PRECISE CONTROL OF COOLING WATER SYSTEM FOR STABILIZATION OF 125 MEV LINAC AT LEBRA*

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Abstract

The 125-MeV linac at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University has been used for the generation of the near-infrared FEL and the Parametric X-ray Radiation (PXR). Currently the FELs from 0.855 to 6µm and the PXR X-rays from 5 to 20keV are available at LEBRA.

Precise experiments using the light sources require a high stability in both the wavelength and the intensity of the lights. Though the linac was operated with the cooling water stabilized at 30±0.2°C, periodical fluctuation of the electron beam energy and the beam orbit suggested that the stability of the cooling water temperature was not sufficient. With this condition a large fluctuation (±15%) was observed for the PXR intensity.

After the improvement of the fine cooling water system and the water flow path, fluctuation of the cooling water temperature at the supply head of the accelerating tubes and the electromagnets was suppressed to within ±0.01°C. As a result of the improvement the PXR intensity fluctuation at the X-ray output port has been suppressed to within ±2% for the operation over several hours.

INTRODUCTION

Research of a high performance electron linac for the generation of Free Electron Laser (FEL) and Parametric X-ray Radiation (PXR) has been continued at the Laboratory for Electron Beam Research and Application (LEBRA) of Nihon University as a joint research with the High Energy Accelerator Research Organization (KEK) [1],[2]. The experiments using coherent X-rays or FELs generally require a high stability electron beam in order to keep high spatial definition and stability of wavelength and intensity.

The electron beam from the linac at LEBRA was stabilized with the klystron RF phase feedback and the beam energy feedback systems [3]. Then the work on the beam stabilization has been devoted to the improvement of the linac cooling water system, because it was found that the effect of the temperature change in the linac cooling water was not sufficiently suppressed by the feedback systems. This paper reports on the achievement of the precise stabilization for the accelerator cooling water temperature and the resultant effect on the stability of the light sources.

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LEBRA 125MEV ELECTRON LINAC

The linac consists mainly of the 100kV DC electron gun, the pre-buncher, the buncher and the three 4m long regular accelerating structures. The accelerating RF has been powered by two S-band klystrons (the peak output power of 20MW has been achieved at the repetition rate of 12.5Hz and the pulse duration of 20µs) [4]. After the improvement of the linac cooling system the accelerating structures, the bending magnet coils and the PXR Si target crystal have been cooled with the water precisely controlled by a single fine cooling unit. On the other hand, the klystrons, the klystron focus coils and the RF dummy loads have been cooled with the coarse cooling water. The layout of the LEBRA electron linac is shown in figure 1, and the specifications of the linac are listed in table 1.

The saturated FEL lasing has been obtained in the wavelength region of 0.855-6µm, with the maximum macropulse output energy of approximately 60mJ/pulse at a wavelength of 1725nm [1]. The PXR generator covers the X-ray energies from 5 to 20 keV by using Si(111) planes as the target and the second crystals[2]. These light sources have been used for the variety of user's experiments [2],[5].

Table 1: Specifications of the LEBRA Electron Linac

Maximum Energy	125	MeV
DC gun voltage	-100	kV
Accelerating RF frequency	2856	MHz
Klystron peak RF power	30	MW
Number of klystrons	2	
Macropulse duration	5~20	µs
Repetition rate	2~12.5	Hz
Macropulse beam current	200	mA
Energy spread(FWHM)	0.5~1	%

PROBLEMS IN THE COOLING WATER SYSTEM

The diagram of the original water flow path in the cooling system for the LEBRA linac is shown in figure 2. The water temperature in the fine cooling system was 30 ±0.2°C at the normal operation. The fluctuation of the PXR intensity measured using an ion chamber was approximately ±15% of the average value, strongly depending on the change in the cooling water temperature. By adjusting the control parameters of the fine cooling

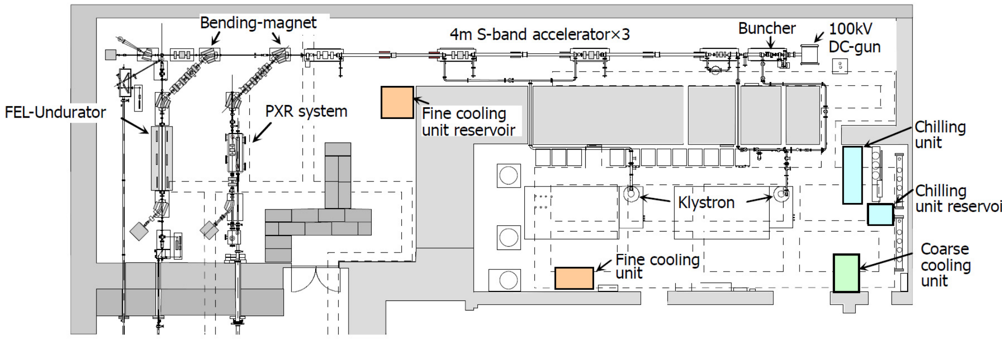

Figure 1: Layout of the 125MeV electron linac at LEBRA.

