

UPGRADE OF THE L-BAND LINAC AT ISIR, OSAKA UNIVERSITY FOR HIGHER OPERATIONAL STABILITY

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Abstract

The L-band linac at the Radiation Laboratory, attached to the Institute of Scientific and Industrial Research, was constructed and began to operate in 1978. We had an opportunity to completely modify the linac in 2002 and 2003. The objective of the modification is to realize high stability and reproducibility of operation, which are essential in production and applications of advanced quantum beams. Almost all the power supplies are replaced and new systems such as a computer control system and a new timing system are introduced. The re-commissioning of the linac is in the final stage. Details of the upgrade and commissioning of the linac will be reported.

INTRODUCTION

The 38-MeV, L-band linac at the Radiation Laboratory of the Nanoscience and Nanotechnology Center, attached to the Institute of Scientific and Industrial Research (ISIR), Osaka University, was constructed and began to operate in 1978. Since then, it has been used mainly for radiation chemistry using pulse radiolysis. New activities are recently launched to develop a laser-synchronized pulse-radiolysis system in the time region down to sub-picosecond using extremely short electron pulses made with the magnetic pulse compression method, as well as to develop a free electron laser (FEL) [1] and self-amplified spontaneous emission in the far-infrared region [2]. The Radiation Laboratory used to be an independent facility directly attached to ISIR, but it merged with another attached facility to be a part of the Nanoscience and Nanotechnology Center in order to establish bases of nanotechnology as well as to promote beam science and technology. In this re-organization process, we had an opportunity to completely modify the linac in 2002 and 2003. The objective of the modification is to realize high stability and reproducibility of operation of the linac, which are essential in production and applications of such advanced quantum beams as described above. Almost all the power supplies are replaced and new systems are introduced such as a computer control system and a new timing system. The re-commissioning of the linac is in the final stage. Details of the upgrade and commissioning of the linac will be reported.

RF SYSTEM

The former RF system consisted of a 20 MW klystron (Thomson), which provided RF power to the main

acceleration tube, and a 5 MW klystron (Toshiba) for the pre-buncher and the buncher. In the new system, we use only one 30 MeV klystron (Thales) and the RF power is divided into three for the pre-buncher, the buncher, and the main acceleration tube. The new klystron has two operation modes; the normal mode with the peak power of 30 MW and the pulse duration of 4 μ s for usual operation and the long pulse mode with 25 MW and 8 μ s for FEL. A pulse modulator for the klystron newly made can provide rectangular pulses with the maximum voltage of 295 kV and the maximum current of 275 A. The repetition rate is 60 pulses per second (pps) and the duration is 4 μ s in the normal mode, while the duration is 8 μ s in the long pulse mode but the repetition rate is reduced to 30 pps. The pulse-forming network (PFN) consists of 16 stages in total, but the first 10 stages can be disconnected with a switch from the remainder for the normal mode. Switching of the operation modes and necessary adjustment of inductance in all the stages are made locally with a touch panel and remotely with a computer. Fig. 1 shows voltage output of the pulse modulator, showing two different pulse durations. A high voltage circuit of the modulator including the PFN is installed in a doubly shielded case to reduce electromagnetic noises. The high-voltage for the modulator is generated with a high-frequency switching power supply using IGBTs. The voltage of the PFN is controlled primarily by the number of charging pulses but precisely by varying their durations in the region near a target value. In specifications for the klystron modulator, the fluctuation in amplitude of output pulses shall be less

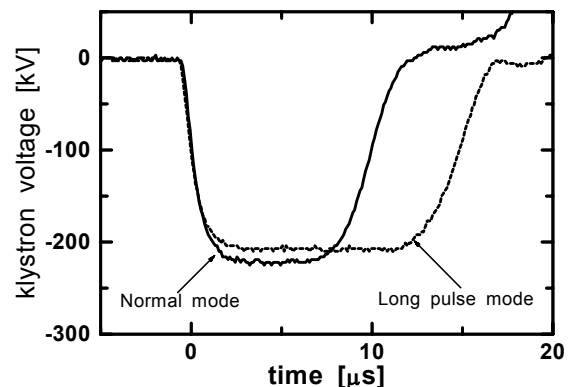


Fig. 1. Voltage pulse shape of the pulse modulator, showing two different pulse durations.



