SYNCHRONIZATION BETWEEN LASER AND ELECTRON BEAM AT PHOTOCATHODE RF GUN

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Abstract

The chemical reactions of hot or room temperature and/or critical water in a time-range of picosecond and sub-picoseconds have been carried out by the 18 MeV S-band linac and a Mg photocathode RF gun with the irradiation of third harmonic Ti: Sapphire laser, at Nuclear Engineering Research Laboratory (NERL), the University of Tokyo. Although this short bunch and 100 fs laser light are enough to perform the experiment of radiation chemistry in the time-range of sub-picoseconds, the total time-resolution become worse by the instability of synchronization between laser and radio frequency of linac. We found that the fluctuation of room temperature causes the instability, particularly the cycle of turning on/off of the air-conditioner. When we decrease the fraction of the room temperature within 0.1 degrees, the timing drift in an hour reaches 600 fs, closed to the timing jitter of 340fs than previous results.

INTRODUCTION

A pulse radiolysis method is a useful and powerful technique for studying fast chemical reactions[1]. The intensive researches using the pulse radiolysis method have been carried out in aqueous solutions, organic liquids and polymeric systems[2]. Especially, the chemical reactions of hot or room temperature and/or critical water in a time-range of picoseconds and sub-picoseconds have been carried out by 18MeV S-Band linac with a BNL-gun IV-type(1.6cells)[3] and a Mg cathode of Spring8/KEK/U.Tokyo for three years[4,5]. The important factor for such as the fast radiation chemistry is not only the pulse length of beam and laser but also the synchronization between the electron beam and laser. The synchronization is much influenced by external environments, especially for the fluctuation of laser-room temperature.

We have experimentally investigated the influence of this fluctuation to the synchronization. Furthermore we discuss active feedback system to achieve to be long-term stable, femto-seconds pulse radiolysis system.

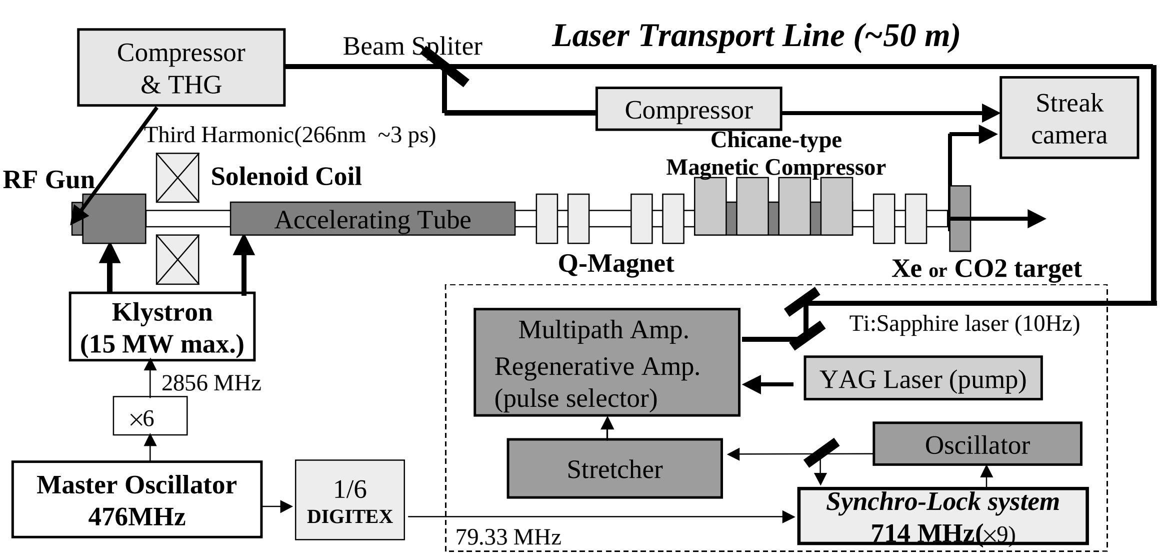

Figure 1: Experimental setup for sub-picoseconds pump- and probe-type radiation chemistry.

