

FIRST BEAM OF THE CEA-SACLAY CW HIGH- INTENSITY MICROWAVE SOURCE.

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Abstract

The High Intensity Light Ion Source SILHI is designed to be a prototype source for high power proton and deuteron accelerators. The aim is to achieve beam currents greater than 100 mA at 95 keV with rms normalized emittance lower than $0.2 \pi \cdot \text{mm} \cdot \text{mrad}$. Installed at CEA Saclay, this ECR source delivered its first proton beam in July 1996. In February 1997, a 107 mA CW beam has been extracted through a 8 mm diameter extraction aperture ($J = 213 \text{ mA/cm}^2$). A microwave power of 900 W at 2.45 GHz was needed. Diagnostic hardware, first beam measurements and last results are presented.

1 INTRODUCTION

A wide range of activities is presently being undertaken at the CEA in the field of high power proton or deuteron linear accelerators. We are now studying the CW IPHI demonstration project [1]. This accelerator will consist of the ECR source presented in this paper, an RFQ and a DTL up to 10 or 11 MeV. The main applications of this kind of accelerators are the production of high flux neutron beam for spallation reactions (TRISPAL, APT, ESS), the international IFMIF program and nuclear waste treatment.

In 1994, it was decided to develop a new ECR proton or deuteron source and a 3 m Low Energy Beam Transport (LEBT) to analyze the beam characteristics. We choose this source-type for simplicity and reliability reasons as demonstrated by Chalk River National Laboratory and Los Alamos National Laboratory. The requirements are: 100 mA proton or 140 mA deuteron in 90% of the total extracted beam, at 95 keV and $0.2 \pi \cdot \text{mm} \cdot \text{mrad}$ rms normalized emittance.

The source, installed on a 100 kV high voltage platform, delivered its first proton beam in July 1996: 46 mA at 70 keV extracted through a 10 mm diameter extraction aperture. In November, a 54 mA beam at 95 keV through a 6 mm diameter extraction aperture ($J = 191 \text{ mA/cm}^2$) and in February 1997, a 107 mA at 97 keV through a 8 mm diameter extraction aperture ($J = 213 \text{ mA/cm}^2$) have been extracted.

In this paper, we describe the different diagnostics installed on the LEBT [2], and present the beam analysis.

2 THE SILHI SOURCE AT CEA-SACLAY

To design the High Intensity Light Ion Source (SILHI) and the LEBT (Fig 1), we took the experiences of other

teams into account [3], [4], [5]. The plasma chamber is cylindrical, with a 90 mm diameter and a 100 mm length. Both ends of the plasma chamber are lined with 2 mm thick boron nitride discs. The RF signal is produced by a 1.2 kW magnetron source at 2.45 GHz and is fed to the source via standard rectangular waveguides with a four stub automatic tuning unit. A three section ridged waveguide transition is placed between the plasma chamber and the cooled bend to enhance the axial RF field. The RF window is located behind the water cooled bend in order to be protected from backstreamed electrons. The magnetic field is produced by four coils tuned and positioned independently.

All these components are placed on the 100 kV high voltage platform with the ancillary equipments. The power supplies are controlled by a computer through optical fibers.

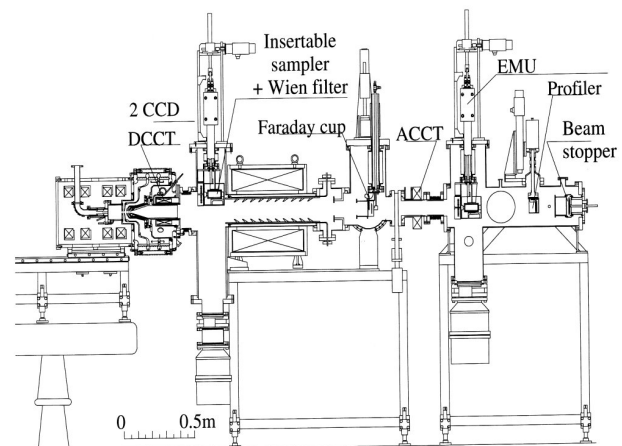


fig. 1: Source and LEBT assembly

The source is connected to the LEBT via a 300 mm long High Voltage (HV) column. The total extraction system includes five electrodes. An adjustable intermediate electrode is located in the acceleration gap to minimize the distortions in the phase-space distribution [6] and allow a beam focusing.

Along the LEBT, several diagnostics are placed in order to analyze the extracted beam [2]. Two CCD cameras allow x and y profile measurements at the end of the HV column. A Bergoz DCCT is located very close to the extraction system. An ACCT is inserted around the chamber for noise measurements. Two water cooled beam stopper are designed to stop the 10 kW total beam

power (0.8 kW/cm^2). Thermocouples measure the two grounded electrodes temperature increases, and a residual gas analyzer is placed at the accelerator column exit.

