# A new high-speed x-ray beam chopper

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## Introduction

A new high-speed x-ray beam chopper has been developed and tested on the SRI-CAT sector 1 beamline at the Advanced Photon Source (APS) storage ring (1). This beam chopper uses a high-precision motor developed for the laser-scanner industry. The rotation of the beam chopper can be phase locked to the orbital frequency of the APS storage ring. Hence the position of the transmission window in time can be synchronized to any desired portion of the temporal structure of the APS storage ring.

## Methods and Materials

<u>Beam Chopper Description</u>
The beam chopper is illustrated in Figure 1. The design of the beam chopper is modeled after a commercial high-speed air-bearing laser scanner marketed by Speedring Systems, Inc., in Rochester Hills, Michigan. The housing is compact in size, being 111 mm tall and 99 mm in diameter. There are two sets of transmission windows built into the housing, BK-7 glass for visible light transmission and 0.23 mm thick Be for the transmission of x-rays. The air-bearing rotor is flattened at one end into a 5 mm thick, 50.8 mm diameter disk made of aluminum. The circumference of the disk is coated with a 1 mm thick layer of nickel to give an attenuation of at least $10^8$ (at 30 keV) to any x-rays crossing the body of the rotor. There is a 0.5 mm wide and 2.29 mm tall slit cut through the diameter of the disk to form the optical path through the beam chopper. With a rotation frequency of 1331.12 Hz (nearly 80000 rpm), this beam chopper has an opening time window of 2450 ns, corresponding to 67% of the revolution time of the APS storage ring. There are two transmission window openings per revolution of the rotor disk, with the closed time between window openings being about 373 microseconds. The rotation frequency of the rotor gives a duty cycle of one transmitted x-ray pulse for every 102 orbits in the APS storage ring.

The drive frequency for operating the motor controller is derived from the APS storage ring rf frequency and is supplied by the control room as the orbital frequency (271548.42 Hz) of the storage ring. This orbital frequency, serving as the master clock frequency, is sent to a frequency divider where it is divided by 51 before being sent on to a high-precision pulse delay generator. The pulse delay generator allows for a shift of phase between the position of the transmission window and the ring structure. The output from the pulse delay generator is used to drive the beam chopper motor controller.

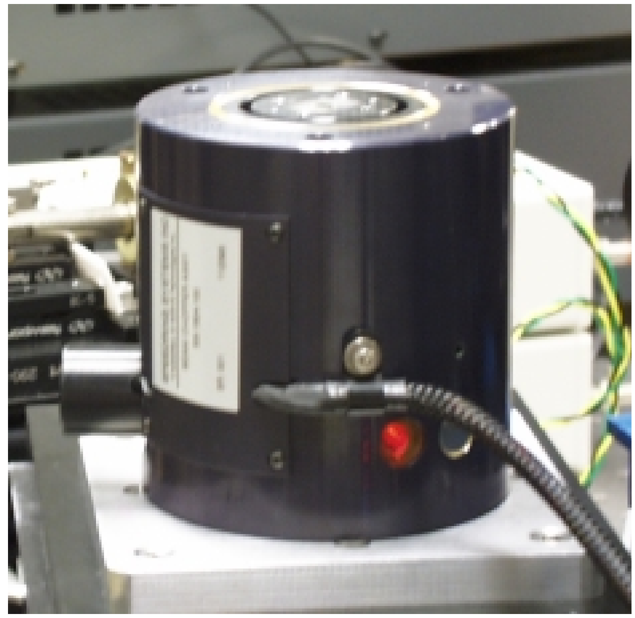
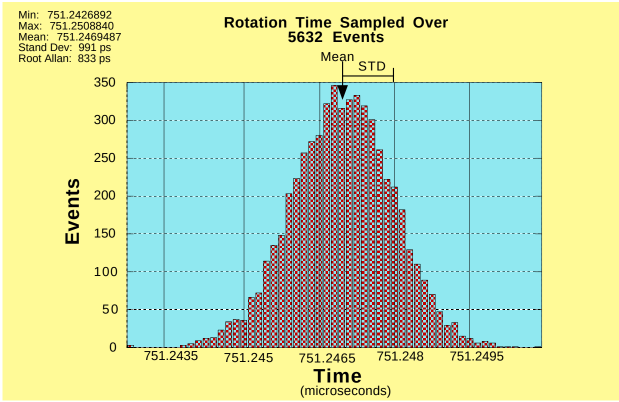


Figure 1: The new high-speed x-ray beam chopper. A He-Ne laser illuminates the visible light window. The Be x-ray window is to the right. The small cylinder extending from the left is the optical encoder.

