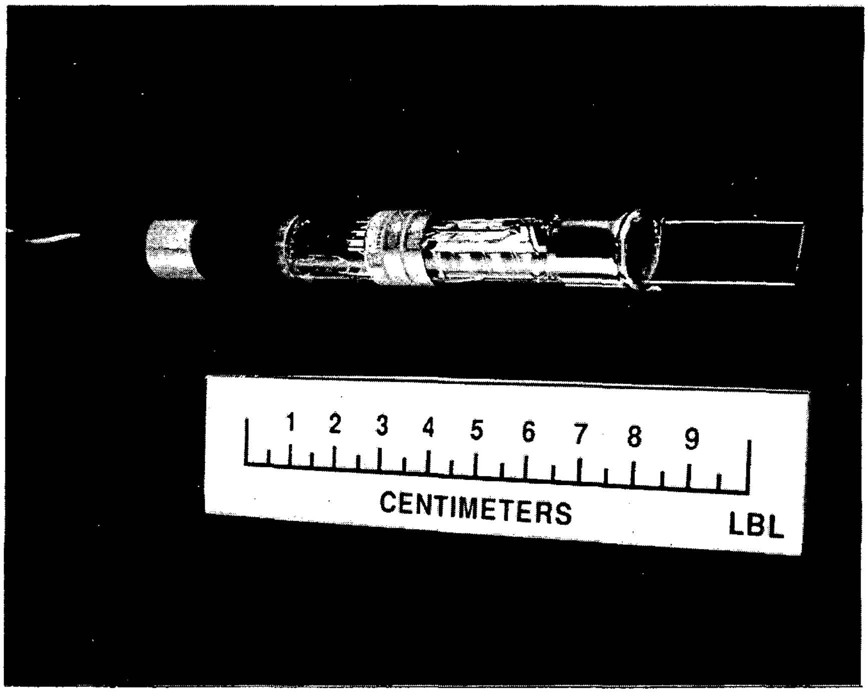

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Figure 1

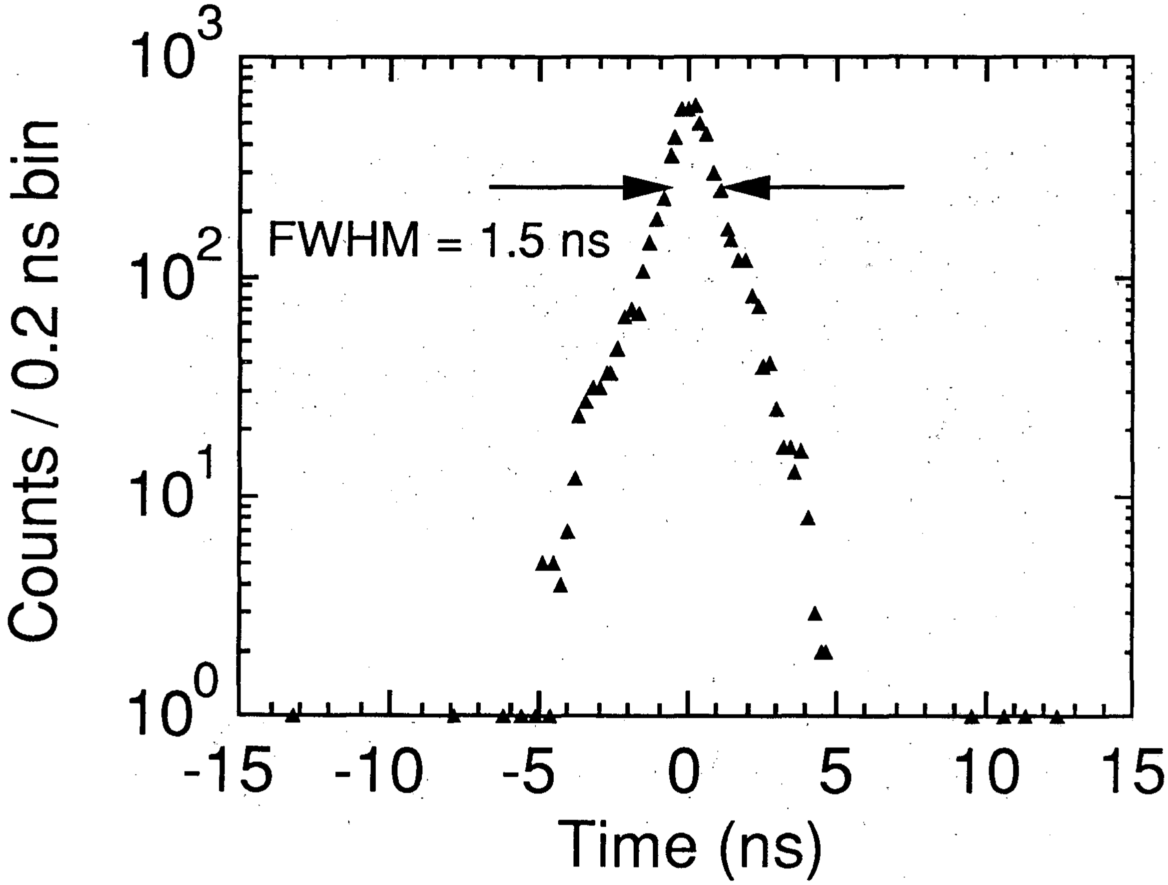

