Development of New Picosecond Pulse Radiolysis by Using Laser Photocathod RF Gun

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Abstract

A prototype of pulse radiolysis system for absorption spectroscopy was developed by using a laser photocathod RF electron gun. The gun was equipped with the 150 MeV s-band linac at ISIR, Osaka University. A picosecond YAG laser was used for the analyzing light and driving pulse of the gun. The RF, triggering, pulse compression and experiment systems are reported.

1. Introduction

Primary processes of radiation chemistry are very important to know the whole reaction processes induced by high-energy radiation. Pulse radiolysis technique is one of the most powerful methods to research the primary processes, because very fast reaction can be detected directly.

Stroboscopic method is used in many picosecond pulse radiolysis system. A sample is irradiated by a picosecond electron pulse to occur a radiation–induced reaction. At the same time, a picosecond analyzing light is injected into the sample to detect the absorption of very short-lived intermediates. By changing the time-difference between the electron pulse and the analyzing light, the time-dependent behavior of the reaction mechanism can be obtained.

A new type of the picosecond pulse radiolysis system [1-3] has been developed at Osaka University. The system has a femtosecond laser to generate the analyzing light. Piocsecond electron pulses from a L-band linac are synchronized with the femtosecond laser pulses. Recently, the synchronizing technique has been applied to subpicosecond pulse radiolysis[4]. Moreover, the development of the femtosecond pulse radiolysis system is expected by many researches. The synchronizing technique will be important in the femtosecond pulse radiolysis.

We have a plane to develop a prototype of pulse radiolysis system by using the laser photocathod RF electron gun. The merits of the system are as follows.

1) It is easy to synchronize the analyzing laser pulses with electron pulse.
2) The femtosecond electron pulse can be obtained, because of the high quality of the electron beam.
3) Whole system will be compact.

2. Pulse Radiolysis System

Figure 1 shows the picosecond pulse radiolysis system. The laser photocathod RF gun[5] was equipped with a 150 MeV s-band electron linac. The laser photocathod was driven by the fourth harmonic laser pulse (266 nm) from a YAG laser. The s-band linac had a prebuncher, a buncher and three acceleration tubes

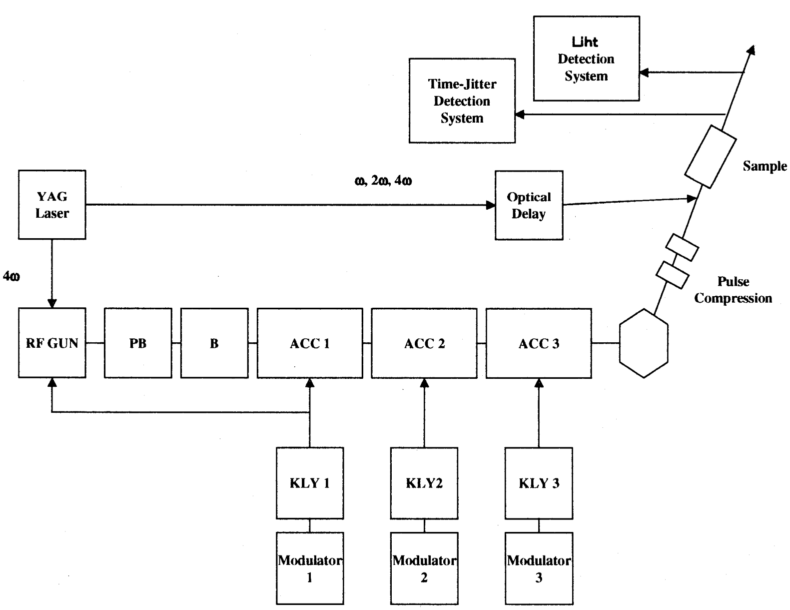

Fig. 1 Pulse radiolysis system by using a laser photocathod RF electron gun

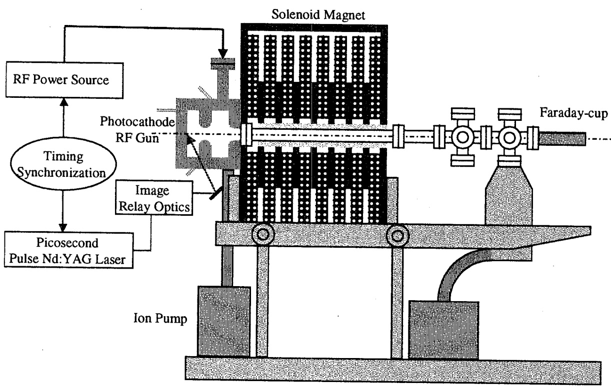

Fig. 2 Cross section of laser photocathod Rf electron gun.