system the fluctuation of water temperature was suppressed to within ±0.1°C and the dependence of the X-ray intensity became insignificant. Then, however, the main source of the intensity fluctuation still as large as ±10% was found to be the vibration of the Si target caused by the high pressure flow of the cooling water.

The investigation of the water flow path revealed another problem of the fine cooling system. The fast change in the temperature of the chilled water caused by on/off of the compressor was found to be transmitted instantly from the chilling unit to the accelerating tubes and the bending magnets, which resulted in the fluctuation of the energy and the position of the electron beam. This implied that the action of the three-way valve was not sufficiently fast to compensate the rapid change of the chilled water temperature.

The stability of the coarse cooling water temperature was sufficiently good for a coarse cooling system. However, the klystron output RF phase was obviously

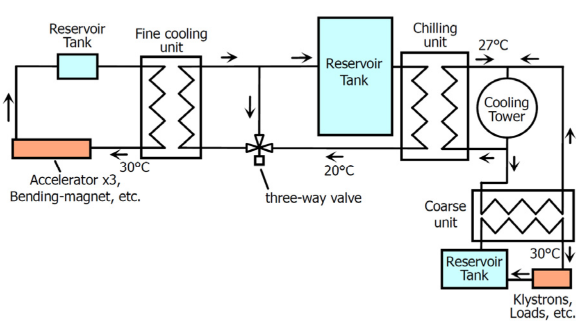

Figure 2: The diagram of the original water flow path in the cooling system for the LEBRA linac.

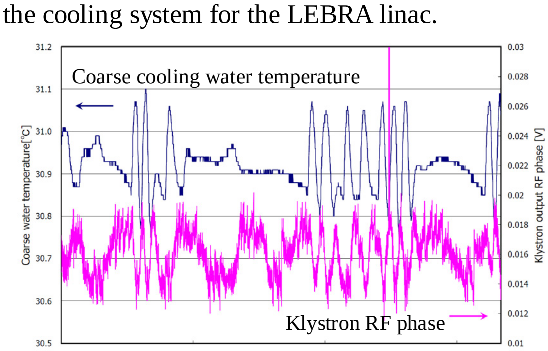

Figure 3: The behaviours of the coarse water temperature and the klystron output RF phase.

depending on the coarse cooling water temperature as shown in figure 3. The temperature of the coarse cooling water at the normal operation was controlled by the action of the three-way valve following to the changes in the temperature of the coarse cooling water itself and the water recirculated through the cooling tower. A rapid change in the temperature of the water from the cooling tower was caused by on/off of the compressor in the chilling unit as well as the cooling fan in the cooling tower. Therefore, the action of the chilling unit had a strong effect on the fluctuation of the output RF phase of the klystron.

IMPROVEMENT OF COOLING WATER TEMPERATURE STABILITY

Improvement of Cooling Water System

Improvement of the cooling water system was undertaken in two steps. In the first step, the setup of the fine cooling system was changed as follows. An additional three-way valve was placed in order to regulate the temperature of the chilled water recirculating through the fine cooling unit. The direction of the fine cooling water flow was reversed so that the rapid change of the water temperature induced in the heat exchanger was reduced in the reservoir tank before flowing through the accelerating tubes and so on, which worked quite effectively in combination with the increase of the reservoir tank volume from 120L to 800L. Then, the cooling water for the PXR Si target was separated from the main path, directly returned to the reservoir tank in order to bypass the high pressure water pump and avoid

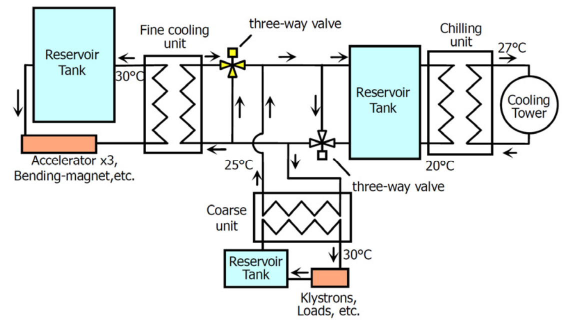

Figure 4: The diagram of the improved cooling water system.

the vibration of the target.

