# Development of precise time resolved technique in X-ray diffraction experiment at SPring-8

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Precise time control is one of the key techniques for the ***X-ray pinpoint structural measurement system*** in SPring-8. In order to reveal the relation between dynamic structural changes and material functions, we have developed a picosecond time-resolved X-ray diffraction measurement system using a pump and probe method combining femto/picosecond laser pulses and the synchrotron radiation pulses (FWHM: ~40 ps). A precise time delay between pump and probe pulses is usually controlled by an optical delay line. Instead, we have achieved the time delay scanning control with less than 5 ps step by using an electronic delay generator. The scheme of electronic timing delay is useful for time delay scan as keeping the irradiation position, which well meets the pinpoint structural measurement requirement. By using the electronic delay unit, our diffraction system has achieved the time control precision of ±8.40 ps and the spatial resolution of 1 μm. The system shall allow the investigation of rapid structure change under short pulsed laser irradiation such as photo-induced metal-insulator phase transition and amorphous-crystal phase transition on recording DVD media.

An experimental station for X-ray diffraction and a laser booth for short pulsed lasers were constructed at BL40XU of SPring-8 for the pinpoint structural measurement. As for achieving the spatial resolution of 1 μm, an X-ray focusing system with Fresnel zone plates was developed. The time resolved system is mainly composed of an X-ray pulse selector, a two circle diffractometer and a femto/picosecond mode-locked Ti:sapphire laser synchronized with the X-ray pulse. We here report the accurate timing control by the electronic delay unit, which is crucial for the ***X-ray pinpoint structural measurement system***.

## Femto/picosecond laser system and timing control system

The laser system consists of the mode-locked Ti:sapphire laser, regenerative amplifier, pulse selector, and optical parametric amplifier. The mode-locked Ti:sapphire laser produces the pulses with a duration of 80 fs, typical energy of 10 nJ/pulse at the wavelength of 800 nm. A repetition rate of the Ti:sapphire oscillator is synchronized to 84.76 MHz which is 1/6 of a master oscillator of the RF system for storage ring acceleration (508.58 MHz). A repetition rate of the regenerative amplifier is also synchronized to 948.98 Hz which is 1/535920 of the master oscillator. Output pulses of the regenerative amplifier meet X-ray pulses on a sample. Delay time between the laser pulse and the X-ray pulse is controlled by a high precision electronic delay generator which is composed of in-phase quadrature (IQ) modulator and D/A converters. A striking feature of the high precision electronic delay generator is capable of wide range scanning without loss of the precision.

## Quantitative evaluation of the precision of the time delay scanning control in pump and probe measurements

In order to evaluate the precision of the time delay scanning control, we have carried out pump-probe measurements for a high-purity undoped crystal wafer of (100)-GaAs. Intensity of the 400-Bragg reflection from the wafer was monitored by an avalanche photodiode. Positions of laser and X-ray pulses were overlapped on the surface of the GaAs wafer. When a laser pulse irradiates the surface of GaAs wafer, the crystal lattice expands instantaneously. Then the angle of the Bragg reflection slightly shifts to lower angle, and the intensity of the Bragg reflection abruptly changes. We determined the time delay control precision of our diffraction system to be ±8.40 ps by estimating the fluctuation of the time when the reflection intensity just changes. The high precision implies that the time response of faster than 40 ps (SR pulse duration) is measurable through deconvolution analysis of the obtained data.