Laser-SR Synchronization

A synchronization system between an intense pulsed laser and synchrotron radiation (SR) pulses has been developed at beamline **BL29XUL** for laser + SR pump-probe experiments such as time-resolved X-ray diffraction and absorption measurements, and for studies on the mixing of X-ray and optical photons. Since the SPring-8 SR has a pulse duration of typically 40 ps (FWHM), the synchronization technique of laser pulses with a precision of less than a few tens picoseconds is required to achieve a perfect overlap of both pulses.

The synchronization scheme is shown in Fig. 1. The output timing of a mode-locked Ti:sapphire laser (oscillator) is synchronized with the radio frequency (RF) provided by the master oscillator which controls the RF cavity for acceleration of the electron bunches in the storage ring. The repetition rate of the laser pulse is determined by its cavity length, which is controlled by a piezo-electric translator with a feedback circuit. The intense picosecond laser pulses with a pulse energy of about 1 mJ were obtained by amplification of the pulses picked up from a mode-locked Ti:sapphire laser. The repetition rate of amplified laser pulses was controlled to be 1/*n* of the RF, where *n* is a multiple of the number of RF buckets in the ring, so that the laser pulses meet the SR pulses originated from a particular electron bunch in partial filling patterns [1].

A monitoring system of the timing for both beams on a picosecond time scale should also be developed, since conventional methods, such as optical cross correlation technique, are still not available for the hard X-ray SR + laser combination. We used a picosecond X-ray streak camera as a timing monitor [2]. Both pulses simultaneously irradiated a photocathode on the streak camera. This method ensures a precise measurement of the interval between both beams without being affected by the drift of the streak trigger timing. The laser and the X-ray SR beams were introduced to the photocathode through a dichroic mirror made of a surface-polished Be plate installed in a vacuum chamber. Figure 2 shows the streak profiles obtained at a fine adjustment of the interval between the laser and SR pulses. Synchronization between the laser and the SR pulses was achieved with a precision of ±2 ps.

Application of this synchronization system to an investigation of electron bunch dynamics is also described here. Since the laser pulses are precisely locked to the phase of the RF in the

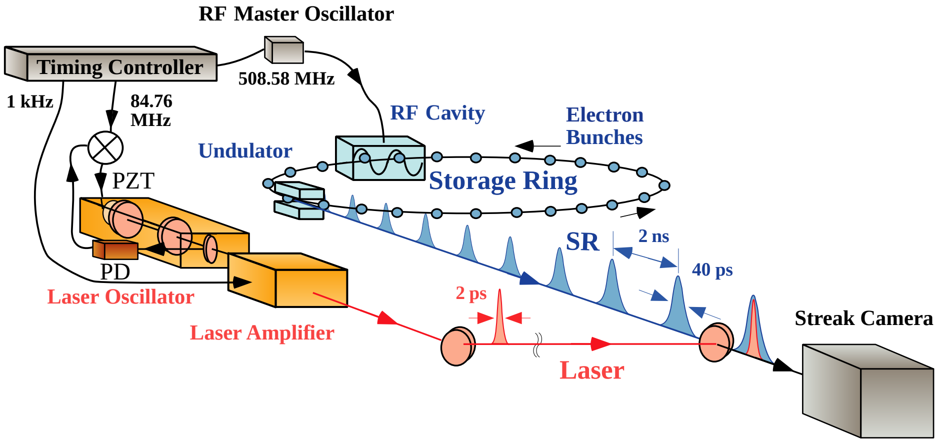

Fig. 1. Laser-SR synchronization system.

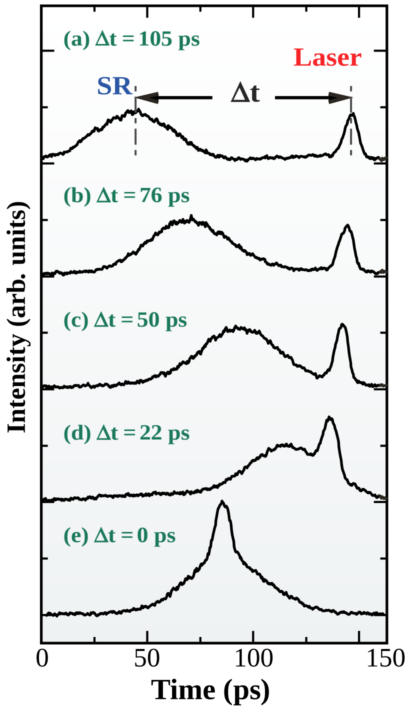

Fig. 2. Overlap of laser pulses with SR pulses.

storage ring, we used this system to show that closing undulator gaps shifts the arrival time of the SR pulses, which is due to the electron energy loss produced by the undulator radiation. The graphs in Fig. 3 are obtained under the conditions that the gaps of 14 undulators are fully opened (a) and closed (b) while the BL29ID gap is fixed to monitor the timing. The shift of the SR pulses between (a) and (b) has a good agreement with the expectations for the increased power loss [3].

