Development of a Fast X-ray Shutter System

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Final Technical Report

The objective of the proposal was to develop a fast shutter mechanism which would allow separation of a single pulse of x-rays out of the given time structure of the Advanced Photon Source (APS). The suggested specifications for such an instrument were based on our experience with a similar instrument used at the European Synchrotron Radiation Facility (ESRF), the unpopularity of the required special operating mode which limits the current in the accelerator to less than 10 % of its design value, and the anticipated unavailability of such a current-limiting operating mode at the APS.

Experiments at the ESRF showed that all time-resolved experiments derived from a single pulse of x-rays are at the very limit of all available photons, and that measures which would eliminate a fraction of such pulse by mechanical apertures are counter-productive. Scientific discussions with APS management resulted in the APS decision to try asymmetric fill patterns in the storage ring essentially to: (1) supply most of the current (85%) during less than 1 microsecond - called a super bunch and equally usable for time-resolved experiments in the micro-second time regime and (2) to provide a separate single bunch on the opposite side of the storage ring for experiments in the nanosecond time regime. These two events altered the design specifications for the device to provide for a larger mechanical opening for the passage of all at the expense of a slower minimal opening time.

The technological challenges in developing this kind of device range from engineering of ultra high strength alloys, mechanical shape development for optimal strength using reliable code and finite element calculations, coupling such materials to motorized shafts, magnetic suspension of high velocity rotors in combination with phase pick-up and excursion monitoring, resonance control, and jitter-free electronics. Each individual optimization is a specialty job, typically performed by different companies and research groups. Initially, several domestic companies were contacted to perform part of the functions, until we found the German National Laboratory (Forschungszentrum Juelich), which had all necessary skills under one roof. This laboratory concentrated on the development of nuclear technology, including the development of gas ultra centrifuges for isotope separation, instruments typically built out of similar materials and operated at high rotary speeds. A great advantage was their familiarity with magnetic suspensions and phase locked driving electronics.

Mutually satisfactory general terms and conditions were arranged so that Forschungszentrum Juelich could collaborate with our researchers in designing and building this device. Juelich based their design on the experience with a similar device manufactured for the ESRF, but changed the opening characteristics and hence the stability requirements both of the rotor and the mechanical housing. The driving electronics were completely re-designed and matched to the experimental requirements for time-resolved experiments at the

APS. The APS provides suitable timing information such that the rotor can be phase locked to the storage ring. This development is a deviation from our previous experience with asynchronous but predictable timing electronics and provides less electronic jitter for better time resolution during x-ray experiments.

The pulse selector was delivered and integrated into the x-ray diffraction environment, tested and improved in another cycle of development to avoid virtually all resonance in the frequency spectrum. Our researchers developed an acoustic delay line as protection against air inrushes and associated catastrophic failure of the rotor and suitable thin diamond windows for maximum x-ray transparency. The excursion of the rotor from its ideal position is constantly monitored and integrated in an emergency shut down system.

Overall, the design goals of the project were reached or exceeded and practical experience with the device is being collected during a synchrotron run scheduled at the APS in March 2000.