SOLID STATE AMPLIFIER FOR A 2,45 GHZ HIGH INTENSITY PROTON SOURCE

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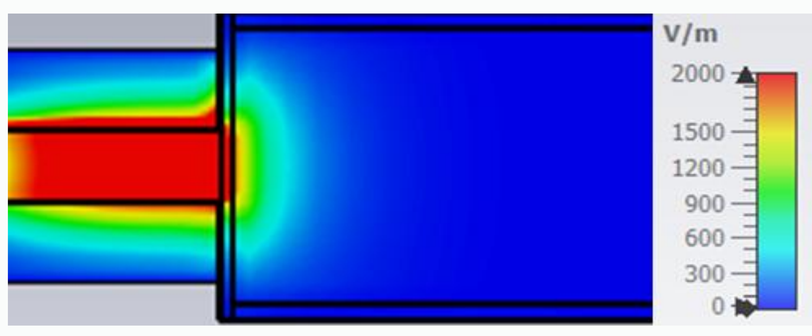
ABSTRACT

The ALISES3 Ion source has demonstrated very good reliability for 30 mA extracted current on a long term operation at 50 kV extraction energy with a single magnetic coil at ground potential. ALISES3 source is originally equipped with a 2.45 GHz magnetron. Several RF measurements of the magnetron, installed on a stand-alone test bench showed a frequency modulation which can lead to detune the ECR heating process. In order to increase even more the reliability, we removed of the whole RF chain (Magnetron + ATU) and installed at its place a solid amplifier that can deliver with up to 1kW µwave power between 2.4 and 2.5 GHz. The measurement of the ALISES ion source with this new µwave generator is presented in this paper.

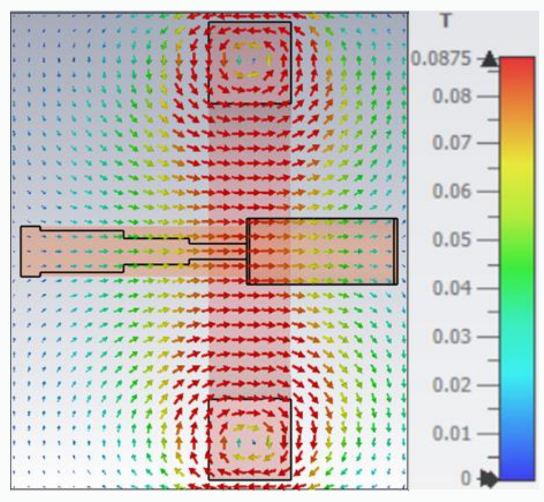
ALISES 3 ION SOURCE

The ALISES ion source is a compact ion source that was designed for intermediate extraction intensities of around 50 mA. The source is based on a magnetron discharge process, that heats up electrons, that ionize H_2 molecules to produce proton particles.
The plasma chamber, ridged waveguide and RF bend are made in a single copper part and are water cooled. The 45 mm diameter plasma chamber leads to a cutoff frequency much higher than the frequency of the injected microwave delivered by the microwave system.

➔ This geometry results in an absence of electric field inside the plasma chamber except near the injection side, i.e. near the ridged wave-guide at the plasma chamber entrance, where the heating process can be established.
➔ To increase the electron density, both sides of the cylindrical chamber are covered with 2 mm thick BN disks
➔ A single coil located around the ceramic tube produces the magnetic field, which is referenced at ground potential. The coil's position can be adjusted to modify the magnetic field shape inside the plasma chamber.
➔ H_2 gas injection is controlled with a precise mass-flow meter and is adjusted from 1 up to 10 sccm.



No E-FIELD INSIDE Plasma Chamber.

