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STATUS AND PERSPECTIVE OF ELECTRON CYCLOTRON RESONANCE BASED CHARGE BREEDERS

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Abstract

Since their invention in the late 1990s, Electron Cyclotron Resonance (ECR) based Charge Breeders (CB) have been used in several Isotope Separation On Line (ISOL) facilities to study radioactive ions. Many developments were carried out on these devices to enhance their performances and improve the knowledge on the ECR charge breeding process in laboratories worldwide. At LPSC, recent experiments in pulse mode were carried out to estimate plasma parameters such as the ionisation, charge exchange and confinement times, providing indications on the high charge state ions confinement. A new model of the 1+ beam capture was also proposed and experimentally verified by studying the stopping of injected ions of different masses. Present ECR charge breeder optimum efficiencies vary from 10 to 20% depending on the ion species and the facilities specifications. The total efficiency ranges from 35 to 90% and the charge breeding time from 10 to 25 ms/q. Electron Beam Ion Source (EBIS) is an alternate CB technology with lower contamination yield, yet limited injection flux capability. ECR CB sustains a higher 1+ beam intensity acceptance and its prospects to improve the efficiency, charge breeding time and beam purity are identified.

INTRODUCTION

In flight and Isotope Separation On Line are complementary methods used to produce radioactive ions. For nuclear astrophysics and nucleus structure studies far from the valley of stability, the energy of the particles have to be raised in the MeV/u range. Elements are produced at rest in the ISOL case and a post accelerator is used to obtain the final energy. Several criteria must be fulfilled to allow successful investigation of these particles which are often produced at low yield or with a short half-life (<1 s) : in particular the beam purity, the possibility to tune the final energy, a low radiation background and the beam optics quality. Since the acceleration of the particles scales with the charge state, a Charge state Breeder is typically installed before the LINear ACcelerator (LINAC) or the cyclotron. Presently 8 ISOL facilities using a CB are in operation worldwide, or in final construction phase. Table 1 summarizes the characteristics of these facilities.

In these facilities, the Radioactive Ion Beam (RIB) production yield ranges between 10^2 up to 10^{10} ions/s and different types of 1+ sources are used. The CB has to be adapted to the configuration and experiment (ion mass, 1+ beam optics, requested charge state ...) and reach optimal performances. Two different technologies are presently in use : EBIS and ECRIS (ECR Ion Source). Recently 2 facilities were converted to EBIS CB mainly to increase the purity of the re-accelerated beams. This paper presents the ECRIS CB technology and possible ways to improve its performances.

ECR CHARGE BREEDING

ECR CB Origin

Charge breeders based on the use of Electron Cyclotron Resonance ion sources emerged in the frame of the PIAFE project [1]. Neutron rich radioactive ions with a mass ranging between 75 to 150 amu were to be produced from the bombardment of ^{235}U target by the high neutron flux (5×10^{13} n/(cm^{2}s)) of the ILL reactor. The species were to be ionised, accelerated at 10-30 keV, mass separated and transported to LPSC (formerly named ISN) over a 400 m distance. The ion charge state had to be increased in order to allow the post acceleration of the particles with the LPSC double cyclotron system «SARA». The idea came up to use the ECR ion source plasma as a «plasma catcher» where the RIBs would be stopped before interacting with the metallic walls, thus suppressing the sticking time of the solid-state catcher which was used until then. In the same time, the ECR plasma had to increase the charge state of the incoming RIBs up to high charge states. The first charge breeding experiments with an ECR ion source were carried out in 1995 with the 10 GHz ISOL MAFIOS ion source using the «backward» injection method, i.e. through the extraction electrode. Soon the injection through the upstream side of the source was tested and adopted : comparable efficiencies were reached in a simpler way and injection in continuous mode was possible, which was of high interest for post acceleration with cyclotrons or LINACs operating in continuous mode [2]. This injection scheme is presently used by all the ECR charge breeders.

