BioCARS News

Generation and Use of 100 fs Hard X-ray Pulses: BioCARS Participation in the SPPS Project at SLAC/SSRL

The X-ray pulse length emitted by synchrotron sources such as the APS is determined by the electron bunch pulse length, which in turn is limited to about 100ps by essential, long-term stability requirements on the electron beam. However, many interesting structural processes in hard and soft condensed matter and in biological systems occur on time scales shorter than 100 ps (Martin and Vos, 1992), which are inaccessible with existing synchrotron sources.

Considerable effort has therefore been put into the development of novel ultra-fast hard X-ray sources, the most promising of which is the proposal to construct a hard X-ray free electron laser (FEL). In this device, extremely bright, fully coherent, 100fs pulses of X-rays are to be generated by the self-amplified spontaneous emission or SASE process (Kondratenko and Saldin, 1980) as a brief electron bunch derived from a linear accelerator traverses a very long undulator of roughly 100m in length.

The funding for a detailed engineering design of such hard X-ray device has been approved for the Linear Coherent Light Source (LCLS), at the Stanford Linear Accelerator Center (SLAC). If funded and built as planned, the LCLS will be completed by 2008. The LCLS source will produce X-ray pulses of tunable wavelength at 60-360Hz, with 10^{11}-10^{12} photons per pulse.

Another FEL facility is under consideration at the DESY particle physics laboratory in Hamburg, Germany, alongside a proposed particle collider TESLA.

A different type of sub-ps X-ray source was proposed by a Stanford University group (Cornacchia et al., 2001; Krejcik et al., 2001). The Sub-Picosecond Pulsed Photon Source (SPPS) will generate 80fs hard X-ray pulses by longitudinal compression of an electron bunch in SLAC as it is accelerated to 28 GeV. The compression takes advantage of an energy chirp imposed on the electrons by multiple magnetic chicanes in the accelerator, in which the electron path length depends on their energy. The compressed electron pulse finally traverses a more conventional insertion device and emits spontaneous hard X-ray synchrotron radiation.

The SPPS radiation is largely incoherent and with approximately 10^8 photons per pulse, this source is comparable to the undulator sources at the beamlines 14-ID (BioCARS) at the APS and ID09 at the ESRF. Both beamlines are successfully used for nanosecond time-resolved experiments on biological systems. However, the SPPS pulse duration of 80fs is 10^3 shorter than that of synchrotron-derived pulses. Thus, the temporal peak brilliance is enhanced by the factor of 10^3. Although significantly lower in brilliance than the future FEL sources, a significant advantage of the SPPS for biological samples is the corresponding reduction in the expected radiation damage.

Despite its limitations of a fixed energy of the X-ray radiation and a repetition rate of only 10 pulses per second, the SPPS represents an intermediate solution between the present third-generation synchrotron X-ray sources and future fourth-generation sources. It can be achieved quickly and cheaply at SLAC/SSRL, well in advance of the LCLS. It will also provide the vital R&D on LCLS accelerator and X-ray optics, and on the all-important timing issues.

BioCARS staff is actively participating in the on-going SPPS project. Our collaboration takes three forms:

- Loaning the BioCARS wiggler to SSRL to use as the radiation source (where it would function as an undulator at the much higher electron energy of 28 GeV)
- Development of novel strategies for achieving 100fs time resolution with much longer, chirped X-ray pulses (Moffat, 2003)
- Participation of BioCARS staff in commissioning of the SPPS experiments that utilize the 80fs X-ray pulses, particularly on biological systems

The collaboration addresses one of the frontiers of time-resolved studies (Moffat 2003), that of time resolution; it builds directly on BioCARS experience at much longer time scales in the 100ps to ns regime; and it provides a foundation for even more challenging experiments when the LCLS is built.

The first X-ray beam at the SPPS experimental hutch was registered at 8:30 pm, May 19 2003. For more details, click here.

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