Fig. 2. Wave guide system assembled above the linac.

than 0.1 % and the flatness of the rectangular pulse shall be better than 0.2 % (peak to peak). For introducing this new RF system, the wave guide system is reconfigured by adding a power divider and a variable attenuator for the buncher system. Fig. 2 shows the wave guide system assembled above the linac. We also renew a variable attenuator and a phase shifter for the pre-buncher.

SHB SYSTEM

The sub-harmonic buncher (SHB) system is comprised of two re-entrant type RF cavities of 108 MHz, which is a twelfth of the main RF frequency 1.3 GHz, and one re-entrant RF cavity of 216 MHz, a sixth of 1.3 GHz. These cavities are excited with independent vacuum tube RF amplifiers. In this remodelling, these amplifiers are not replaced with new ones, but remodelled considerably. The power supply part and the control part are replaced with new ones, but the amplifier part including a vacuum tube remains as it was, though some of its components and parts are maintained and the others are replaced. In the former system, the RF pulse duration was 20 μ s, but it was not long enough to fill the RF power in the 108 MHz cavities, as their Q-factors were measured to be 4400. In order to meet a requirement from the long pulse mode of the RF system, the pulse duration of the new SHB system can be expanded up to 100 μ s. We currently operate the SHB system at 35 μ s duration to avoid a heating problem of the cavities by a long RF pulse, as present Q-factors are lower than the above value.

TIMING SYSTEM

Three RF sources at 1.3 GHz, 216 MHz, and 108 MHz and several timing signals are necessary for operation of the L-band linac. Relative phases between the three frequencies have to be kept precisely constant, so that the three frequencies are produced with a single master oscillator. Various timing signals in the time range from a fraction of a microsecond to tens of milliseconds are necessary for operation of the linac. The timing signals must be synchronized with the main acceleration frequency, 1.3 GHz, even though the repetition rate of a

timing signal is only 60 pps at most. The timing signals are, therefore, generated with the same master oscillator.

In order to realize highly stably operation of the linac and to produce precise timing signals for experiments, a new timing system is being developed. The master oscillator is a frequency synthesizer producing a 1.3 GHz signal. The time base of the synthesizer, a 10 MHz signal, is provided with a Rb atomic clock, which is as precise as 10^{-15} in the long term. The 1.3 GHz signal is directly counted to produce a sixth signal and twelfth signal for the SHB system as well as sixteenth signal for experiments to be used as a master oscillator for a laser system and a forty-eighth signal for synchronization between the electron beam and the laser, 27 MHz. The last one is used as a clock signal for the timing system. The linac must be operated synchronously with the AC line frequency, which is 60 Hz in the western half of Japan, and the maximum repetition rate of the linac is 60 Hz, so that the start signal is made from the AC line frequency using a preset counter and then synchronized with the clock signal. To make a timing signal, this start signal is used as a start signal for a standard digital delay generator with a timing jitter of ~ 50 ps and the delay generator makes a delayed signal. This delayed signal is used as a gate signal to slice out one of the clock signals. Thus any timing signals can be made in an interval of 37 ns and the timing jitter of the delayed signals are primarily determined by stability of the clock, which is expected to be as good as 1 ps. This timing system is made with commercially available standard components and modules except for the frequency divider and consequently it is flexible for future expansion and improvement.

CONTROL SYSTEM

The linac was operated with the analogue control system consisting of remote control boxes with helipot and only expert operators could operate it. In order to improve reproducibility of operation and to make operation easy, a new computer control system is introduced. The hardware configuration of the new control system is shown in Fig. 3. It consists of some personal computers (PC) and programmable logic controllers (PLC) connected with networks. PCs are used for operator terminals, while PLCs control various devices. The PLCs and wiring terminals are installed in device control stations (DCS) and all the devices for the linac are wired to DCSs. Three DCSs are placed in the control room, four in the linac room, so that the number of cables and their lengths are reduced. The SHB amplifiers and the modulator, which were newly made or largely remodelled, have their own PLCs for their internal control and a network board was added to each PLC, so that they can directly join the control network.