ECR CB Principle

ECR CB are based on minimum-B type ECR ion sources. Modern configurations consist of a set of 2 or 3 coils and a yoke to generate an axial magnetic field profile with a maximum B_{inj} at injection, a local maximum B_{ext} at extraction and a minimum B_{min} in between, as illustrated in Fig. 1. An

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Table 1: Characteristics of the ISOL facilities equipped with a charge breeder. "LINAC'", "SC LINAC" and "RFQ" account to respectively room temperature LINAC, superconducting LINAC and Radio Frequency Quadrupole Accelerators.

Lab Facility	**Prim. beam**	**Reaction Ionisation source**	**Charge Breeder I+ (pps)**	**Post accel. Energy**
ANL CARIBU		^{252}Cf fission fragments He gas catcher	ECRIS → EBIS	SC LINAC 10 MeV/u
CERN ISOLDE	1.4 GeV p^+	Spallation, fragmentation, fission Surface, laser, plasma, LIST	EBIS 10^7	LINAC + SC LINAC 10.4 MeV/u at A/q=2.5
GANIL SPIRAL1	95 MeV/u C 24 MeV/u U	Fragmetation, fusion evaporation ECR, Febiad	ECRIS 10^2 to 5×10^8	Cyclotron Up to 25 MeV/u
LNL SPES	30-70 MeV 1.5 mA H^+	UCx target fragmentation	ECRIS 10^6	RFQ, SC LINAC Up to 10 MeV/u for A/q=7
MSU ReA	80 MeV/u	Projectile fragmentation He gas catcher	EBIT CW 10^{10}	RFQ, SC LINAC 20 MeV/u light, 12 MeV/u heavy
Texas A&M	80 MeV H^+	(p,n) reactions He gas cell	ECRIS	Cyclotron 26-57 MeV/u
TRIUMF ISAC	500 MeV H^+	Spallation, fragmentation Surface, laser, plasma	ECRIS+EBIS 10^5 to 10^9	RFQ, LINAC, SC LINAC 0.15-9.5 MeV/u
IBS RAON	70 MeV p^+	UCx target fragmentation	EBIS Up to 10^9	SC LINAC 20 MeV/u

hexapolar magnet is set around the plasma chamber, to produce the radial magnetic field. B_{rad} is the radial field on the poles generated by the hexapole at the wall of the plasma chamber.

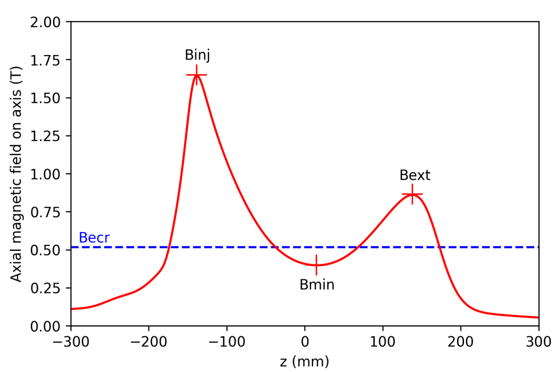

Figure 1: Typical 14 GHz ECRIS axial magnetic field profile on axis.

The combination of these components creates a magnetic trap for charged particles, where the magnetic field strength has a minimum at the center of the plasma chamber. The Electron Cyclotron Resonance allows the electron heating by the injection of microwaves into the plasma chamber. The ECR surface is defined by the iso magnetic field strength B_{ecr} value. Due to successive crossings of the ECR surface, the trapped electrons gain enough energy to ionize the atoms and ions up to a high charge state, through step by step ionisation. On the other hand, charge exchange with neutral atoms or other ions is the main phenomenon counteracting ionisation and limiting high charge state production. Due to their lower mass, electrons are more mobile than ions in the plasma which induces an ambipolar diffusion and the build-up of an electrostatic plasma potential Φ (Fig. 2). In addition, the existence of a potential dip ΔΦ in the center of the plasma has been proposed to explain the confinement of highly charged ions, where the dip would be due to the hot electron population strongly confined within the magnetic trap [3].

