# PRESENT STATUS OF THE COMPACT ERL AT KEK*

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*Abstract*

The recirculation loop of the Compact ERL (cERL) was constructed from July to November in 2013 after commissioning of the injector. Then commissioning of the entire cERL was started in December 2013 and the beam could be accelerated up to 20 MeV in a short time. The beam recirculation and energy recovery were also achieved without significant beam loss in February 2014. Generation of laser-Compton scattering X-rays is scheduled for the end of FY2014 and generation of THz coherent radiation is planned for FY2015.

## INTRODUCTION

The Compact Energy Recovery Linac (cERL) project is ongoing at KEK in order to demonstrate excellent ERL performance toward a future light source [1]. The cERL is illustrated in Fig. 1 and its parameters are listed in Table 1.

Table 1: Parameters of the cERL

| | |
|---|---|
| Nominal beam energy | 35 MeV |
| Nominal injector energy | 5 MeV |
| Beam current (initial goal)<br>(long-term goal) | 10 mA<br>100 mA |
| Normalized emittance | < 1 mm·mrad |
| RF frequency | 1.3 GHz |

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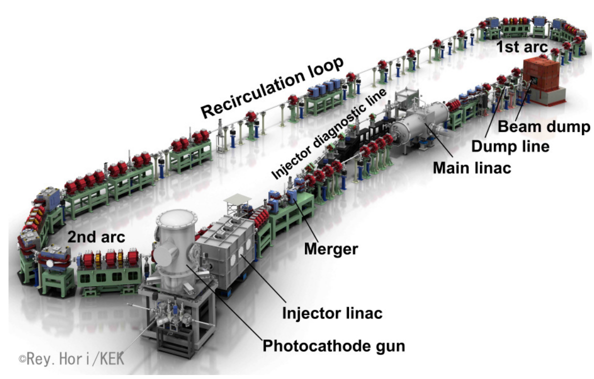


Figure 1: Illustration of the cERL.

The cERL injector was already constructed with its diagnostic beamline and successfully commissioned [2]. In the next step, the cERL recirculation loop with the merger and dump sections was constructed from July to November in 2013 and its commissioning was started in December 2013. Significant progress has so far been made. In this paper, we will describe the present status of the cERL including future developments.

## CONSTRUCTION OF RECIRCULATION LOOP

Construction of the cERL recirculation loop started in July and completed in November. The cERL components described below were installed and prepared inside and outside the accelerator room (radiation-shielding room).

There are 8 dipole magnets for the two arc sections, 12 dipole magnets for the merger, injection, dump and path-




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length-control chicanes, 60 quadrupole magnets for the recirculation loop and the dump line. All the quadrupole magnets can work as horizontal and vertical steering magnets by using their sub-coils. All the dipole magnets for the arc sections and the chicanes also have sub-coils for horizontal steering. These magnets and their girders were installed and aligned by using a laser tracker and a tilting level by referring 40 surveying references on the inner wall surfaces. The position and angle accuracies of the magnets were better than ±0.1 mm and ±0.1 mrad [3]. They became worse after the magnets were disassembled and reassembled for installing beam pipes into them. However, the cERL has been operated without any trouble caused by the misalignments.

Power supplies for all the magnets were installed outside the accelerator room. A switching-type power supply with 100 A @ 40 V output rating excites the 8 dipole magnets of the arc sections electrically connected in series [4]. On the other hand, all the quadrupole magnets including the sub-coils are individually powered by using linear amplifier power supplies with ±5 A @ ±60 V output rating. For the four chicanes, the main coils connected in series are excited by four 10-A power supplies and the sub-coils of individual chicane magnets for fine adjustment by 5-A power supplies. Ripples of all the power supplies are less than 40 ppm of the rated output currents.

The beam pipes, made of 316L stainless steel, are cylindrical with an inner diameter of 50 mm for the straight sections and an oblong octagon with an aperture of 40 mm in vertical and 70 mm in horizontal for the arc sections. For about 150 flange connections, gapless flanges were used to reduce the impedance against short-bunch beams [5]. High-grade ultra high vacuum (UHV) conditions of $1\times10^{-8}$ Pa or below were achieved in the vicinities of the superconducting(SC) cavities and the DC photocathode gun. Beam pipes are pumped down mainly by Non-Evaporable Getter (NEG) pumps and sputter ion pumps (SIPs), and the pressure is monitored by cold cathode gauges (CCGs) and the SIPs. The entire vacuum system is ready for in-situ bakeout.