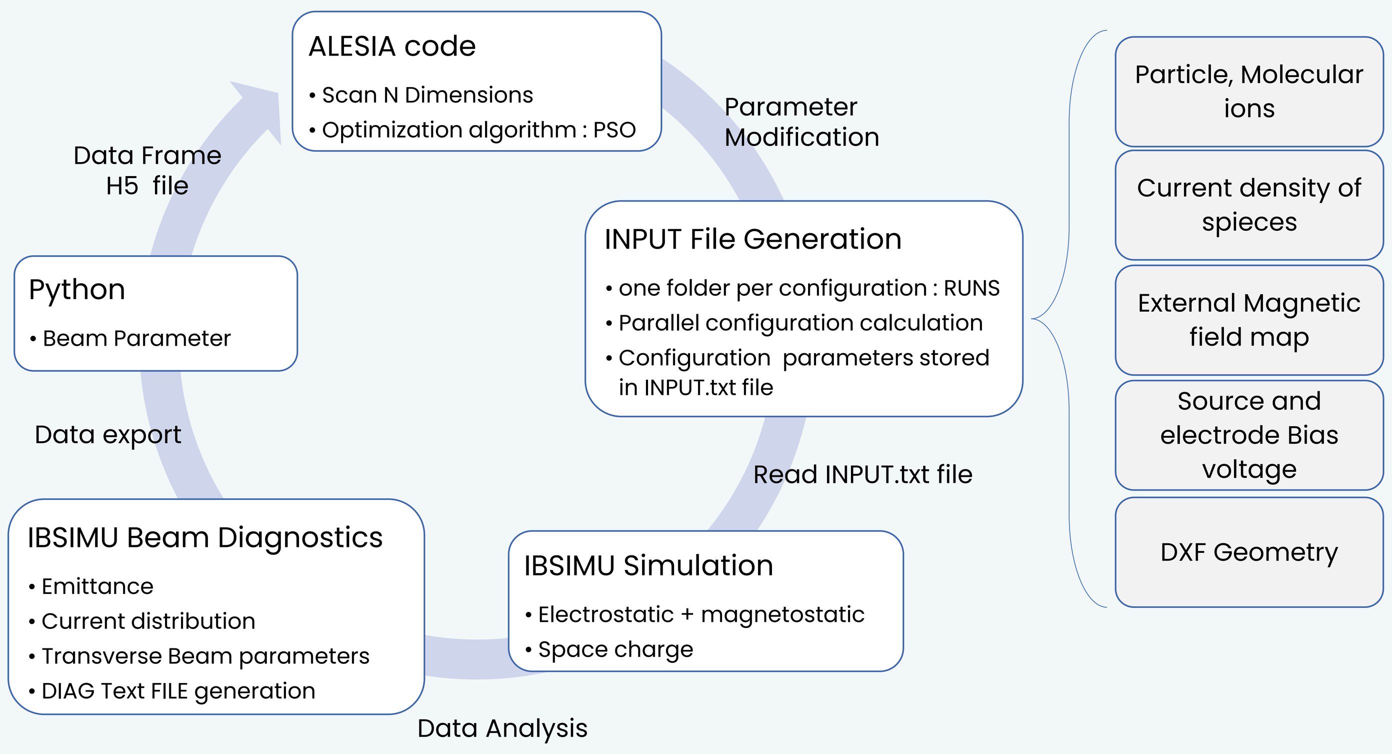


SINGLE COIL for ECR HEATING.

SIMULATION WITH ALESIA AND IBSIMU CODES

The extraction system is a 4 electrodes system, with an 8 mm aperture hole in a Plasma Electrode (PE) biased at 50 kV. This electrode is followed by a group of 3 stainless-steel electrodes named Ground Electrode1 (GE1), electron Repeller Electrode (eRE) and Ground Electrode 2 (GE2). With this configuration, a single gap acceleration is produced.

To minimize the normalized RMS emittance value (noted ε), the transverse beam size and the angle for a fixed extraction voltage, we used IBSIMU software [4] for positive particle extraction, coupled with ALESIA software, which was developed by CEA Saclay. ALESIA can change the ion source parameters by modifying the gap length, the diameter of the electrode aperture hole, or the plasma density current at the PE aperture hole. The new configuration is set as an input of IBSIMU simulations.
It can also run several configuration simulations in parallel independently.