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EXPERIMENTAL SETUP

The eexperimental setup for sub-picoseconds pump-and probe-type radiation chemistry is shown in Fig. 1. The S-band linac, which provides an electron bunch as a pump-beam, consists of the photocathode RF gun, an accelerating tube and a chicane-type bunch compressor. Driven laser for RF gun and a probe-laser are generated from a Ti:Sapphire oscillator, which produces a laser light with a wavelength of 795 nm, an energy of 35mJ/pulse, a pulse duration of 300 ps and a repetition rate of 10 pps.

The laser and RF pulse of Klystron (and relevant gun and accelerator) are synchronized by using same master Oscillator. The frequency of master Oscillator is 476 MHz, so that we generate sixth harmonic(2856MHz) for the Klystron and sixth sub-harmonic(79.33MHz) for the laser.

The sub-harmonic generator (DIGITEX) also synchronizes detectors or other components. The laser Oscillator is synchronized with the frequency of 714MHz (9th harmonic) and the laser stretches from 100 fs to 300 ps. After stretcher the laser is amplified and retrieved with the frequency of 10 Hz.

In order to achieve good synchronization, we use fs-Ti: Sapphire laser beams which separate to driven laser for RF gun and probe laser: A driven laser is compressed and irradiates to a third harmonic generator (THG), which is provided the third harmonic laser with a wavelength of 265 nm, an energy of ~100 µJ/pulse and pulse duration of a several picosecond. A spot size of the laser on the surface of the cathode is about 3 mm in diameter.
Another laser beam is also compressed to the time duration of 100 fs with the beam energy of several mJ for probing beam.

The performance of RF injector and the relevant laser and electron beam are shown in Table 1. The QE of the Mg cathode is achieve to 1.3 × 10^{-4}[4], corresponding to 1/10 as smaller as the expected value currently[6]. We think the reason that Mg cathode was exposed in air or moisture, unfortunately, though we kept it in helium gases immediately after diamond polishing. The beam is generated stably with the energy of 22 MeV, the charge of 1~2 nC(up to 3nC) /bunch and the bunch width of less than 1 ps. The normalized beam emittance are 26 πmm·mrad (horizontal) and 24 πmm·mrad(vertical)[4]. These bad emittance are thought to be caused by un-matching spot shape from oblique irradiation.

Table 1: Performance of RF injector

RF Injector			RF	
Cathode		Mg	Power	6.0 MW
Q.E.		1.3× 10^{-4}	Pulse Duration	2 µsec
Charge		1nC/bunch	Repetition	10 Hz
		Up to 3nC/bunch	**Laser**	
Dark Current		800 pC/bunch	Driven Laser	Ti:Sapp., THG
Emittance	Horizontal	26 πmm· mrad	Laser Energy	100 µJ/pulse
	Vertical	24 πmm· mrad	Laser spot size	φ 3mm
Bunch Duration		0.7 ps (1.5 nC, FWHM)		
Beam Energy		22 MeV		

The electron beam generated from the photocathode is focused by solenoid coil(1.0-1.8 kGauss), and a laser injection phase are optimized to charge-maximum.

After accelerating, the beam transports by sets of quadropole magnets and the electron bunch is compressed using the chicane type magnet (see Fig. 1). The compressed bunch goes through a chamber filled in Xe or CO_2 gas, in which the electron bunch is emitted the Cherenkov light. The bunch duration is observed using a streak camera(FESCA, Hamamatsu Photonics Co.), which is measured the pulse duration of the Cherenkov light. The bunch duration is measured to be 0.7 ps (FWHM). The probe laser also irradiates to the streak camera after optical delay. The synchronization between the probe laser and the electron beam is measured from the relative time difference between the laser and the electron beam. Room temperature in laser room measures thermometer with a resolution of 0.1 degrees and the time evolution data are recorded in PC.

EXPERIMENTAL RESULTS

The previous results of the time evolution of the synchronization between the probe laser and the electron beam (lower), and the relevant temperature of the laser room(upper) are shown in Fig.2. We found that the frequency of the synchronization is good agreement with that of the temperature. It means the fluctuation of the room temperature has effect to the synchronization, especially much influence to laser Oscillator.