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Figure 2

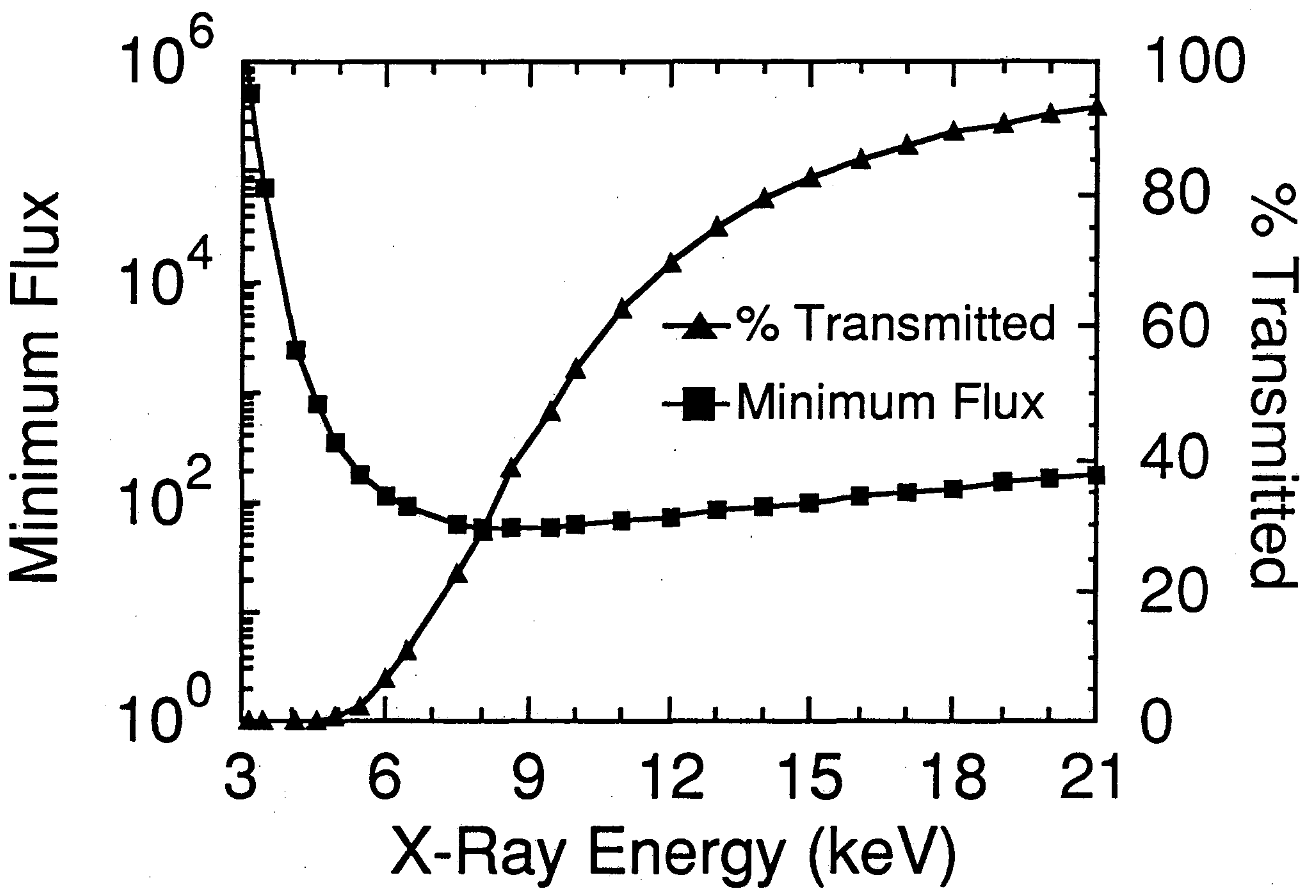

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