Empirical laws were formulated by Geller regarding the performances of ECRIS as a function of their configuration. One can cite, for instance, that the electron density scales with the square of the frequency [4]. Considering the magnetic trap, as experimentally demonstrated and reported in [5], the source performances can be optimized with adequate mirror ratios as a function of B_{ecr} at injection $\frac{B_{inj}}{B_{ecr}} \geq 3.5$, extraction $\frac{B_{ext}}{B_{ecr}} \geq 2$ and regarding the radial confinement $\frac{B_{rad}}{B_{ecr}} \geq 2$. In addition the balance between the ratios should respect the values $\frac{B_{min}}{B_{ecr}} \approx 0.8$ and $\frac{B_{ext}}{B_{rad}} \approx 0.9$.

In the ECR based charge breeding method, the ions are injected into the plasma, slowed down, captured, multi ionised and extracted. The capture process proposed by Geller [6] relies on the deviation of the injected ions by Coulomb collisions with the plasma ions, leading to their thermalization and trapping by the magnetic field. The energy of the injected ions is tuned by adjusting the potential difference ΔV between the 1+ source and the CB, as displayed on Fig. 2.

From this theory, the 1+ ions energy must be high enough to overcome the plasma potential and adjusted to optimize the capture, i.e. injected ions must have an average speed

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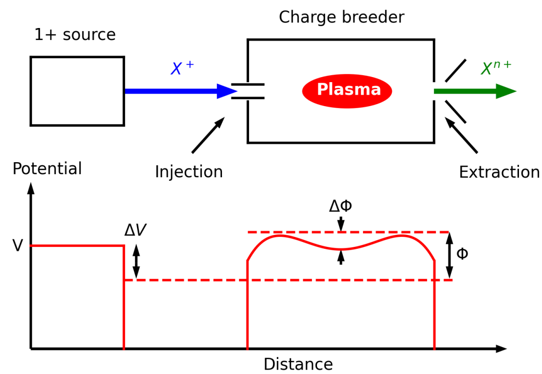

Figure 2: Electrostatic potential profile from the 1+ source to the ECR CB.

equal to the average speed of the plasma ions [6]. After their thermalization, the ions behave like the other plasma ions, they are ionised by the plasma electrons and extracted.

The ECR CB efficiency for one charge state is calculated by the formula $\eta = \frac{(I_{n+} - I_{n0+})}{(n * I_{1+})}$, where I_{1+} and I_{n+} are the electrical currents of the 1+ and n+ beams and I_{n0+} is the electrical current of the n+ beam measured when the 1+ beam is switched off. The total efficiency is calculated by summing all individual efficiencies for each charge state, for charge states ≥ 2. It represents the proportion of 1+ ions that were effectively charge breed.

ECR CB Development

Even though the PIAFE project was not funded, the LPSC group decided to continue the R&D on ECR charge breeding for other facilities, in particular for a possible use for the SPIRAL1 project at GANIL [7]. The new 14 GHz PHOENIX type ECR CB was then conceived and commissioned in the early 2000. Two copies were manufactured, one for TRIUMF and one for ISOLDE, the last being ordered by Daresbury Laboratory. At KEK, a 12 GHz ECR ion source was turned into a CB and the obtained results were in good agreement with those achieved with the PHOENIX CB, for example regarding the CB efficiency as a function of the ion mass, charges and species [8]. A new 18 GHz ECR CB was then designed and assembled by KEK to produce ions with an A/q ratio of 7 [9]. At ANL, a 10 GHz AECR type source was severely modified and transformed into a CB for the CARIBU facility [10], whereas at Texas A&M a brand new source was designed and manufactured by Scientific Solutions (San Diego) [11]. The Daresbury CB, tested at ISOLDE as an option to the EBIS CB, was donated to GANIL in 2011 for the SPIRAL1 facility. This source was upgraded in collaboration with ANL, tested at LPSC and installed on the SPIRAL1 facility in 2016 [12]. Another PHOENIX CB was manufactured by the LPSC group for the SPES project, the source is installed on the facility and will be commissioned soon [13].