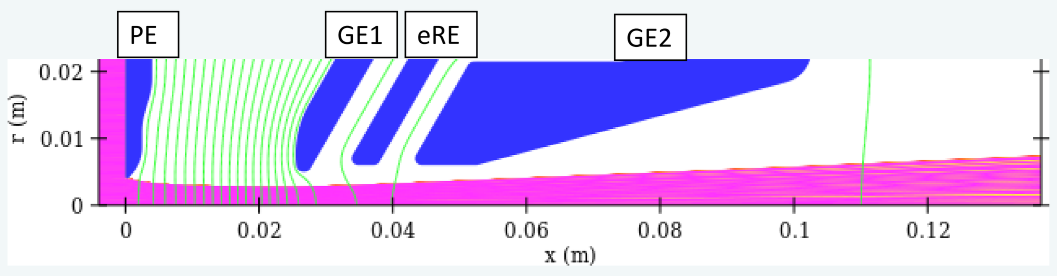


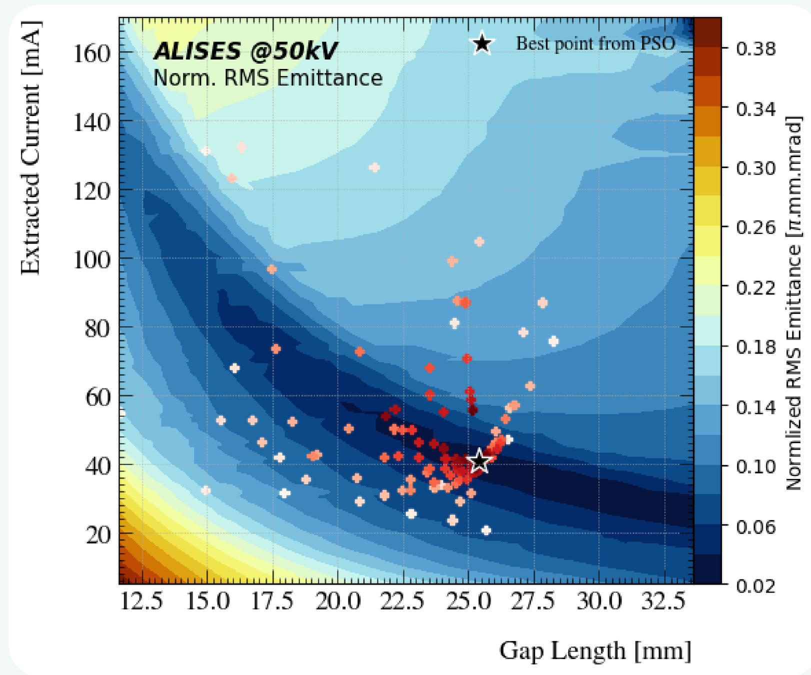
Two different simulations at 50 kV of extraction voltage :
❑ in a 2D map in scaled color (Z) the normalized RMS emittance value versus :
• (X) the single acceleration gap length
• (Y) the extracted current.
❑ ALESIA use
• a "Scored parameter" which is defined as a linear combination of several output beam parameter with their own individual weights.
• A Particle Swarm Optimizer (PSO) algorithm minimize the Scored parameter by adjusting the remaining input parameters: the gap length parameter and the extracted current. Red cross are located on the 2D map. The daker the red, the higher the iteration number. A black star shows the best configuration that was simulated.