Figure 3

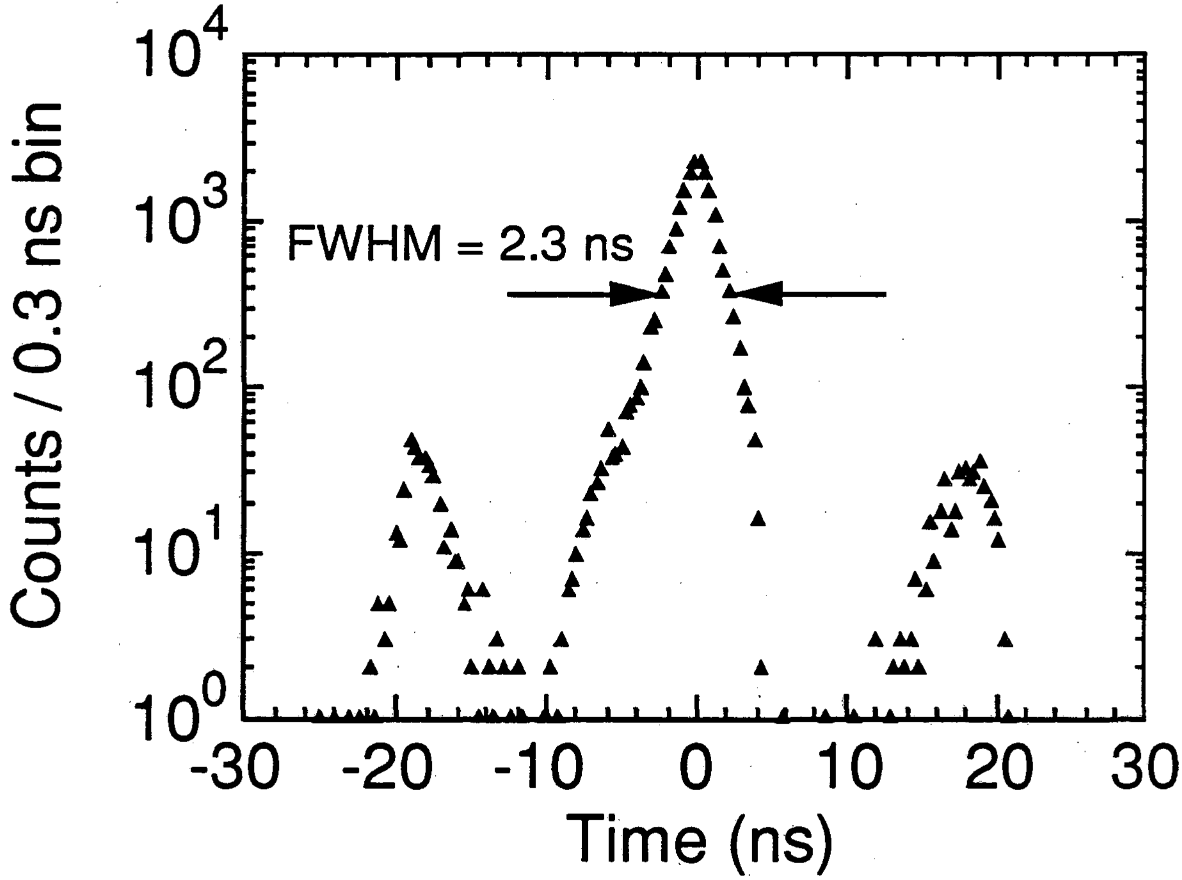

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Figure 4