Forty-five stripline BPMs and thirty screen monitors were installed with the beam pipes [6]. The BPMs were so designed as to have maximum frequency response at 2.6 GHz. Two kinds of screen material, Ce:YAG crystal and Aluminium for optical transition radiation (OTR) can be used in each screen monitor. A movable Faraday cup made of a water-cooled copper block was installed after the 2nd arc section to measure the beam current of the circulated beam before the energy recovery. The 40-kW main beam dump made of GlidCop was installed at the end of the dump line and can work as a Faraday cup for measuring the beam current after the energy recovery.

The main linac module with two SC 9-cell cavities [7] was already installed at the end of 2012. In 2013, the monitoring and protection system was constructed and the module was carefully connected to the adjacent beam pipes. The alignment of the cavities in the cryostat was watched during the cooling process with an optical scope and a subsidiary system using a laser, which demonstrated the movement within 0.4 mm for both cavities. A 30-kW IOT and 16-kW SSA(Solid State Amplifier) were first introduced as RF sources of the two cavities [8] and later a 8-kW SSA replaced the IOT in January 2014 for increasing reliability. An FPGA-based digital low-level system is used for their control and stabilization.

The constructed cERL is shown in Fig. 2.

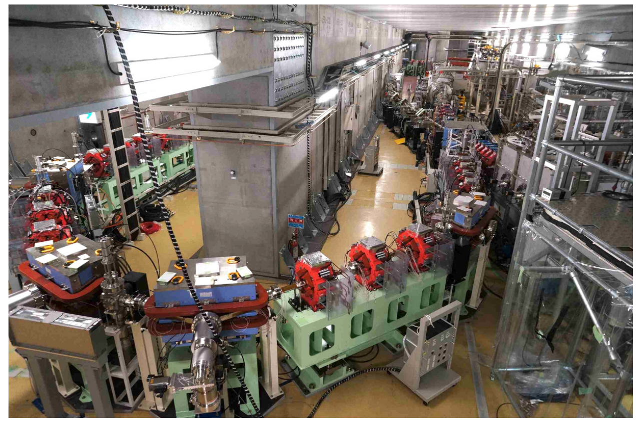

Figure 2: cERL constructed in the accelerator room.

## BEAM COMMISSIONING

The commissioning of the entire cERL including the constructed recirculation loop started in December 16, 2013 after the cooling down of the SC cavities. During the commissioning, the beam energy was set to about 20 MeV with an injection energy of 2.9 - 3.4 MeV and an acceleration voltage of 8.3 - 8.6 MV per cavity of the main linac in order to sufficiently reduce the field emission of the main SC cavities. Within only a week after the first day of the commissioning, the beam was successfully accelerated up to 20 MeV and transported to the entrance of the dump line, though the beam did not reach the beam dump.

In the short shutdown between 2013 and 2014 runs, stray fields due to CCG magnets were found to be non-negligible and to deteriorate beam orbits and profiles especially for the pre-accelerated and decelerated beams. Furthermore the fringing fields generated by the chicane dipole magnets of the recirculation loop close to the injection or dump line also affected the injection and decelerated beams. We removed or shielded most of these unwanted fields in order to make the beam tuning easier. As a result the beam was well recirculated and transported to the beam dump without significant beam loss on Feb. 6, 2014. The magnetic field of the chicane dipole magnet for extracting the decelerated beam to the dump line was adjusted to correspond to the injection beam energy. Since the beam was observed around the horizontal center position of the screen monitor at the entrance of the dump line, energy of the decelerated beam was nearly equal to that of the injection beam. This means that the energy recovery was well achieved. The measured beam profiles and currents are shown with the fundamental parameters



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in Fig. 3. After further beam tuning, the beam quality was improved and in CW operation the maximum averaged current was recorded at 6.5 μA for the beam energy of 20 MeV on March 14, the last day of the last FY2013 run. The maximum beam current will be increased to 10 mA in a step by step manner for several years. More details of the beam commissioning are reported in ref. [9].