## Results

<u>Manufacturer's Performance Test</u>
The primary feature that made this laser scanner technology ideal for development into an x-ray beam chopper is the high level of rotational speed control of the rotor that comprises the beam chopper element. An optical feedback circuit is used to sample the rotational speed and to make any necessary adjustments four times per revolution. In evaluating the product, the manufacturer measured (using 5632 samples) the time required for the rotor to make one revolution. The jitter in this revolution time was determined to be only 3 ns at the 3-sigma level (or 95% confidence level). The results are illustrated in Figure 2. This level of jitter is comparable to the "bucket" spacing in the APS storage ring and, hence, would produce no noticeable change in the transmitted x-ray flux during operation of the chopper.



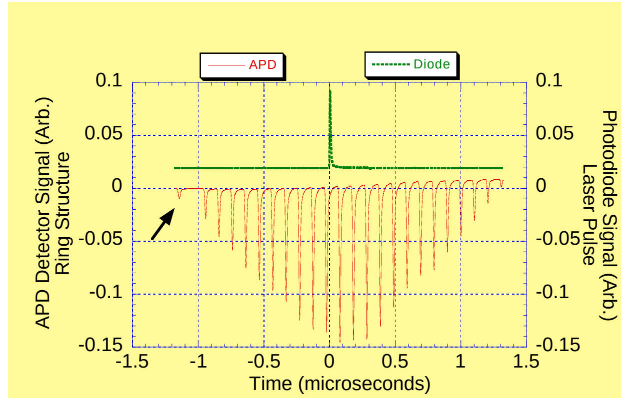




Figure 2: Jitter in the beam chopper position as measured by the time required to make one rotation.

Figure 3: Beam chopper performance test recorded in an average mode for 100 trigger events. A laser pulse synchronized to the x-ray pulses transmitted through the beam chopper was used to trigger the digital storage scope.

APS Synchronization Test

The design goals for the beam chopper were to develop a high-speed beam chopper capable of transmitting an x-ray pulse shorter than the revolution time of the APS storage ring and to be able to phase lock the chopper rotation to the temporal structure of the storage ring. Two performance tests were conducted to evaluate the design goals. The first test was to demonstrate synchronization of the rotation of the beam chopper to the temporal structure of the storage ring. The second test was to synchronize a laser pulse to the x-ray pulse transmitted through the beam chopper.

Since the drive frequency for rotation of the beam chopper is derived from the orbital frequency of the storage ring, phase locking was immediate. An avalanche photodiode (APD) detector and a digital storage scope were used to record the x-ray pulses transmitted through the beam chopper. Figure 3 illustrates the results. The arrow marks the sextet followed by 23 triplets (unresolved because of the 5 ns response time of the APD detector) that could fit within the transmission window time of 2450 ns. The storage ring structure was recorded in an average mode of 100 trigger events. A laser pulse positioned after the tenth triplet (the second test) was used as the trigger for the scope. The known jitter level of 3 ns is small enough not to be noticeable in this measurement. The triangular envelope of the storage ring structure is characteristic of the transmission function of the beam chopper since the x-ray beam was larger than the slot through the rotor.

**Discussion**

A performance test of a new high-speed x-ray beam chopper has been conducted at the APS. The test demonstrates that: (a) the open window position of the beam chopper can be synchronized to any 2450 ns portion of the temporal structure of the APS storage ring and (b) a laser pulse can be synchronized to the transmission of an x-ray pulse through the beam chopper. These two tests taken together demonstrate that experiments with time resolution approaching the achievable limit at the APS storage ring are possible.

**Acknowledgment**

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**Reference**

[1] A. McPherson, J. Wang, P.L. Lee, and D.M. Mills, *J. Synchrotron Rad.* **7**, 1–4 (2000).