Extensive R&D work was carried out by the different groups to improve the ECR CB performances. Different schemes to improve the efficiency of the 1+ injection were tested like the 2-stage deceleration system (TRIUMF) [14], tuning the deceleration cylindrical electrode position (ANL, GANIL) [15,16], increasing the injection electrode diameter (LPSC) [17], or using a sextupolar ion guide injection system in the particular case of the Texas A&M CB [18]. The magnetic field at the source injection was symmetrized to prevent steering of the 1+ beam [15,19].

The plasma conditions were also enhanced. In order to reduce charge exchange and produce higher charge states, the residual vacuum was improved. The magnetic confinement was optimized by increasing the injection axial magnetic field and changing the field gradients [20]. Regarding microwave heating, the use of two frequencies and fine frequency tuning was profitable to increase the CB efficiency and stabilize the plasma, but in some cases it was observed to affect the charge breeding time [21,22].

The RIB purity issue in the ECR CB was early pointed out by KEK (2004) [23], LPSC (2004) [24] and TRIUMF (2006) [25]. Chemical elements, coming from the wall sputtering, the support gas or the residual vacuum are present in the ECR CB plasma. Depending on the mass of these contaminants, they can be extracted from the CB with a A/q extremely close to the RIB of interest which makes their separation difficult with the downstream spectrometer and leads to the degradation of the RIB purity. At KEK, the use of a NEG type material was tested to make a selective pumping. Pure aluminium coating on aluminium alloy plasma chamber was also used, together with a careful cleaning by sand blasting and high-pressure rinsing [9,22]. New methods were proposed by Vondrasek [26] to reduce the contaminants in ECR CB like the CO_2 cleaning or the ultra pure aluminium coating with appropriate heating system. Atomic Layer Deposition was also introduced for in situ deposition of Al_2O_3. ECR plasma studies on the kinetic instabilities demonstrated that unstable plasma conditions enhance the level of contaminants in the extracted ion beam of the CB [27]. The contamination issue is currently addressed by a collaborative work between LNL, LPSC and GANIL [28]. Preliminary experiments were done with the LPSC CB to measure contaminant spectra that will be used as reference for comparison with future configurations. High purity liners will be inserted in the plasma chamber to minimize the number of species sputtered by the plasma as well as decontamination of the support gas and vacuum improvement.

ECR Plasma Studies

The experimental analysis of ECR plasma can hardly be done by introducing physical probes into the plasma as this would perturb the plasma equilibrium [29]. Meanwhile, some plasma properties like the electron energy distribution function, the ion temperature or the electrostatic field distribution, remain poorly known. The possibility to use the 1+ beam as a probe was early proposed by Lamy [30]. Several studies with ECR CB contributed to a better understanding of ECR plasma.

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Experiments were carried out with the LPSC CB by injecting (i) Rb^+ and Cs^+ into an oxygen plasma [31] and (ii) Na^+ into a helium plasma [32]. The ion-ion collision mean free path and the lower limit of the electron density were estimated by analysing the captured portion of the 1+ beam.

The capture process was also simulated using different plasma models [33, 34] and measured ΔV curves (high charge state efficiency response as a function of ΔV) and efficiencies were used as input data to estimate the plasma potential, electron density or ion temperature. The simulated ion temperature is not in good agreement with experimental findings done by optical emission spectroscopy [35], similar to the plasma potential value from measurements done with a retarding field analyser [36].

The capture process was recently investigated with the LPSC CB injecting 1+ ions with different mass in a plasma sustained by different support gas. One conclusion of this work is that the final slowdown of the injected particles is mainly caused by the electrostatic force due to the plasma potential rather than long range Coulomb collisions, as previously postulated.

