

6 - 18 Operation Status of On-line Ion Sources in 2012

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There were three ion sources serving as the ion beam pre-injectors of HIRFLcomplex in 2012, and they were Superconducting ECR ion source at Lanzhou (SECRAL), Lanzhou ECR ion source No. 3 (LECR3) and Lanzhou All-Permanent magnet ECR No. 1 (LAPECR1). The total operation time of the three ion sources in 2012 added up to about 7276 h, 3894.5 h of which are contributed by SECRAL, 2997.3 h by LECR3, and 384 h by LAPECR1, respectively. The ion beams delivered by these three ion sources are detailed in Table 1.

Table 1 Ion beams delivered by SECRAL, LECR3 andLAPECR1 to HIRFL accelerators in 2012

Ion source		Beam	Extraction HV(kV)	Beam intensity($e\mu A$)	Time(h)
SECRAL	1	$^{86}\text{Kr}^{20+}$	17.76	70	684
	2	$^{40}\text{Ca}^{12+}$	19.37/23.05	50	257.5
	3	$^{40}\text{Ar}^{12+}$	23.58	80	223
	4	$^{209}\text{Bi}^{31+}$	10.33	30	310
	5	$^{40}\text{Ca}^{12+}$	18.73	40	237
	6	$^{40}\text{Ar}^{11+}$	18.29	150	19
	7	$^{86}\text{Kr}^{17+}$	18.89	95	710
	8	$^{112}\text{Sn}^{26+}$	17.82	55	1454
LECR3	9	$^{18}\text{O}^{6+}$	17.72	110	240.5
	10	$^{84}\text{Kr}^{17+}$	18.84	70	566
	11	$^{19}\text{F}^{7+}$	19.69	70	117
	12	D^{+}	22.52	300	112.5
	13	$^{12}\text{C}^{4+}$	23.07	300	1098.25
	14	$^{18}\text{O}^{6+}$	23.07	200	222.5
	15	$^{20}\text{Ne}^{7+}$	19.39	95	303
	16	$^{18}\text{O}^{6+}$	20.35	210	337.5
LAPECR1	17	H^{+}	26.0	500	200
	18	H^{2+}	22.6	500	184

Among the three ion sources, SECRAL mainly provides highly charged heavy ion beams, and LECR3 deliverersmedium mass number ion beams with low or medium charge states, while LAPECR1 is only running as a pre-injector of very light ion beams such as proton beam. Since being put into routine operation for HIRFL in 2007, SECRAL operation time has increased year by year, and 2012 is the first year the operation time of SECRAL exceeded that of LECR3. The operation time of the on-line ion sources in the past 10 years are summarized in Fig. 1.

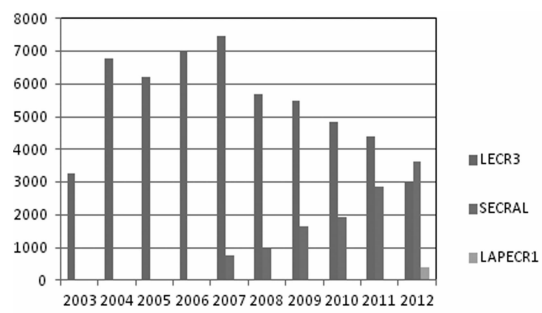


Fig. 1 Operation time of on-line ion sources.



Fig. 2 LAPECR1 in the on-line.

The operation of SECRAL has been interrupted by the shortage of liquid helium (LHe). Again SECRAL has delivered intense high charge state heavy ion beams to the accelerators for the mass measurement research with CSRe this year. For this experiment, SECRAL was operated for 1454 h to provide 40~70 eμA of ¹¹²Sn²⁶⁺ beam with an average material consumption rate of 1.43 mg/h.

Thanks to a compact He recycling system, long-term running at low RF power (usually below 1500 W) without any refilling of LHe is possible with SECRAL, and the non-interruption record was up to 35 d. This system had been designed and constructed by the end of 2009. Helium gas evaporated from the cryostat of the superconducting magnet system is condensed and liquefied by 5 refrigerators and then flows back to the cryostat, which leads to a closed loop of LHe circulation. The nominal liquefying rate of the system is 90 L/d. The total LHe consumption of SECRAL was 5000 liters in 2012 that is much less in comparison with a total consumption of 15000 L in 2011 when the liquefying system was sent to repair.

LECR3 was run for the production of low and medium charge state ion beams only in the first half year of 2012. The degraded hexapolemagnet of the ion source has been replaced by a new one in the summer. With the accomplishment, the delivered current intensity of Ar⁸⁺ beam was increased from 240 to 300 eμA with only 300 W microwave power.

Table 2 Key parameters of LAPECR1

Index	Parameter
B_{inj} (T)	1.0
B_{extr} (T)	0.56
B_{rad} at inner wall of chamber (T)	1.1
Plasma chamber ID (mm)	40
Frequency of RF (GHz)	14.5
Max. RF power (kW)	0.7
Dimension (mm ²)	φ102×296
Weight (kg)	~25
Permanent material	N45M, NdFeB
L_{mirror} (mm)	74
L_{ecr} (mm)	55
HV (kV)	30~50

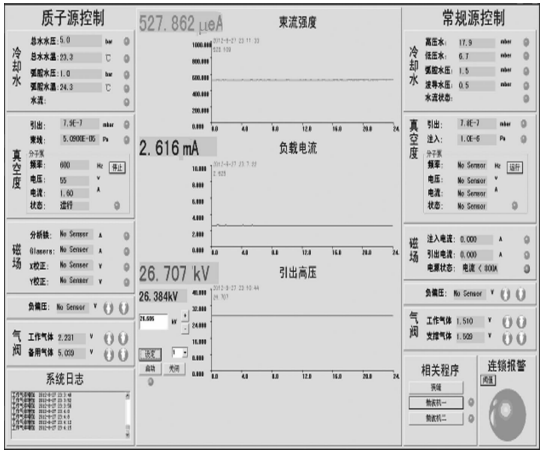


Fig. 3 Common control interface of LECR3 and LAPECR1.

LAPECR1, a compact all permanent magnet ECR ion source fabricated in 2002 for the production of low and medium charge state ion beams, was installed to the injector beamline of HIRFL during the summer maintenance as shown in Fig. 2, and Table 2 gives the key parameters of LAPECR1. The ion source was put on a high-voltage platform of 30~50 kV to deliver proton beam with the energy more than 30 keV. During the operation, the voltage reached 35 kV without sparking, and 1000 e A of proton beam could be achieved. LECR3 was moved for ward for 1830 mm to make a room for LAPECR1 and its analyzing magnet. LAPECR1 was run for about 400 h to deliver H⁺ and H₂⁺ beams for HIRFL in the latter half of the year.

The remote control of LECR3 and LAPECR1, shown in Fig. 3, was realized in 2012. Now, the major parameters of the three on-line ion sources can be controlled and monitored remotely.