In the second step, the setup of the coarse cooling system was changed. The cooling water from the cooling tower was replaced by the chilled water, because the fluctuation of the regulated chilled water temperature was less than ±0.1°C which was far more preferable than the former for the precise control of the coarse cooling water temperature. The diagram of the cooling water system after the improvement is shown in figure 4.

Result of the Improvement

After the improvement of the fine cooling water system and the water flow path, the fluctuation of the cooling water temperature at the supply head of the accelerating tubes and the electromagnets was stabilized to 30±0.01°C. On the other hand, the coarse cooling water temperature was stabilized to 30±0.05°C. The behaviours of the cooling water temperatures over a few hours in the original and the improved setups for the fine and the coarse cooling water systems, respectively, are compared in figure 5. The water temperature was measured using an Extremely-Thin-Platinum-Resistance-Thermometer (ETPRT, 0.2 mmt). As shown in figure 6, the X-ray intensity fluctuation measured at the X-ray output port has been reduced from ±10% to ±2% by the improvement of the fine cooling water system. Due to a high stability of the electron beam and the X-ray intensity, the X-ray image by the diffraction enhanced imaging (DEI) method has been obtained clearly. The DEI image of a tetra fish is shown in figure 7.

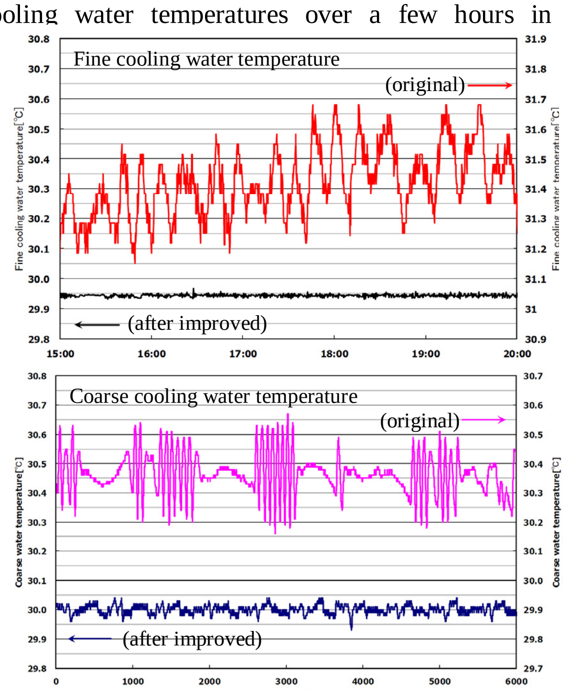

Figure 5: The comparison of the water temperature between the original and the improved setups for the fine and the coarse cooling system, respectively.

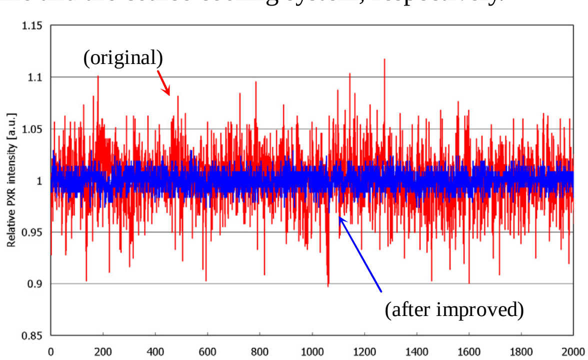

Figure 6: The comparison of the X-ray intensity fluctuation between the original and the improved fine cooling system.

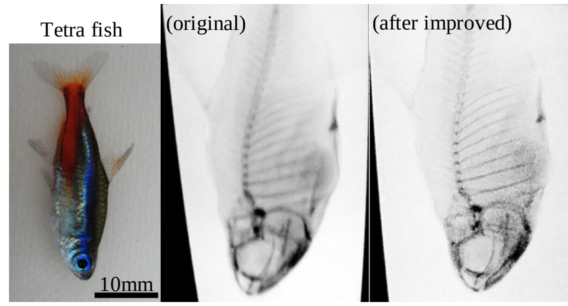

Figure 7: DEI images of a tetra fish taken with the original and the improved cooling water system, respectively (16keV, exposure time 15min (net 21ms) using the IP.).

CONCLUSION

Precise experiments using the FEL or the PXR beam require a very high stability in both the wavelength and the intensity of the light sources. After the improvement of the cooling water system, the temperatures of the fine and the coarse cooling water systems were stabilized to 30±0.01°C and 30±0.05°C, respectively. Combined with the improvement of the water flow path, the PXR intensity fluctuation at the X-ray output port has been suppressed to within ±2%, resulting in appreciable effect in the DEI experiment using PXR.

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