Experiments were also done by injecting short 1+ pulses [37]. The response of the n+ beam was analysed with a 0D code to estimate confinement, ionisation and charge exchange characteristic times together with other plasma parameters. These characteristic times play a key role in the charge breeding process. This short pulse method, tested by injecting K^+ with 2 different plasma conditions [38], showed that the K^{9+} efficiency increase in the new configuration was linked to a higher pile up of these ions induced by a better characteristic times configuration (minimisation of the ionisation time from lower charge state and reduction of the charge exchange time from higher charge state). This was eased in this case by the closed shell of the electronic configuration of K^{9+}. Recently, new experiments were done to improve the method accuracy [39]. The ECR plasma was probed with different isotopes and different species using a single 1+ alkali ion source pellet. The uncertainty on the fitted characteristic times was decreased by injecting different species and isotopes in the plasma, resulting in the reduction of the possible plasma parameter (electron density and average energy) matching all those configurations. The confinement times of high charge state ions were found to be in good agreement with the potential dip electrostatic trapping model which brings additional credits to this theory [40].

All these developments and studies contributed to a better understanding of the ECR CB process and to an improvement of the performances.

Discussion on the Performances of ECR CB

Table 2 summarizes the specifications of the recently developed ECR CB. These CB exhibit different performances depending on both their design and the characteristics of the accelerator facility they are installed on.

The ECR CB efficiency for a given charge state typically ranges from 5% to 20% and the total efficiency between 35% and 90%. Limited efficiencies is often due to the specifications of the facility such as high 1+ beam emittance [34] or high residual pressure. Moreover, in order to produce very high charge states, the CB may be operated with specific tuning, thus limiting the maximum value of the efficiency charge state distribution. This large variety of operation conditions makes the comparison between different charge breeders difficult.

Nevertheless, some parameters appear essential for efficient charge breeding like high magnetic mirror ratios (ANL, LPSC). This is in agreement with the ECRIS theory and it should be noticed that the mirror ratio at injection is often lower than the recommended value (≥ 3.5). The ECR CB configuration requires a port into the soft iron injection plug for the 1+ beam injection, reducing B_{inj} and so the magnetic mirror ratio. The presence of a median axial coil (case of 3 coils configuration), for the fine tuning of B_{min}/B_{ecr}, is beneficial to obtain a stable plasma with an optimum efficiency.

As illustrated by the short pulse experiments method, the plasma conditions may imply more suitable ions characteristic times and so improve the source performances. A higher microwave frequency would induce a higher electron density and reduce the ionisation times. It would improve the high charge state production together with the 1+ beam capture.

The lifetime of the high charge state ions can also be enhanced with a larger plasma chamber diameter [41] like in the case of ANL and Texas A&M. It should improve high charge state production as it increases the probability of ionisation. In addition, a lower residual vacuum, like TRIUMF, GANIL and ANL, may contribute to this goal by increasing the charge exchange times of the ions with neutral atoms. Fine frequency tuning or double frequency heating are also mandatory to enhance high charge state efficiency or optimize the efficiency on a given charge state.

Charge breeding time is measured in the range 5 to 25 ms/q which means that for high mass species, the process can take several hundreds of milliseconds. This duration can be relatively long in the case of short half-life isotopes. In some cases, a tuning providing a lower efficiency together with a shorter charge breeding time can be considered. Due to the step by step process of ionisation, shorter ionisation times obtained with a higher electron density should reduce the CB time. On the other hand, a larger plasma chamber radius would mechanically lengthen the the ion confinement time but this could be mitigated by acting on B_{ext}. In fact, reducing the axial magnetic field strength at extraction would create an electron leak on axis and, as a consequence, would reduce the ion confinement time [42].

ECR CB are robust instruments that can accept high intensity primary beam ($> 10^{13}$ ions/s) in CW or pulsed operation mode. Their performances are compared to EBIS type CB instruments, which are often operated in pulse mode for efficiency reasons, in Table3. EBIS CB require an ion cooler-buncher upstream to prepare the beam for injection. The EBIS cooler-buncher efficiency ranges between 10% and $\approx$ 60% depending on the ion mass and the RIB flux. The total efficiency of the trap and EBIS is between 5 to 20% which is close to ECR CB performances. High charge state

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Table 2: Specifications of the ECR charge breeders developed worldwide. The results are provided for stable metallic elements. SPES CB data were measured during the commissioning phase at LPSC.

