At the beginning of 2017, the pulsed $^{40}Ar^{12+}$ beam of 120 eμA was provided to HIRFL by SECRAL with afterglow mode for the first time, as shown in Fig. 2. The pulsed beam was injected into the storage ring, CSR, accelerated and accumulated successfully. The running time of SECRAL with the pulsed mode was more than 48 h. However, the gain of the pulsed beam compared with the continuous one was less than 2. The further researches on afterglow mode will focus on the increasing of the gain.

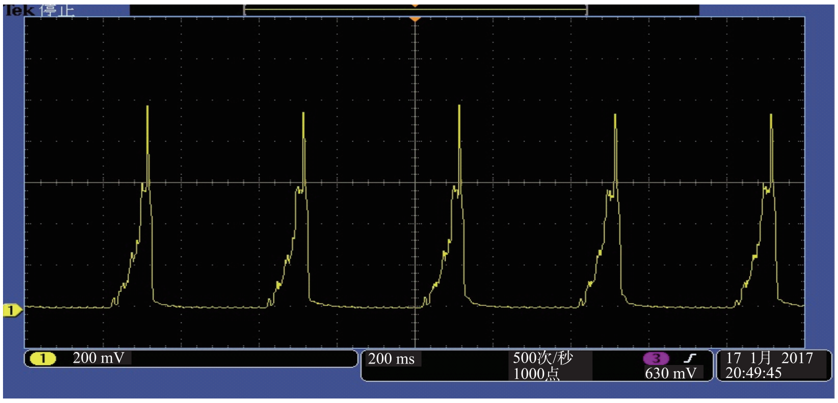

Fig. 2 The pulsed beam provided by SECRAL source with afterglow mode.

6 - 19 On-Line Operation and Machine Study of LECR4

Qian Cheng, Lu Wang, Fang Xing, Guo Junwei, Yang Yao, Li Xixia, Wang Hui, Ma Baohua, Sun Liangting, Zhang Xuezheng and Zhao Hongwei

LECR4 is the first ECR ion source using evaporative cooling technology in the world. Its unique feature is that the solenoids were made from solid square copper wires (3.32 mm × 5.77 mm with insulation), and that all the coils are entirely immersed in the room temperature coolant. The coils can produce a maximum axial magnetic field up to 2.5 T. LECR4 aims to provide intense multiple charge state ion beams for SSC-Linac project - a new Linear injector for the Separated Sector Cyclotron (SSC). Presently, some ion beams with different M/Q ratio have been accelerated successfully with the RFQ and DTL, such as 200 eμA of $^{16}O^{5+}$, 200 eμA of $^{40}Ar^{8+}$, 50 eμA of $^{209}Bi^{30+}$ *etc*. The measured transmission efficiency of RFQ is up to 90%. The layout of LECR4 ion source and the LEBT is shown in Fig. 1.

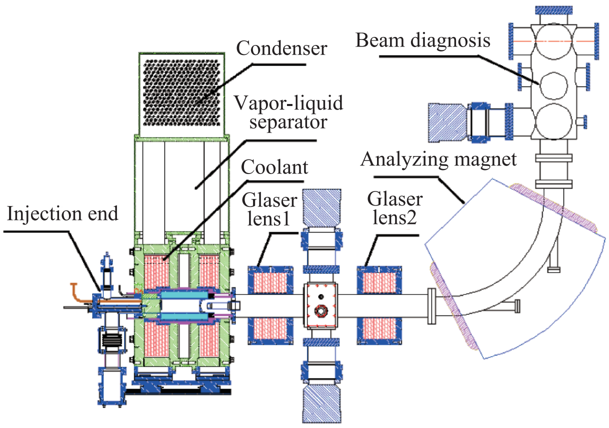

Fig. 1 Layout of LECR4 ion source and the LEBT.

In 2016, the influence of injection stage of LECR4 was studied systematically. The test results demonstrated that the injection pump is critical for the production of intense highly charge state ion beams, such as: $^{40}Ar^{14+}$, $^{129}Xe^{20+}$. While it is not necessary for the production of low or medium charge state ion beams, such as: $^{16}O^{6+}$ and $^{40}Ar^{11+}$. A dual-solenoid prefocusing system has been implemented to improve the beam quality and transmission efficiency. As a result, the beam resolution problem at the Faraday cup after the analyzing magnet has been solved, and hollow beam issue has been improved. LECR4 ion source has been optimized for the operation at 18 GHz with a microwave power of about 1.6 kW. Table 1 shows some latest results from LECR4.

Table 1 The latest results of LECR4 at 18 GHz in 2016.

f/18 GHz	Charge state	Beam current (CW)/eμA
^{16}O	6+	2 110
	7+	560
^{40}Ar	9+	1 230
	11+	620
	12+	430
	14+	185
	16+	30.5
^{129}Xe	20+	430
	21+	320
	23+	275
	25+	215
	27+	135
^{209}Bi	28+	170
	29+	145
	31+	92
	32+	63
^{238}U	31+	35
	32+	32
	33+	31

6 - 20 Development of SECRAL II Ion Source at IMP in 2016

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SECRAL II is the second fully superconducting ECR ion source developed at IMP. It's almost the duplicate of SECRAL, except for the cryogenic system[1]. SECRAL II has integrated LHe recondensation system, which has the dynamic cooling capacity of more than 5 W. The main parameters of SECRAL I & II are shown in Table 1. The magnets of SECRAL II has been successfully fabricated and tested in 2015. In 2016, SECRAL II has been commissioned at 18 and 28 GHz with O and Xe ion beams, which has given very promising results.

Table 1 Main parameters of SECRAL I&II.

Parameters	SECRAL II	SECRAL
ω_{rf}/GHZ	18-28	18-24
Axial Field Peaks/T	3.7(lnj.), 2.2(Ext.)	3.7(lnj.), 2.2(Ext.)
Mirror Length/mm	420	420
No. of Axial SNs	3	3
B_r at Chamber lnner Wall/T	2.0	1.7/1.83
Coldmass Length/mm	~810	~810
SC-material	NbTi	NbTi
Magnet Cooling	LHe bathing	LHe bathing
Warm Bore ID/mm	~142.0	140.0
Chamber ID/mm	125.0	116.0/120.5
Dynamic cooling power/W	~5	0

In April 2016, the stainless steel plasma chamber of SECRAL II was firstly conditioned with oxygen plasma. In June, the 28 GHz/10 kW gyrotron microwave oscillator and its transmission lines were installed to SECRAL II. At 28 GHz, with power of 1 kW, about 2.2 emA O^{6+} has been extracted. The plasma responds almost linearly to microwave power input. At 4.5 kW, 6.2 emA O^{6+} has been obtained at the extraction high voltage potential of 25 kV. At 3.5 kW, a 1.57 emA O^{7+} beam has also been extracted. After oxygen plasma test the ion source was then switched to Xenon and optimized for the production of Xe^{27+}. After several days tuning, an optimum result of 510 eμA of Xe^{27+} was obtained with 3.5 kW of microwave power. Fig. 1 is the spectrum when Xe^{27+} is optimized. But at high power test, we had the fatal problem of plasma chamber damage as a result of localized overheating by the