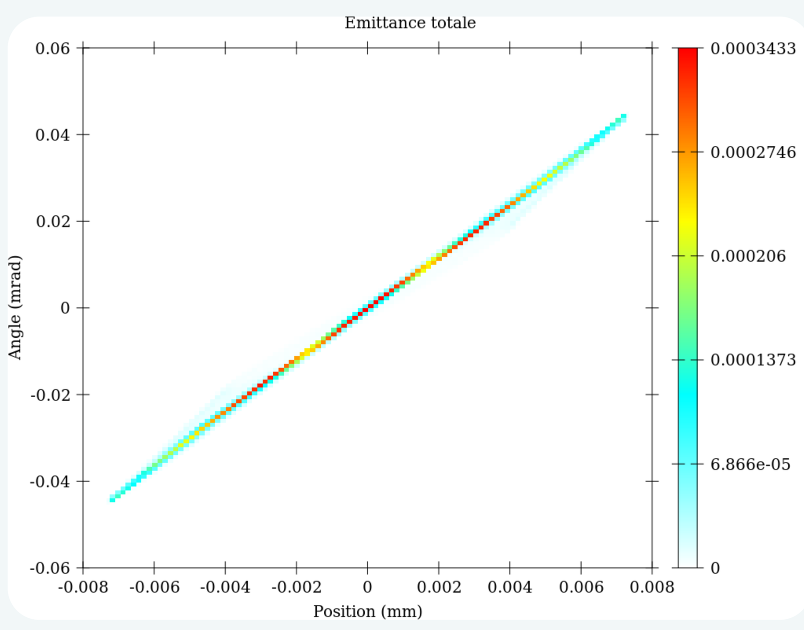
This 2D map is composed of :
(X) 23 values for the gap length from 11.6 to 33.6 mm
(Y) 34 current values in range from 5 to 170 mA.

➔Those 782 configurations were simulated using 4 parallel processes and was carried out in 4h 48min and 32s.

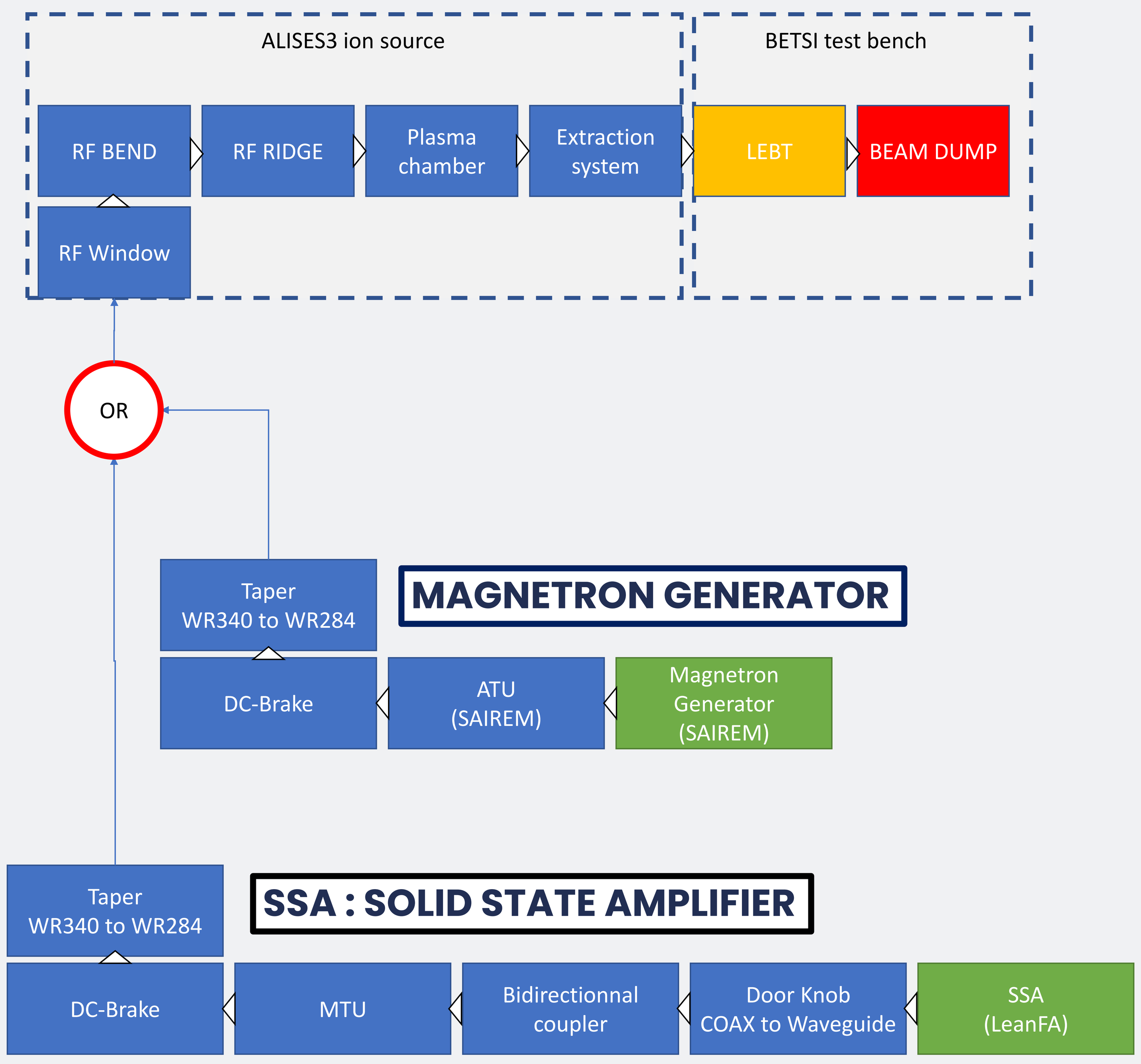
➔With the PSO algorithm 120 configurations were finished with 10 parallel processes in only 34min and 49s.





