8 - 23 Afterglow Operation Scheme of ECRISs for HIRFL

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In 2022, two on-line ion sources have been operated with the afterglow mode to deliver pulsed ion beams to the HIRFL accelerators successfully.

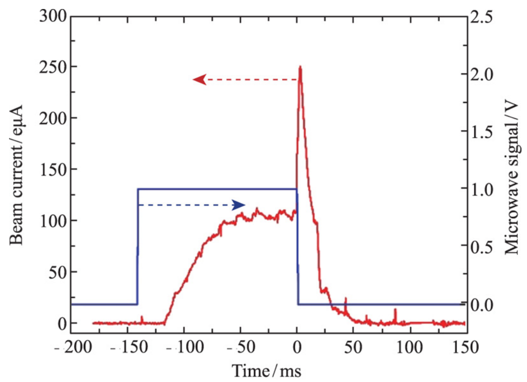

Fig. 1 (color online) A typical afterglow waveform of Bi^{36+} produced by SECRAL-II ion source.

Intense pulsed $^{209}Bi^{36+}$ beam with 3 Hz repetition rate was produced with the SECRAL-II ion source operated in afterglow mode and eventually injected to HIRFL-CSR. This is the first time that pulsed heavy ion beams directly produced by an ion source are accumulated and accelerated in the CSRm and then extracted to experimental terminals. As shown in Fig. 1, the peak current in afterglow mode was up to 250 eμA. The corresponding beam intensity of Bi^{36+} ions accumulated and accelerated in the CSRm reached 110 and 320 eμA, respectively (shown in Fig. 2).

In addition, the LECR4 ion source, serving as the injector of the SSC-LINAC, was also operated in afterglow mode successfully and produced pulsed $^{238}U^{37+}$ beams with 5 Hz repetition rate. As shown in Fig. 3, the peak current reached 70 eμA, and the corresponding charge state distribution (CSD) are shown in Fig. 4. The extracted beam current from SSC got to 4.0 eμA thanks to the gain factor of the beam intensity, which is the best record until now.

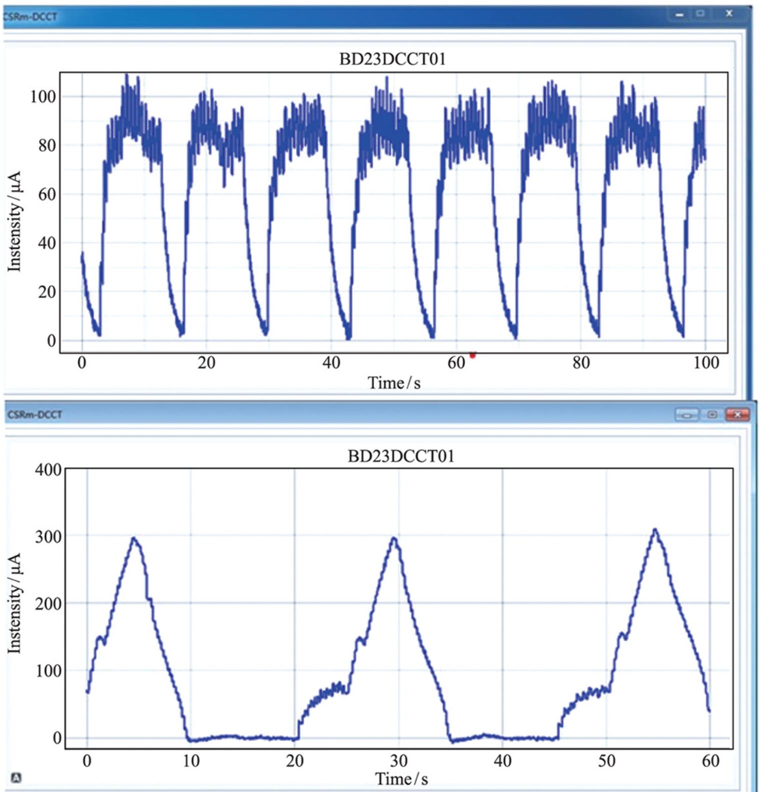

Fig. 2 (color online) Accumulated and accelerated beam intensity of Bi^{36+} ions in CSRm.