Laboratory Facility	**ANL CARIBU**	**GANIL SPIRAL1**	**KEK TRIAC**	**LNL SPES**	**LPSC R&D**	**Texas A&M**	**TRIUMF ISAC**
Source type	AECR	PHOENIX	KEKCB	PHOENIX	PHOENIX		PHOENIX
Freq. (GHz)	10-14	14.5	18	14.5	14.5	14.5	14.5
Chamber Φ (mm)	80	72	75	72	72	90	72
Pressure (mbar)	2.5×10^{-8}	1×10^{-8}		4×10^{-7}	3×10^{-8}	1×10^{-7}	1×10^{-8}
Coils nb	2	3	3	3	3	2	3
B_{inj}/B_{ecr}	3.8	2.9	2.3	2.8	3.1	2.5	2.2
B_{rad}/B_{ecr}	2.3	1.5	1.7	1.5	1.5	2.2	1.5
ϵ_{CB} (%), A ≈ 20	10.1	17.0			18.7		
ϵ_{CB} (%), A ≈ 80		9.5		7.8	11.3		3.0
ϵ_{CB} (%), A ≈ 130	14.1		2.4	11.7	14.1	10.0	4.0
Total eff. (%)	47 - 77	44 - 72		50-65	60 - 90		>35%
τ_{CB} (ms/q)	10 - 46	4 - 20		17-28	13 - 26		10 - 20
A/q, A ≈ 20	3.3	3.3			2.9		5.5
A/q, A ≈ 130	5.1	4.5	7.0	5.1	5.1	5.5	6.3
Separation Δm/m	300	10000		1000	140		250

Table 3: Order of magnitude of the performances and features of the cooler-buncher and EBIS system compared to 14 GHz ECRIS CB.

Technology	**EBIS CB**	**ECRIS CB**
Max 1^+ RIB intensity	$<10^{10}$/s	$>10^{13}$/s
CB time to n+ (ms)	15 - 200	100 - 300
Operation mode	pulsed	CW or pulsed
Robustness	medium	high
1+n+ conversion efficiency	5 - 20%	10 - 20%
RIB total contamination rate extracted	$\sim 10^5$/s	$\sim 10^9 - 10^{10}$/s
Upstream requirement	Ion cooling	None
Maximum A/q	Bare ions	3→A∼ 60 5-6→A∼ 150

ions with A/q between 2 and 7 are typically extracted from the EBIS for ISOL application [43]. The charge breeding time, taking into account both the trapping and the charge breeding steps ranges between 15 to 200 ms (for A ≤130) which is faster than ECR CB. The maximum 1+ beam intensity acceptance ranges between 10^8 and 10^{10} ions/s and is limited by the number of charges that can be stored in the cooler-buncher or in the electron beam of the EBIS. ECR CB can accept three orders of magnitude higher RIB flux.

For the EBIS, the n+ beam contamination mainly originates from the residual gas and the typical vacuum level to mitigate this problem is 10^{-11} mbar. In the ECRIS case, the charged particules of the plasma have more interactions with the surrounding surfaces leading to higher wall desorption and material sputtering.

Contaminants density into the ECR plasma can be reduced by increasing the plasma chamber diameter (more favorable volume over surface ratio) [41] whereas a higher plasma density, obtained with higher microwave frequency, would increase the wall sputtering and thus increase the RIB contamination.

The contamination rate can be estimated to 10^5pps in the EBIS case and up to 10^{10}pps for the ECRIS. This is particularly problematic when a low RIB rate is produced or with low downstream separation. RIB contamination can be limited by the fine tuning of the post accelerator or the use of a stripping foil like done at TRIUMF. Nevertheless, TRIUMF decided to manufacture and install an EBIS CB as previously done at ANL. At SPIRAL1, a cyclotron is used for post acceleration allowing a high resolution mass separation (Δm/m > 10000).