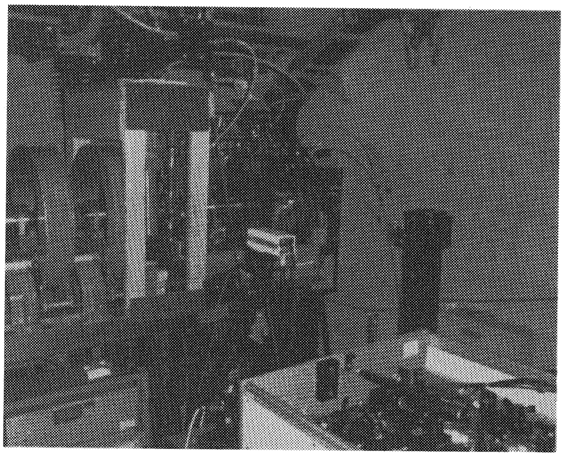

Fig. 3 YAG laser system and the gun installed in the s-band linac.

(ACC1, 2 &3). The RF power of 2 MW for the RF gun was provided from the klystron, which drives the 1st acceleration tube. The RF power for both of the prebuncher and the buncher was not provided.

After the acceleration tubes, there is a pulse compression system which is composed of a bending magnet and a Q-magnet (doublet).

A sample was irradiated by a picosecond electron pulse from the linac. The laser pulse of 1064 nm, 532 nm (SHG) or 266 nm (FHG) from the YAG laser was used as the analyzing light. To make the time-difference between the electron pulse and the laser pulse, the optical delay was inserted in the transport line of the analyzing light

3. Laser photocathod RF gun

The laser photocathod RF gun was developed by Sumitomo Heavy Industries and Brookhaven National Laboratory[5]. Figure 2 shows the cross section. The RF cavity has 1.6 cells of s-band, and the material of photocathod is Cu.

The YAG laser system, which is composed, of an oscillator, a regenerative amplifier, an amplifier and a harmonic generator is installed in a compact box. The frequency of the oscillator is 119 MHz, which is equal to 1/24 of s-band frequency. The timing stabilizer system in the oscillator depresses the timing drift of the laser pulse against the RF frequency of 119 MHz. The laser pulse width, power and repetition rate of 266 nm were 10 ps, 100 μJ/pulse and 10 Hz, respectively.

Figure 3 shows a photograph of the laser photocathod RF gun and the YAG laser, which were installed in the s-band linac.

4. RF and trigger system

The RF and trigger system was changed for the picosecond pulse radiolysis, as shown fig.4. The basic RF frequency was 119 MHz, which was derived to the laser oscillator and a synchronized circuit for a streak camera. The 2856 MHz for the RF gun and the s-band linac was produced by multiplying of 119 MHz by 24.

The system clock of 10 Hz for the linac trigger was generated from a clock generator of 480 Hz. Also, the pre-trigger for Laser Diode (LD), which excites the YAG laser, was produced from the clock of 480 Hz.

