STATUS REPORT OF L- & S-BAND LINAC AT ISIR, OSAKA UNIV.

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Abstract

The L-band and S-band linacs at ISIR, Osaka Univ. were used for quantum beam science, such as picosecond and subpicosecond pulse radiolysis, slow positron beam, FEL, coherent radiation. The recent activities are reviewed.

1.Introduction

The radiation laboratory, the institute of scientific and industrial research, Osaka University, has two electron accelerators, a 38 MeV L-band linac and a 150 MeV S-band linac for the quantum beam science. Figure 1 show the location of two linac and experimental areas for pulse radiolysis, slow positron, FEL and coherent radiation. The 32 themes as shown below were adopted in 2001.

Pulse radiolysis (material)	12
Pulse radiolysis (biology)	3
Irradiation effect	3
Application of subpicosecond pulse	2
Slow positron	3
FEL & coherent Radiation Lab	5
Machine study	4

Many themes are closely related with nano science and nano technology by using quantum beams. The detail of the theme will be mentioned in section 3

2. Application of Quantum Beam

2.1 Picosecond pulse radiolysis

The performance of the L-band linac has been used in the study of picosecond pulse radiolysis to investigate the primary process of radiation chemistry. The development of the laser-synchronized picosecond pulse radiolysis was started in 1995.

Figure 2 shows a block diagram of laser synchronized picosecond pulse radiolysis. The electron pulse (pulse widthe: 20 ps, energy: 28 MeV,) was used as the irradiation source, and the 200 fs white continuum light pulse which was produced by Ti-sapphire laser amplifier system, was used as the analyzing light. The transient absorption was obtained by using so-called stroboscopic method. The time-resolution was decided by the pulse width of the irradiation source and the analyzing light and time-jitter between the irradiation source and the analyzing source.

The Ti-sapphires laser amplifier system was composed of a Ti-sapphire oscillator excited with an Ar-ion laser and a Ti-sapphire regenerated amplifier excited with an Nd:YAG laser. The amplified laser pulse was focused into a water cell to produce the continuum white light. The analyzing light through a sample cell was detected by a Si-photo detector located after a monochromator.

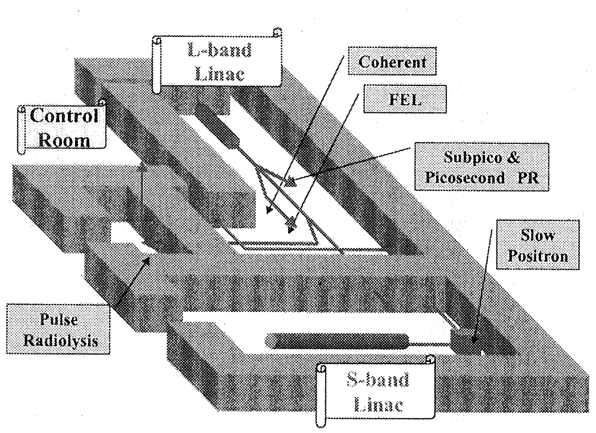

Figure 1 Location of L-band and S-band linacs and experimental section at ISIR. Osaka Univ..

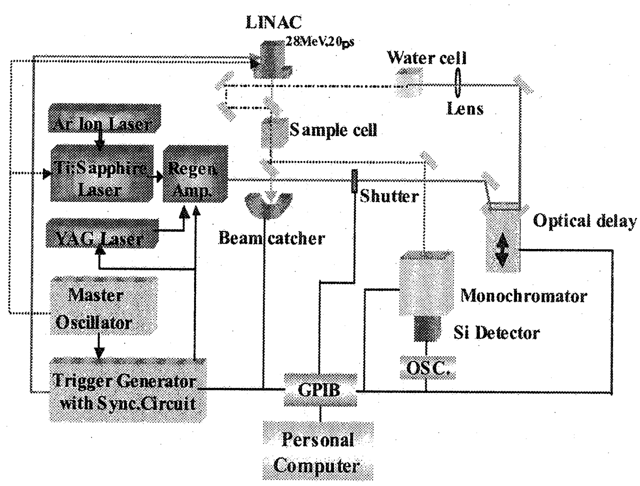

Figure 2 Block diagram of laser synchronized picosecond pulse radiolysis.

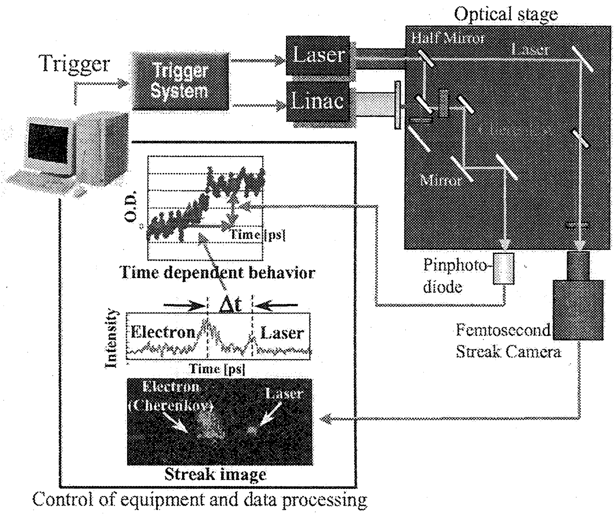

Figure 3 Double pulse method in subpicosecond pulse radiolysis pulse radiolysis.

The L-band linac and the Ti-sapphire oscillator were synchronized with the common RF to reduce the time jitter between the irradiation source and the analyzing light pulse.

All components of the system were controlled by a personal computer. The tome-resolution of the system was about 30 ps.