Some picosecond time-resolved X-ray diffraction experiments were performed using the laser-SR synchronization system. Figure 4(a) shows the time-resolved rocking curves of a GaAs crystal, obtained by varying the delay between the pump laser and the probe X-ray pulses. The Bragg peak is shifted by the lattice expansion with a response time of a few hundred picoseconds. The diffracted

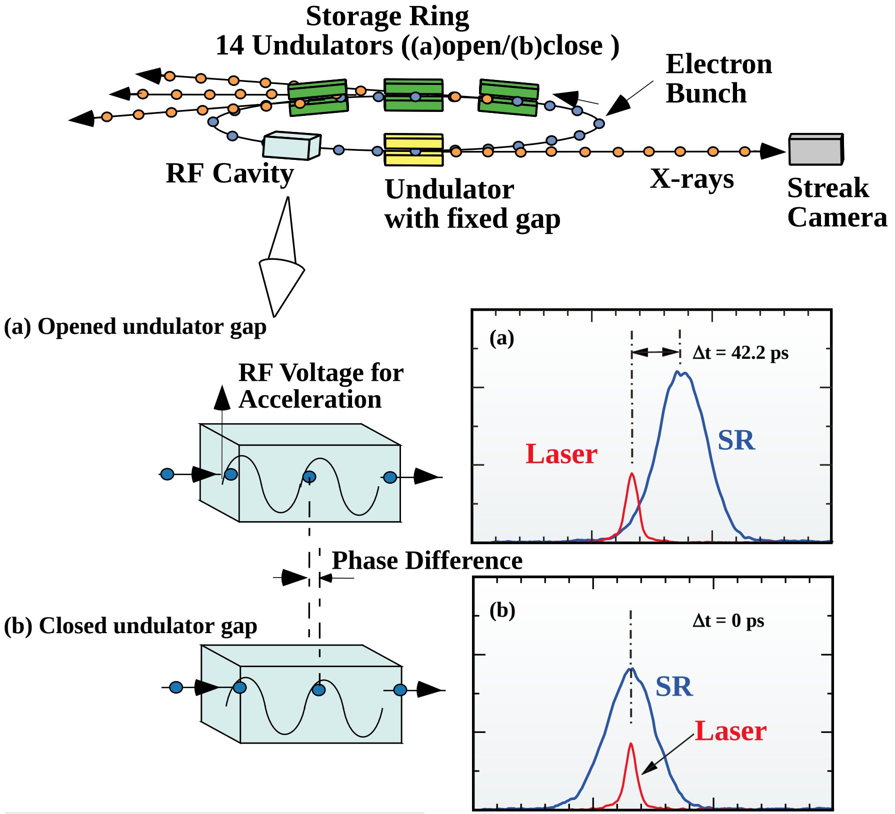

Fig. 3. Temporal drift of SR pulses due to the undulator power.

X-ray intensity at a certain offset angle is drastically changed according to the Bragg peak shift as shown in Fig. 4(b). It is to be noted that the lattice recovered from the expansion within 1 ms corresponding to a laser pulse repetition rate of 1kHz. We also investigated the optical switching method of the X-rays using the lattice expansion, as shown in Fig. 5. A single pulse was extracted from the synchrotron radiation pulse train using a double crystal arrangement of GaAs, in which the two crystals were irradiated by way of two successive laser pulses with an appropriate time delay [4]. This technique may enable individual beamline-users to employ SR pulsation with a pattern required for their experiments, which is usually supplied with a filling pattern of electron bunches in the storage ring. Further development of a faster X-ray switch will allow for an ultrashort X-ray pulse to be shaped from a single SR pulse.

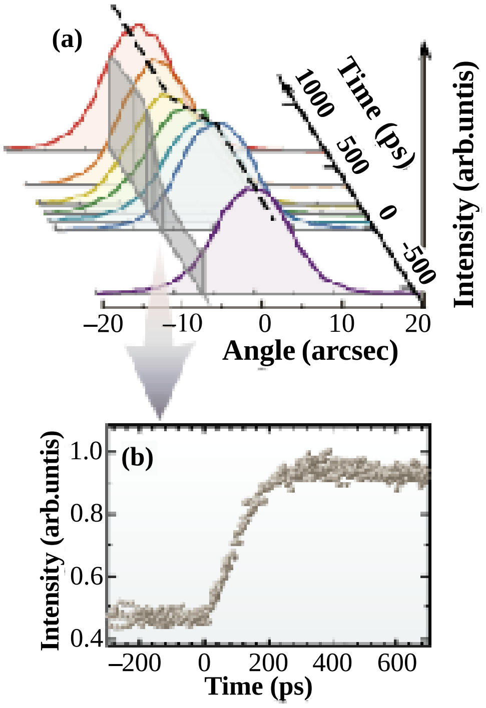

*Fig. 4. **(a)** Time-resolved rocking curves and **(b)** change in diffracted X-ray intensity at an offset angle of –7 arcsec.*

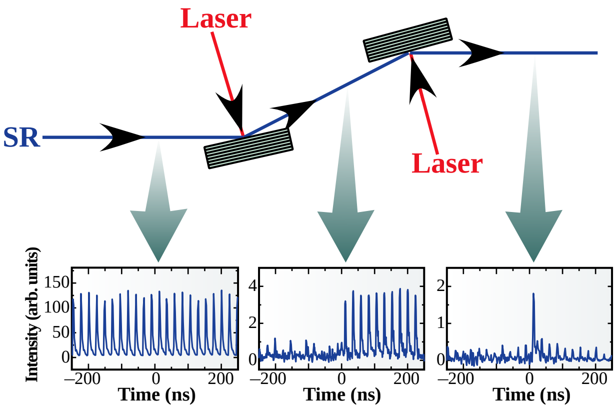

Fig. 5. Extraction of a single X-ray pulse from the SR pulse train by optical-switching using laser-induced lattice expansion.

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References

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