We have chosen FL-net as the network connecting these DCSs and the independent devices. FL-net will be the standard network in the next generation in factory automation (FA) and any components from different

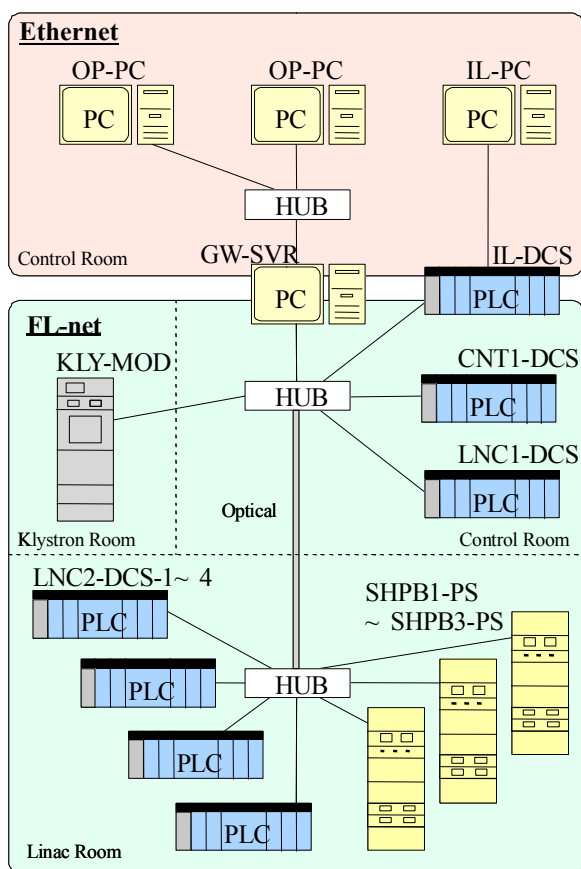


Fig.3 Hardware configuration of the computer control system.

manufacturers can be used in a network, as long as they are made in conformity with the specifications. FL-net uses the same hardware as that for Ethernet, so that cables and HUB for Ethernet can be used. PLCs communicate each other with a data area or common memory imaginary shared by network members. On the other hand, PCs communicate each other with Ethernet, so that we use a PC equipped with both FL-net and Ethernet as a gateway server (GW-SVR). The GW-SVR converts data in the common memory in FL-net to the form accessible to the other PCs and works as a data base server.

FACILITIES

The cooling water system and the air conditioner for the klystron room were also replaced with new ones at this opportunity. New cooling water system provides cooling water with temperature stability $\pm 0.1^\circ$ in the first stage to the klystron and other temperature sensitive devices. Part of the cooling water in the first stage is sent to the second

stage to produce cooling water with stability $\pm 0.03^\circ$ and it is used for cooling the acceleration tube, the pre-buncher, buncher, and the SHB cavities. The other less-sensitive devices such as magnet coils are cooled with water provided from a cooling tower as in the past.

The old air conditioner for the klystron room renewed 2 years ago, but the temperature stability is not satisfactory, approximately 3° , due to ON/OFF control. Air circulation in the klystron room was not enough because the ceiling is 5 m high. A new air conditioner of the inverter type is added on the ceiling. When the old air conditioner is used as a air circulator together with the new one, the temperature in the room is regulated within 0.3° in the short time and less than 1° in the long run.

PROGRESS AND STATUS

All the devices and instruments were delivered by March 2003. Installation and adjustment of the computer control system were completed in July 2003. Operational test and adjustment of the linac are being conducted, and defects found in the commissioning are being fixed one by one. The pulse-to-pulse fluctuation of the modulator output 0.1 %, which is one of the crucial specifications, has been fulfilled after a minor modification of the monitor circuit for the charging voltage. The flatness of the square pulse output falls within the specification, 0.1 %, in a trial, but the PFN circuit has to be modified and improved in order to achieve the specification in regular operation. A more serious problem is discharge found in the power transmission lines for the acceleration tube and for the buncher. Traces of discharge are found in two 90° twist wave guides for the buncher, in a directional coupler for the pre-buncher, and in the phase-shifter for the buncher. The first two are modified to cope with the problem and the last one will be replaced with a new phase shifter, which is being manufactured.

A remaining serious problem is discharge or power fluctuations in the transmission line for the acceleration tube. An RF window of the acceleration tube was suspected and hence replaced, but it was not a source. The problem has not been solved yet and study to identify the source is still going on.

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