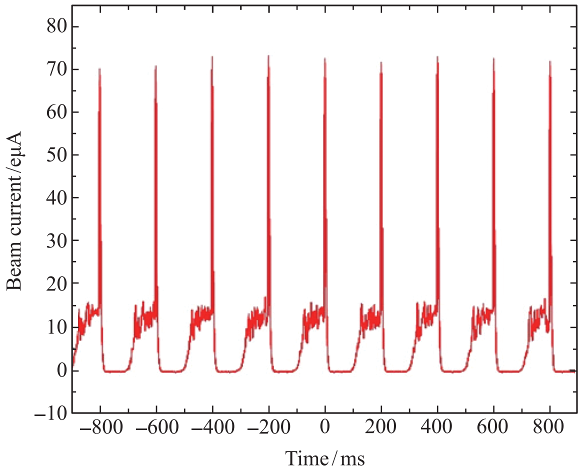

Fig. 3 (color online) Typical afterglow waveforms of U^{37+} produced by LECR4 ion source.

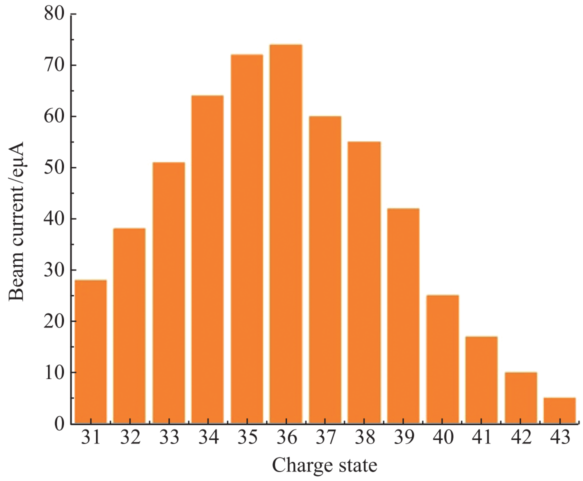

Fig. 4 (color online) Uranium charge state distribution of LECR4 ion source with afterglow mode.

8 - 24 Progress of HECRAL Ion Source

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A Hybrid superconducting Electron Cyclotron Resonance ion source Advanced in Lanzhou (HECRAL) has been designed and constructed at IMP. The schematic layout of the ion source is shown in Fig. 1. The axial superconducting magnet of the ion source is optimized and tuned using four sets of superconducting coils, while the radial magnetic field employs a new Non-Halbach structure to achieve better radial confinement. This configuration is advantageous for the generation of highly charged ions. The magnetic field of the ion source allows it operate both at 18 and 24 GHz. The main parameters of the ion source are listed in Table 1.

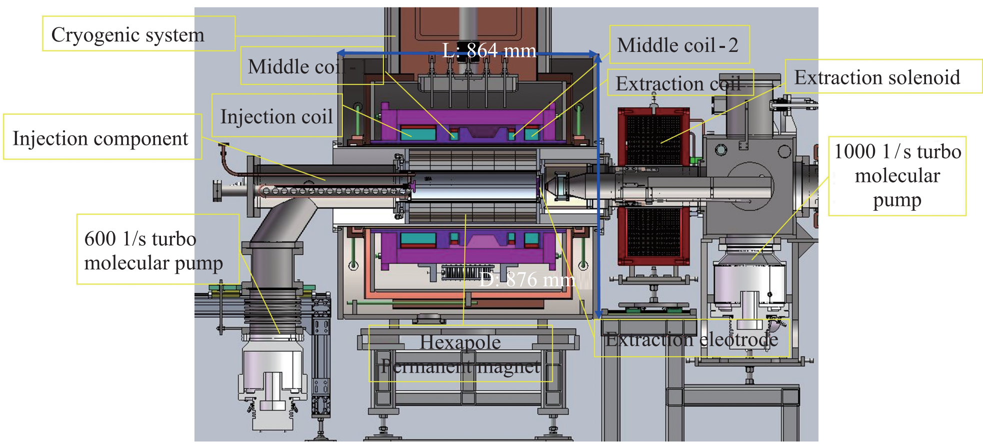

Fig. 1 (color online) The schematic layout of HECRAL ion source.

HECRAL ion source was initially tested in 2021 at a frequency of 18 GHz and a power of 2 kW maximum. The performance achieved was comparable to that of an 18 GHz room-temperature ECR ion source. In 2022, the ion source underwent further testing at a higher power of 3 kW. As a result of this increased power, the proportion of highly charged ion beams was enhanced by more than double. The performance of the ion source reached the level of a fully superconducting ECR ion source operating at the same frequency, as shown in Table 2. Currently, the ion source is operating steadily under an 18 GHz magnetic field frequency, and the low-temperature system is consistently maintaining a zero-evaporation state. Next year, 18∼24 GHz multi-frequency heating and higher microwave power will be used to further explore the performance of HECRAL.