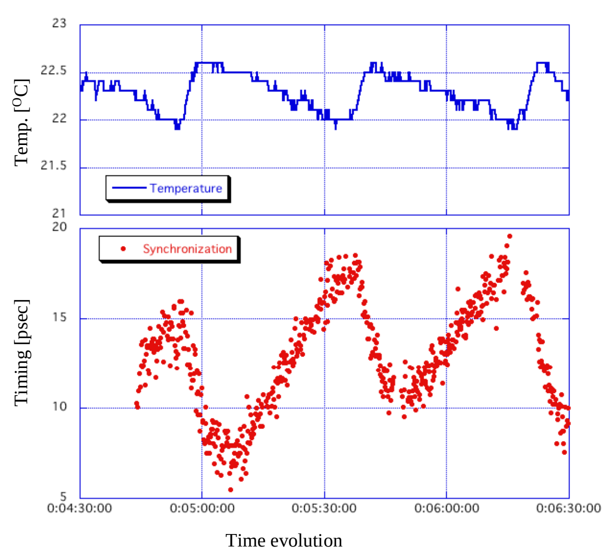

Figure 2: Previous results of the time evolution of the synchronization between the probe laser and the electron beam (lower), and the relevant temperature of the laser room(upper). The frequency of the synchronization is good agreement with that of the temperat ure.

In order to decrease the fluctuation, we remove the local heat source near oscillator[7]. After re-construction, we can decrease the fluctuation within 0.1 degrees, limit of our thermometer (Fig. 3). Figure 3 also shows the Time evolution of the synchronization. We found quick and large components in the drift disappear. The jitter in one and a half hours reaches 600 fs(rms), which is closed to the jitter in short period (340 fs(rms)) than previous results(in Fig. 2). Nevertheless in more long period (ex. 1day), we still observe 6 ps drift (peak to peak) by temperature shift of outside in day and night. Our laser transport line is 50 m long, so that stretchy of the building might have bad influence to the synchronization.

DISCUSSION

We could observe a good synchronization between the pumping electron beam and the probe laser in hour, and

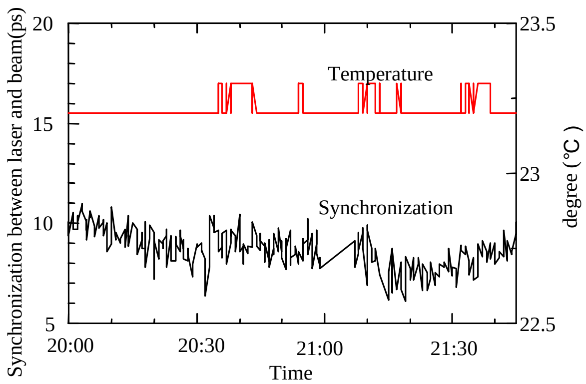

Figure 3: Time evolution of the synchronization and the relevant temperature. The fluctuation of the temperature decreased within 0.1 degrees, and quick and large components in the drift disappears. The jitter in one and a half hours is 600 fs(rms), which is closed to the short time jitter of 340 fs(rms) than previous results (in Fig. 2).

we can also observe that the stability of the electron beam current is ~4%(rms) during 1 hour. These results are enough for one experiment of sub-picoseconds pulse radiolysis. However the experiments in long period are still not. When we change the accelerator RF phase slightly, synchronization can be adjusted. It means that the laser phase automatically goes out of whole alignment by laser's Synchro-Lock system. In order to avoid losing synchronization, we are developing the phase feed back system to fix the phase difference between accelerator and laser.

We have also aligned, manually, the beam point on the mirror in front of Compressor by CCD camera and mirror with computer controllable micro-motor. In an hour, we have hardly aligned, but need to align in one-day period. In order to obtain a good point stability, we are also developing the automatically feedback system.

Additionally, the sub-harmonic generator (DISITEX) has also problem, misfired and jitter between the streak camera and the beam. These might be bad influence, so that we are fixing the DIGITEX, together with 6th harmonic generator.

CONCLUSION

We can reduce the fluctuation of room temperature within 0.1 degrees, so that we can observe a good synchronization of 600 fs between the pumping electron beam and the probe laser in an hour. It has the potential to do the experience of the pulse radiolysis experiment in an hour. In order to synchronize in long period as one-day, we are developing to new feedback system of phase matching and point stabilizing.

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