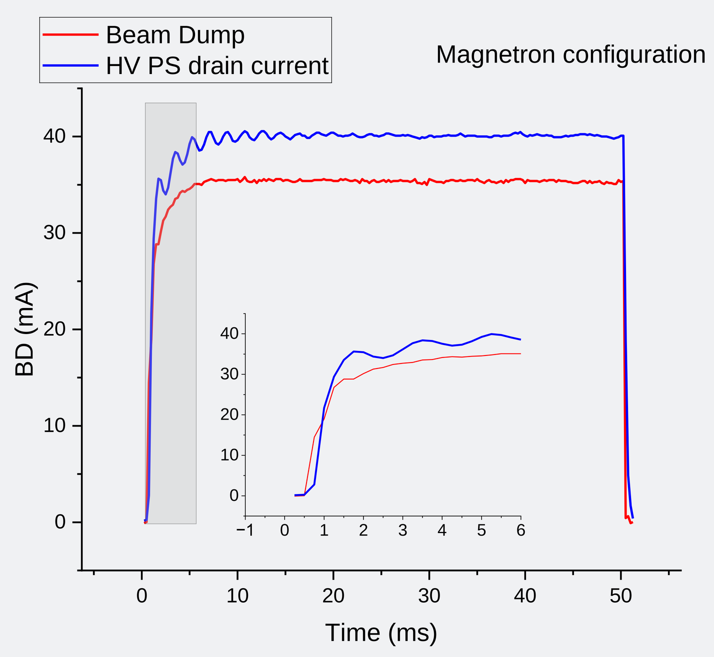


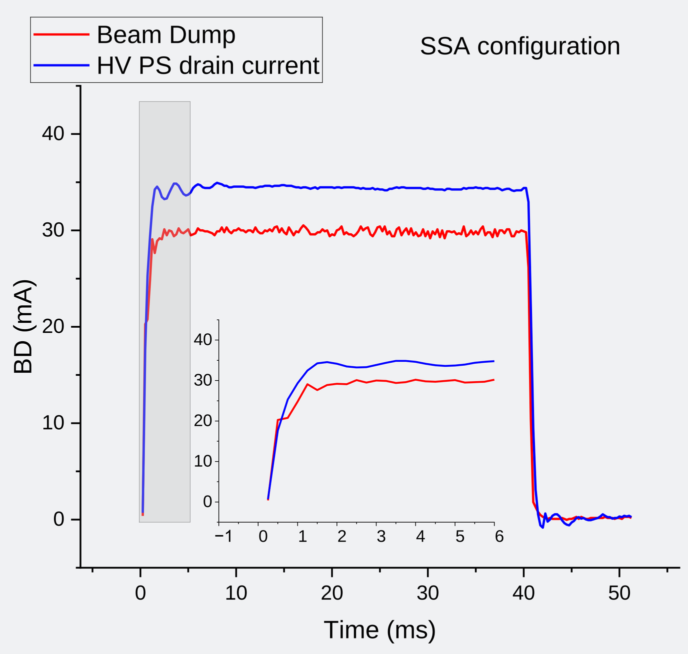
µWAVE CONFIGURATION

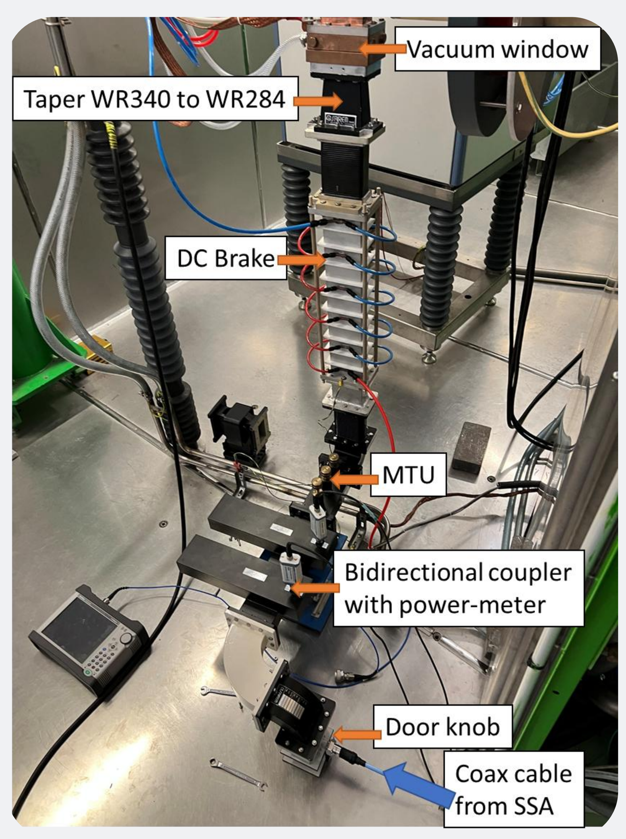


We tested both configurations and compared the extracted beam pulse characteristics.
• Intensity over power and ripple of the extracted current
• Pulse shape

The best tuning was obtained with approximately 300 W injected into the source. The maximum extracted currents (Figure 5.) are 40 and 35 mA respectively for a magnetron and an SSA µwave generator. More than 88.3 % of extracted current is transmitted to the beam dump at the end of the LEBT, which is close to the maximum achievable. The ion source produces approximately 12% of molecular ions (H_2^+ and H_3^+), which are produced alongside proton particles. However, they are not transported to the beam dump due to the pair of solenoids.
➔ This clearly demonstrates that the beam divergence is low and that transport to the end of the low energy beam line is efficient.







When comparing the extracted beam pulse ripple for both configurations:
• the amplitude for the magnetron generator is higher than of the SSA µwave generator, at 4 and 2 mA, respectively
• and lasts much longer (25 ms) compared to the SSA generator, where the signal flattens after 10 ms.
• For the magnetron generator, the pulse rise also seems to occur in two stages: a fast increase of approximately 2 ms, followed by a slower increase of around 4 ms to reach the beam plateau. For the SSA generator, the pulse rise time is less than 2 ms to reach the beam plateau.

CONCLUSION

In this paper we present the first optimization of ion source configuration using both ALESIA and IBSIMU software codes. The ALISES3's electrodes were fabricated in stainless-steel and we installed the ion source on the BETSI test bench for beam characterization. First, we used the usual the standard magnetron configuration, then we switched to an SSA µwave generator. It was clear that the extraction current was of the same order of magnitude in both cases, but the rise time is much shorter for the SSA, and even the ripple amplitude was smaller. Although the SSA was only operated for a few days, it helped to produce very promising results for the development high intensity proton ion sources.