The 2200 Gauss, 500 mm long solenoid, centered 1.1 m from the plasma electrode aperture, focuses the proton beam on the Emittance Measurement Unit (EMU) installed 1.2 m farther downstream.

The EMU is composed of a water cooled copper beam stop, with a 0.2 mm diameter aperture tantalum sampler placed at the center and a 64 wire profile monitor 0.5 m downstream. The unit is moved across the beam by two stepping motors. In order to measure the emittance of only the proton beam, a Wien filter is inserted close to the sampler. This species-separator combines a 2000 Gauss permanent magnetic field and a 1 MV/m adjustable electric field. Its total horizontal acceptance is $\pm 5 \text{ mrad}$.

3 RESULTS:

The first plasma was produced in July 1996. Two weeks later a 46 mA total proton beam current at 70 keV was extracted through a 10 mm diameter extraction aperture. Beam losses destroyed the 1 mm thick stainless steel intermediate electrode as shown by thermal simulations. New drawing of the five-electrodes extraction system has been made using Axcel [7] and Opera 2D codes [8].

3.1 New extraction system.

To increase the electrode power dissipation, we chose more appropriate material and we slightly modified the shape of the electrodes. For the same beam extraction

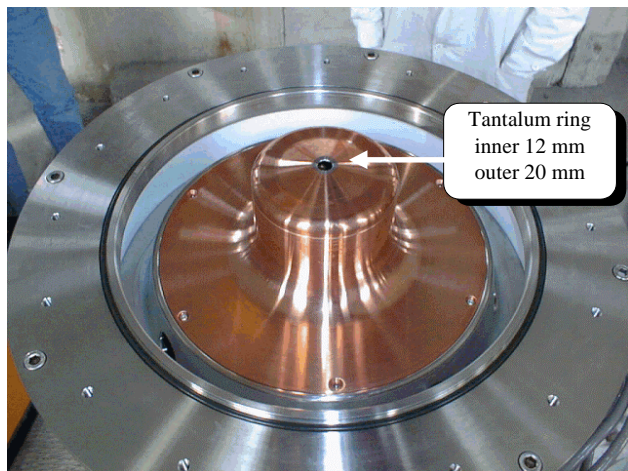


Fig. 2: Picture of the new SILHI intermediate electrode.

conditions, the maximum calculated electric field at the electrode surfaces decreased from 82 kV/m for the earlier design to 58 kV/m for the new one. The intermediate electrode and the first grounded electrode are now made in two parts (Fig. 2). For each one, the part close to the beam is made of tantalum and the other part is made of cooper. The intermediate electrode has been thickened from 1 to 2 mm and the first grounded electrode thickness was increased from 1 to 4 mm. The thickness of the

copper electron trap electrode has also been reduced from 12 mm to 4 mm.

The aperture diameter is chosen to be 8 mm for the plasma electrode and 12 mm for the last four electrodes. The intermediate electrode voltage can now be set from 0 to 65 kV (relative to the ground potential) to optimize the beam extraction.

With the new extraction system, the conditioning is easier; only few sparkdowns have been observed at the pressure limit, for a 100 kV source potential. Compared to the former extraction system, and for the same plasma conditions, the extracted beam is more stable. Sparkdowns due to beam rarely occur. A continuous 8 hours run has been achieved with a 80 mA total extracted beam. The resulting availability was found to be 96 %.

The AC toroid showed a beam noise about $\pm 2\%$.

3.2 Plasma tuning.

For the following experiments, we installed a 8 mm diameter aperture plasma electrode. The other four extraction electrodes were set at 12 mm diameter aperture. The diameter aperture of the boron nitride disc close to the plasma electrode was 11 mm.

A complete mapping of the total extracted beam current as a function of the magnetic field inside the plasma chamber has been done. Two set of current coils gave a maximum extracted beam [2]. Computations indicate that these magnetic field values (875 Gauss) overlap with the ECR zone located at both plasma chamber extremities.