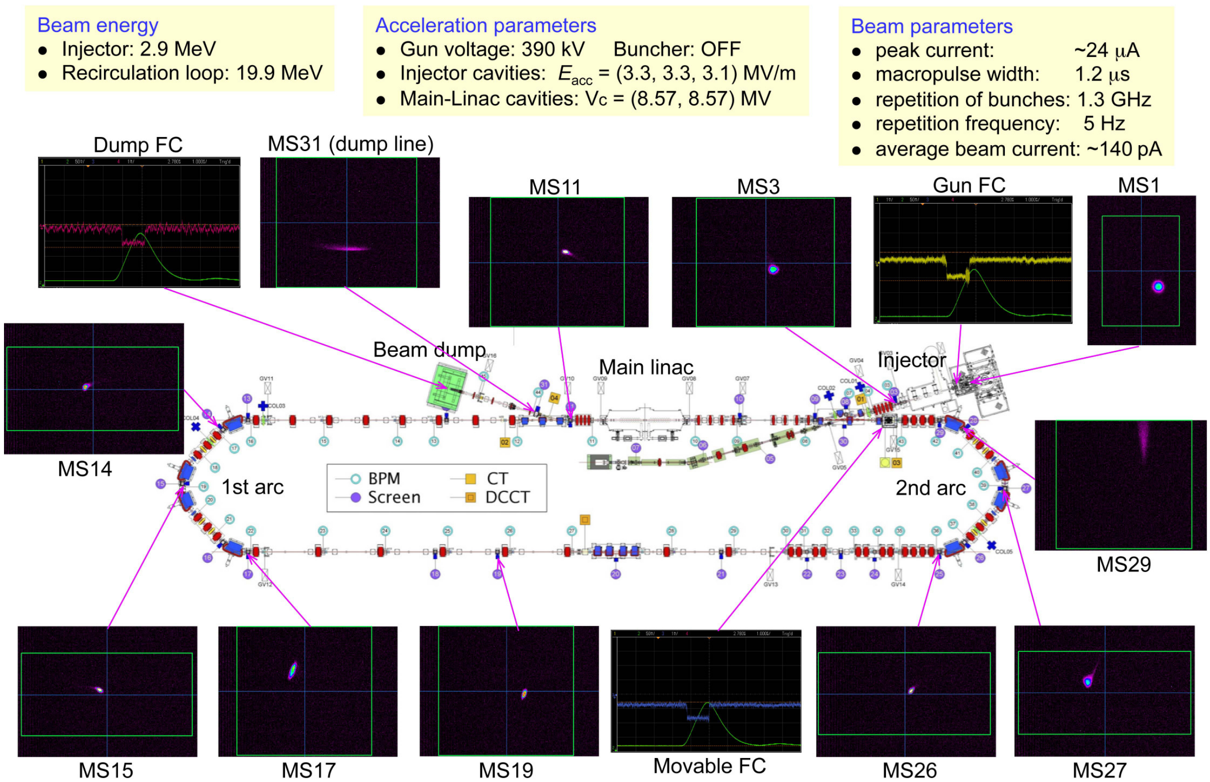


Figure 3: Electron beam profiles at the screen monitors (MS1-31) and beam currents at the Faraday cups (FCs) on February 6 2014, when the decelerated beam in the main linac was transported to the beam dump and the energy recovery was achieved. The beam was clearly observed around the horizontal center position of MS31 at the entrance of the dump line. The beam current measured at the dump FC was almost the same as that at the gun FC.

## FUTURE DEVELOPMENTS

Two kinds of experiments are planned at the cERL. Generation of laser-Compton scattering(LCS) X-rays is scheduled for the end of FY2014[10]. Eight quadrupole magnets were already installed in the south straight section for focusing the electron beam in order to collide the electron beam to the small-size laser beam efficiently. The laser cavity will be set in the center of the LCS magnet section. The generated X-rays will be guided to the experimental hutch constructed outside the accelerator room. Generation of THz coherent radiation is planned for FY2015. The THz coherent radiation generated at the 1st dipole magnet of the 2nd arc section will be transported to another experimental hutch.

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