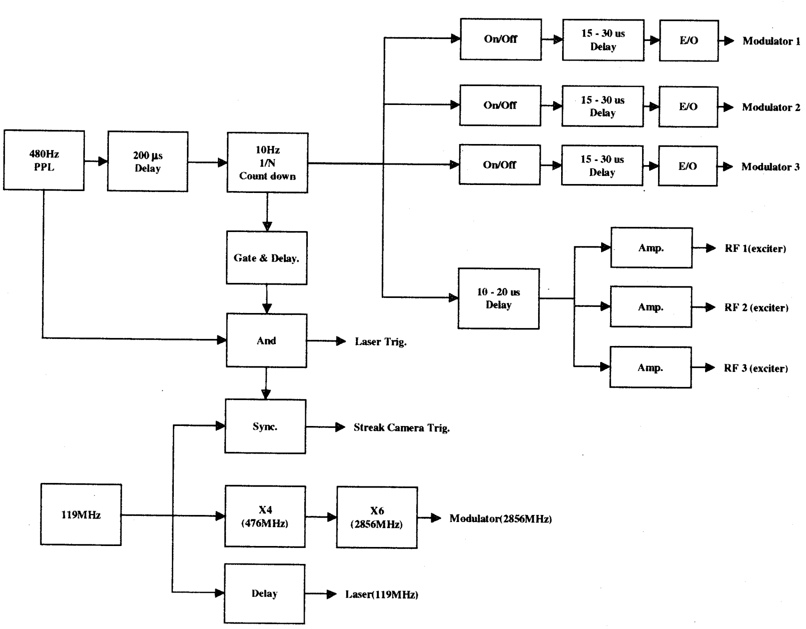

Fig. 4 RF and trigger system for pulse radioysis

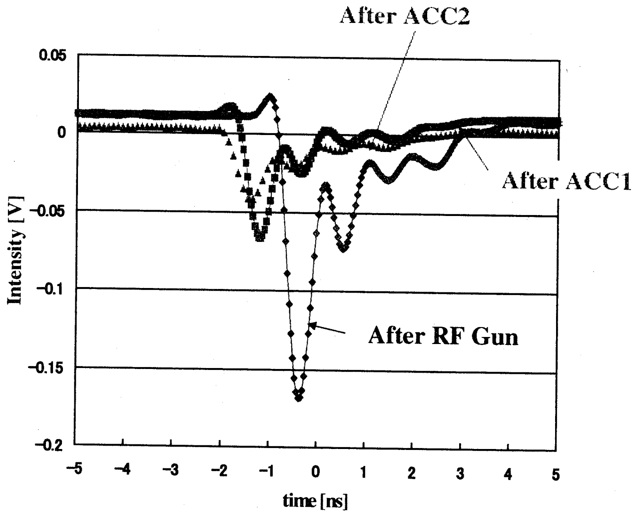

Fig. 5 typical profile from beam monitors at the end of RF gun, ACC 1 and ACC2

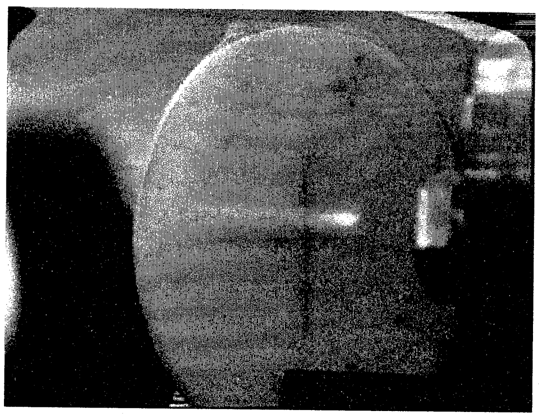

Fig. 6 beam profile on a desmarquest screen monitor at sample position

5.Acceralation test and pulse compression

Figure 5 shows typical profile from beam monitors at the end of the RF gun, ACC 1 and ACC2. The charge after the ACC2 was reduced to one fourth of that after the gun, because the aliment of the s-band linac was not good. Figure 6 shows the beam profile on a desmarquest screen monitor at the sample position. The profile was composed of the main part and weak tail part on the left side of the main part. The position corresponds the beam energy. The energy of the tail part should be caused by the dark current from the gun. The dark current can be depressed by conditioning of the surface of the photocathod.

The pulse compression test has not been finished. ACC1 & ACC2 is used as the acceleration, and ACC3 was used as the modulation of the energy for the magnetic pulse compression.

6. Performance of picosecond pulse radiolysis

The time resolution of the pulse radiolysis is decided by the pulse width of the electron pulse, the pulse width of the analyzing light pulse, timing-jitter between both pulses, and thickness of the sample. Present pulse width of the laser is 10ps, which decides the time-resolution.

The estimated charge of the electron pulse was less than 100 pC, which was slightly low for the pulse radiolysis. The intensity of the optical absorption depends on the concentration of the intermediates produced by the electron beam. If the beam size can be made small by the optimization of the operation parameters of the linac, we will get the enough absorption intensity.

7. Summary

The prototype of new pulse radiolysis system by using the laser photocathod RF electron gun showed high performance. By improvement the laser system and the gun system, the femtosecond pulse radiolysis system will be developed.

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