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 lost plasma at the chamber wall. With stainless steel plasma chamber, we are limited to inject microwave power less than 5 kW.

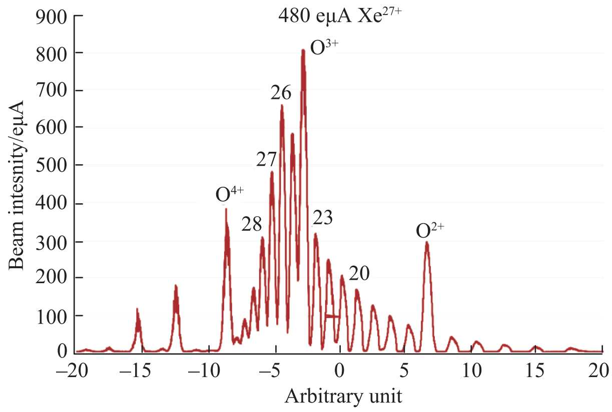

Fig. 1 (color online) Typical Spectrum optimized for 480 eμA Xe^{27+} beam production.

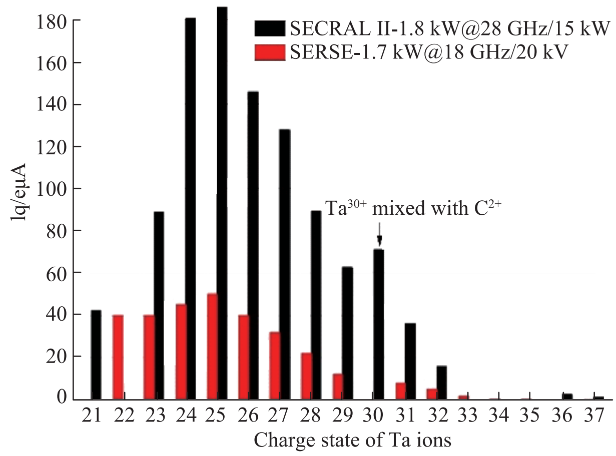

Fig. 2 (color online) The charge state distribution of the Ta ion beams produced by the ECR ion sources (SECRALII & SERSE) coupled with laser ablation plasma.

The experiment concerning metallic ion production by an ECR ion source coupled with laser produced plasma has been carried out preliminarily. The laser beam focused by a long focal length lens was injected into the vacuum chamber of SECRAL II through the K9 window at the end of the straight-through port of the analyzing magnet, and hit a tantalum plate installed at the injection baffle of the source. The laser produced ions and the ECR plasma were immediately coupled as soon as the laser was switched on, and then the highly charged Ta ions were produced. The charge state distribution is shown in Fig. 2, in comparison with the results of the similar experiment carried out with SERSE ion source[2]. After this, highly charged tantalum beams were produced using sputtering method. At 28 GHz, we have obtained 375 eμA Ta^{30+} at 4 kW and 204 eμA Ta^{38+} at 7.5 kW with both Ar and O_2 as the support gases. Fig. 3 is the spectrum when Ta^{38+} is optimized. During this experiment, the tantalum target was fixed at the center of the bias disk, *i.e.*, on-axis positioned. Besides, less than 0.2 kW microwave power of 18 GHz was fed into the ion source to help improving the beam intensity and stability.

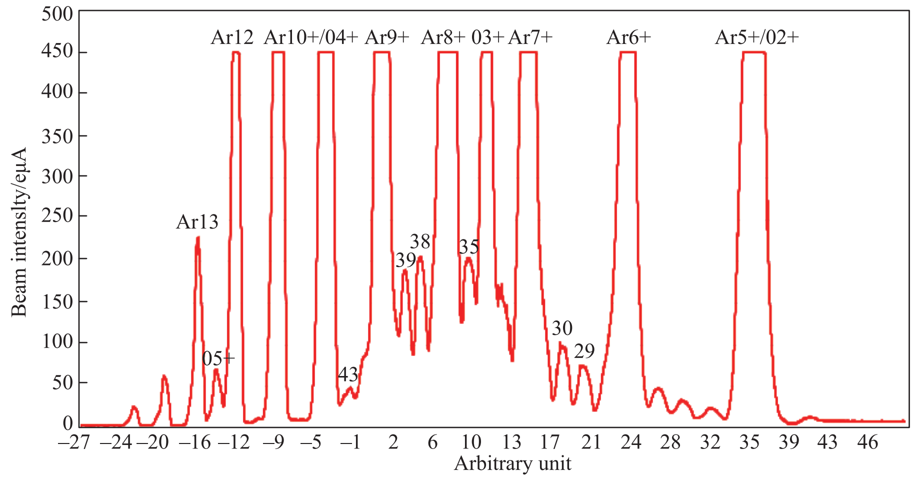

Fig. 3 Typical Spectrum optimized for 204 eμA Ta^{38+} beam production.

Some major improvement of the SECRAL II such as adoption of an aluminium plasma chamber and new microwave coupling system will be made in the near future, to investigate better performance, especially for the production of high charge state ion beams.

References

[1] L. Sun, W. H. Zhang, X. Fang, et al., The 22nd international workshop on ECRIS (2016).

[2] S. Gammino, L. Torrisi, G. Ciavola, et al., J. Appl. Phys., 96(2004)2961 .