ECR technology is efficient for ISOL charge breeding when the downstream separator has a high resolution. It still can be improved and it could play a key role in the frame of future facilities with high intensity RIB production.

PERSPECTIVES

Future ISOL Projects

At MSU, the FRIB project is in its final construction phase. At maximum power, the new facility will produce radioactive ions with a rate $>10^{10}$ pps. The new «HCEBIS» charge breeder was assembled to allow their post acceleration. It will operate with an electron beam current of 4 A, a density of 200 A/cm^2, the trapping length being ≈0.7 m. The expected charge capacity is 10^{11} allowing charge breeding with production rates up to 10^{10} for light ions.

In Europe, beyond the SPIRAL2 and SPES projects, the EURISOL project aims at the construction of an ISOL facility increasing the production yield by a factor of 100 or more. It is based on a new 1 GeV proton linac with 5 MW power, 2 different types of targets and a 150 MeV LINAC. Presently, only ECR CB can accept high flux RIBs on the order of 10^{12} ions/s.

Future ECR CB Configurations

At LPSC, a development plan was set to enhance the PHOENIX type CB performances.

As a first step, the source will be implemented in the so called "5 coils configuration" (consisting in removing one axial coils among the existing 6) to ease the CB tuning and to stabilize the plasma. The yoke and coils structure will be modified to reduce the coupling between the 3 groups of solenoids generating B_{inj}, B_{min} and B_{ext} (see Fig. 1). The injection and extraction plugs will be replaced, together with the plasma chamber. The reduction of the port diameter of the injection soft iron plug will be tested to enhance the injection mirror ratio from 3.1 (see Table 2) up to 3.6, while maintaining a good 1+ beam injection. The source length will be reduced (by 80 mm) and the injection and extraction electrodes will be shortened to improve the optics. To reduce contamination, residual gas pressure will be minimized using alumina insulators with brazed metallic flanges at injection and extraction, thus limiting the number of o-rings. Contamination reduction will also be studied by introducing into the plasma chamber liners of different materials, such as Nb and Ta. All the parts have been manufactured and the assembly is planned in September 2022.

As a second step, a larger diameter plasma chamber configuration of the PHOENIX CB was designed to increase high charge state production and reduce further the contamination yield. In this design, the plasma chamber diameter is increased from 72 mm to 100 mm with a new hexapole providing a 1.1 T maximum field at the plasma chamber wall. The whole new central core parts under vacuum will be made of the same material and so, no soft iron parts will be set under vacuum in this case. Vacuum sealing will be performed exclusively with metallic gaskets. The injection coil current supply will be upgraded to reach the maximum possible current in the injection coil (1350 A) and improve the magnetic mirror ratio at injection. The magnetic configuration will allow operation up to 18 GHz (against 14 GHz today). For double frequency heating, the plasma chamber will be equipped with 2 WR62 waveguide ports and a 500 W 9-18 GHz amplifier will be purchased, also allowing fine frequency heating. Manufacturing of the parts will be completed by the end of 2022 to test this configuration in 2023.

Finally, a new concept of 18 GHz superconducting ECR CB was proposed by Thuillier [42]. The driving idea is to apply the feedback learned with ECR ion sources by the community along the past decades and apply it to define a new generation ECR CB. The design is adapted to optimize the ion capture, maximize the high charge state production and minimize the output RIB contaminants. A high tuning flexibility is obtained with a set of 8 axial coils, able to produce either short or very long ECR plasma. The radial magnetic field is also created by a superconducting hexapole magnet tunable up to 1.4 T. The plasma chamber would have a 200 mm diameter and could be baked online up to 300°C. Ultra High Vacuum would be reached with cryogenic pumps set at each side of the source. Pure Beryllium was proposed to manufacture all parts surrounding the plasma in order to reduce the number of contaminant species produced by the plasma sputtering of the walls. This design should allow a +20% increase of the efficiency together with a -40% reduction of the charge breeding time and drastic reduction of the contaminants. Such design could be advantageously considered for next generation facilities like EURISOL where high intensity RIBs are expected.

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