2.2 Subpicosecond pulse radiolysis

The subpicosecond pulse radiolysis system has been developed by advancing the laser-synchronized picosecond pulse radiolysis system. The subpicosecond electron pulse was generated by the magnetic compression system at the L-band linac. The time jitter between the electron pulse and the laser pulse reduces the time-resolution strongly in the subpicosecond region. To avoid the problem, the timing detection system as shown in figure 3 was introduced. The concept of the timing detection system is that the time jitter is detected by a femtosecond streak camera. The achieved time resolution was 800 fs.

The performance of the subpicosecond pulse radiolysis system had not been enough to detection the transient absorption due to the low S/N. This was caused by cause the vibration of the optical components, such as the mirror, lens, and so on in the laser line. The double-pulse method solved the vibration. The stability of the laser intensity was kept in 0.8 % which was reduced from 5 %. The details of the system will be reported elsewhere.

2.3 Slow positron beam

In order to estimate the free volume size and sub-surface structure of the material, the lifetime spectroscopy and S parameter measurement of the positron are very useful method. Figure 4 shows the experimental setup of the short-pulsed positron beam and the high brightness one based on the s-band linac.

The present pulse width of the positron beam is about 550 ps, which is mainly caused by the wide energy spread of the positron beam. The width will be reduced below 200 ps for the study of polymers. Moreover, the background is too high to measure the lifetime. This problem will be improved by modifying the detection system.

The high brightness positron beam is obtained with the aid of W re-moderator. The transport efficiency of the high brightness positron beam was about 2 %, which is not enough for the measurement. To improve the low efficiency, a new small moderator was redesigned by using numerical calculation.

Solid Ar is one of the most favorite materials to get the high reemission efficiency, in which free electron and free volume do not exist in principle, and the diffusion length is quite long (500nm). The efficiency increased up to a factor of 1.3 in the preliminary experiment by adopting this moderator. The details of the solid Ar re-moderator will be studied.

Further, a new positron beam experiments has been planed by using the L-band linac. By synchronizing the femtosecond laser system with the positron pulse, the behavior of the positronium in the solid material can be studied. The experiment is quite new method to advance the positron science.

2.4 FEL

R&D of the far infrared free electron laser (FEL) based on the L-band linac is in progress. We are analyzing the power gain of the FEL

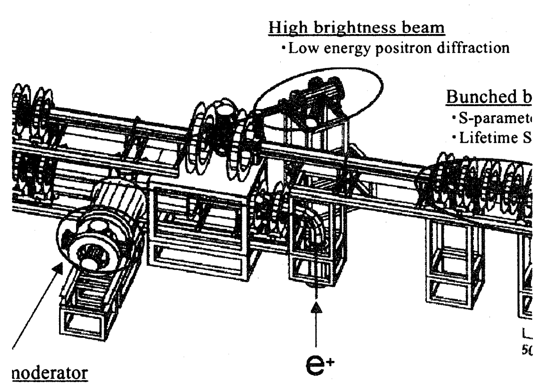

Figure 4 Experimental setup of the short-pulsed positron beam and the high brightness one based on the s-band linac.

measured so far, using the one-dimensional theory and the three-dimensional simulation code, TDA3D. The energy spread of the electron beam integrated over the macro pulse accelerated with the L-band linac is 4.4 %. We evaluated the gain from exponential growth of the measured power in the later half of the macro pulse, where the FEL signal is largest. In order to know the temporal variation of the energy spread over the macro pulse, we measured the energy spectra by changing the macro pulse duration, and obtained the energy spread in the later half to be approximately 2 %. The experimentally measured gain is in good agreement with FEL gain calculated with TDA3D, using the energy spread 2 %, peak current 50 A and the normalized emittance 150 π mm mrad. The analysis of the gain with the TDA3D shows that the high-gain effect and the optical guiding effect play important roles.

The proof-of-principle experiment of self-amplified spontaneous emission (SASE) in the infrared region is also conducted using the L-band linac. The intense light was radiated when the electron beam passed through the wiggler. The light was assigned to be SASE, because dependency of the optical intensity on the K-value agreed well with the prediction of the one-dimensional theory. Moreover, the second and the third harmonics were observed in the SASE spectrum, which was the first observation of non-linear harmonic generation of SASE.

In order to study the optical properties of the FEL and SASE, stability of the electron beam is very crucial, though it is not realized. Fluctuations of the power and the phase of the RF for accelerator cause those of the electron beam. We therefore analyzed fluctuations of RF system together with environmental parameters including temperatures at varied locations and the AC line voltage using Autoregressive model. It has been found that the fluctuation of the RF system is closely related to fluctuations of the AC line voltage and the temperature of the klystron room.

2.5 Coherent Radiation

The generation mechanism of the coherent radiation has been studied by using the electron beams of the L-band linac. The bunch shape of the beam observed with a streak camera has been compared with that obtained from the spectrum of the coherent radiation emitted by the beam. According to the results, the operational parameters of the L-band linac have been optimized.

The peak intensity of the coherent radiation at ISIR is more than five orders of magnitude higher than that of the tera Hz wave light sources using femtosecond pulse lasers. The application researches of the new light source to absorption spectroscopy and pulse radiolysis in a submillimeter to millimeter wavelength region have been started.

3. Nano science and technology by using quantum beams

The picosecond and subpicosecond pulse radiolysis, slow positron beam, FEL, and coherent radiation are powerful methods to investigate the nano science and technology. Basic researches have been started as follows.

a) Femtosecond pulse radiolysis system for analysis of reaction mechanism in nano space.
b) Pulse radiolysis system for nano material.
c) Analysis system for nano structure by using positron beam
d) Basic research of FEL and SASE for nano material application.
e) Development of THz source for spectroscopy of nano materials.