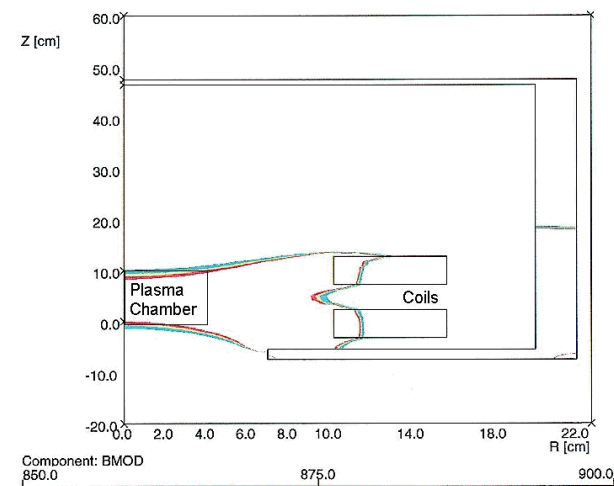


Fig. 3: Magnetic field calculation for the maximum extracted beam. Two ECR areas are located at both plasma chamber extremities.

We then decided to set two ECR zones located at both plasma chamber extremities simultaneously (Fig 3). For this requirement, we used only two coils with adequate current intensity. The total extracted beam current increased significantly up to 107 mA ($J = 213 \text{ mA/cm}^2$) at 97 keV in February 1997.

3.3 Species fractions.

The species fraction is analyzed 2.3 m from the plasma electrode, through the sampler and the Wien filter. The particles are detected at the beam stopper 75 cm downstream. During measurements, the LEBT solenoid is turned off and the Wien filter electric field increases from 0 to 6 kV.

Preliminary results indicated a poor fractions : 67 % H^+ , 23 % H_2^+ and 10 % H_3^+ .

With the new electrode design, the diameter aperture in the boron nitride disc close to the extraction was changed to 8 mm, exactly the same as the plasma electrode aperture. Measurements have been done as a function of RF power, hydrogen gas flow, and sampler position within the beam diameter (± 2 cm with a 5 mm step). The species fraction were found to be 75% to 88% for H^+ , 20% to 9% for H_2^+ and 5% to 3% for H_3^+ (Fig. 4).

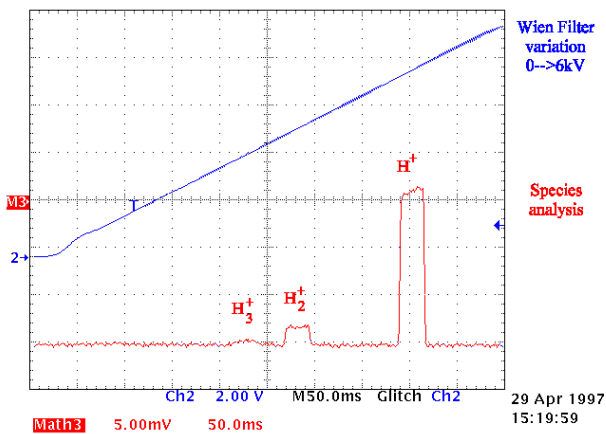


Fig. 4: Species fraction analysis

3.4 Emittance measurements.

The influence of the intermediate electrode potential has been checked on the proton beam emittance at 57 mA and 78 keV. The beam was focused with a cross-over point 50 cm upstream from the sampler. The rms normalized emittance decreased from 0.26π .mm.mrad to 0.11π .mm.mrad as the intermediate electrode voltage rose from 32 kV to 49 kV. This result is in good agreement with previous calculation. Typical emittance value for a 80 mA total beam current is 0.17π .mm.mrad (fig. 5).

4 REMARKS.

The new extraction system enhanced greatly the general working of this source. The proton fraction and the extracted beam seems to be slightly better, perhaps due to the new boron nitride diameter aperture. The temperature increase of the grounded electrodes are less important. The reliability of the whole device has been greatly improved with the new connection of the intermediate electrode power supply. The beam extraction tuning is

now easier.

One of the next steps will be to install an automatic fault recovery system.

The source instabilities did not allow us to make emittance measurements with a total extracted current higher than 100 mA. Our next goal is to enhance the reliability of the source.

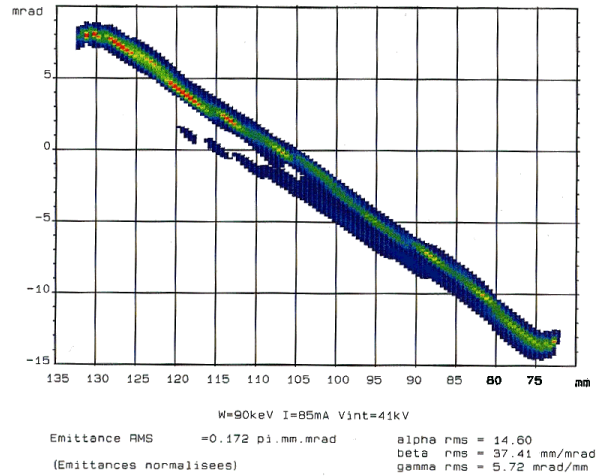


Fig. 5: Proton beam emittance measurement with 80 mA

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