PRELIMINARY DESIGN OF BLISI, AN OFF RESONANCE MICROWAVE PROTON SOURCE

Slobodan Djekic, Ibon Bustinduy, David de Cos, David Fernandez-Cañoto, Jorge Feuchtwanger, Hooman Hassanzadegan, Igor Rueda, Juan Luis Munoz, ESS Bilbao, Bilbao, Spain
Daniel Cortazar, ESS Bilbao, Bilbao and Universidad de Castilla-La Mancha, Ciudad Real, Spain
F. Javier Bermejo Bilbao, Bilbao, Spain
Victor Etxebarria, Josu Jugo, Joaquin Portilla, University of the Basque Country, Bilbao, Spain
Miguel Angel Carrera, Julio Huguet Galipienzo, AVS, Eibar, Spain
Julio Lucas Elytt Energy, Madrid, Spain

Abstract

A new high current off resonance microwave H^+ source is currently in the last stages of design at ESS-Bilbao, in collaboration with two external companies Elytt and AVS. The design is intended to be a high-stability, high-current ion source capable of delivering a 70 mA proton beam with a 70 keV energy.

INTRODUCTION

The Bilbao Center for Accelerator Science and Technology is a large scale accelerator facility under construction in Spain. Its main headquarters have been inaugurated at the University of the Basque Country (UPV/EHU) campus at Leioa, Biscay. The first machine of the future facility will be a high intensity Proton Linear Accelerator. The first part of such a proton LINAC will be BLISI – Basque Light Ion Source Injector, that is to be completed within two years.

The main parts of the future BLISI Ion Source are magnetic structure, microwave system, gas inlet system and extraction system. The first two parts are designed in collaboration with Elytt. They are consists of a water-cooled plasma chamber that sits between two independently powered magnetic coils that generate the ECR magnetic field, a CPI 2.7 GHz klystron which provides the microwave energy and a fully controlled microwave system to minimize reflected power and improve the source overall performance.

The gas inlet system is designed for simultaneous introducing of two gases and it will have an automatic control loop for the gas flow stabilization.

The extraction system has been designed in collaboration with AVS. It will consist of a movable tetrode system designed for a maximum acceleration potential of 70 kV, the shape of the electrodes is at an earlier design stage at ESS-Bilbao.

The list of the desired parameters of the BLISI proton beam is given in Table 1.

We will present the current layout of the source, simulations and schematics of the source.

MAGNETIC STRUCTURE

The magnetic structure of the BLISI Ion Source consists of two solenoid coils divided into two pancakes and shielded by an iron yoke. The coils will be powered via four power supplies for higher flexibility in shaping of the magnetic field configuration. The coils are remotely movable via use of two stepping motors with a linear accuracy of 20 μm.

General Consideration

For optimal microwave power absorption in plasma chamber that will enhance production of high current of single charged ions one has to provide the special magnetic field configuration. Experimentally has been proven that such configuration has to have electron cyclotron resonance (ECR) conditions at both ends of the chamber and across the chamber to have a flat field around 10% higher then ECR field [1]. For our working frequency of 2.7 GHz corresponding resonance field will be B_{ECR} = 96.4 mT, so we have to provide flat magnetic field of around 106 mT through the whole length of the plasma chamber. We have considered two different solutions for the BLISI magnetic structure configurations.

Magnetic Field Proposals

In the first proposed magnetic structure, a plasma electrode and its support are made of magnetic material so they have a strong influence on the overall magnetic field shape. It is shown on the left part of the Fig.1.

Table 1: Expected proton beam characteristics

Proton Beam Parameters	Values
Beam energy	70 keV
Total current	80 mA
Proton fraction	>85 %
Emittance	<0.2 π mm mrad
Availability	98 %
Reliability	170 hours
Duty Factor	3 % to 10 % (pulsed beam)
Pulse	1.5 to 2 ms
Repetition Rate	Up to 50 Hz
Klystron	2 kW @ 2.7 GHz

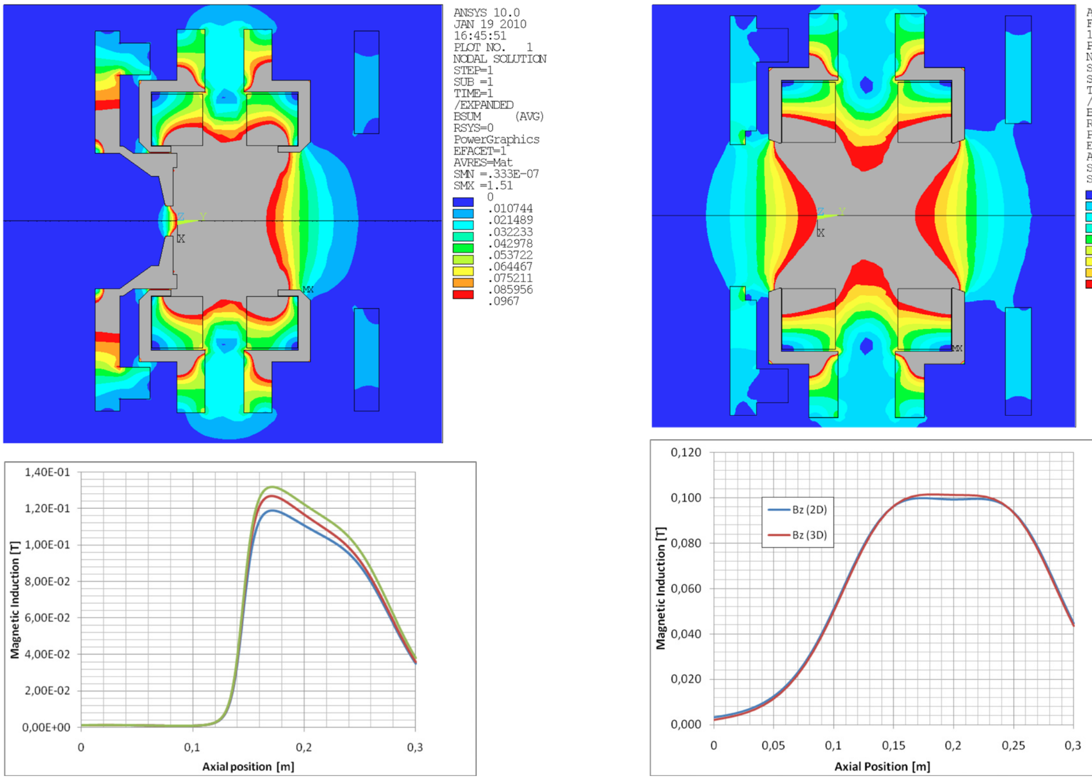

Figure 1: Magnetic Field Simulations for two cases of interest. On the left side the plasma electrode and its support are made of magnetic material, and on the right side of the figure they are made of non-magnetic one.

This solution has advantages that a magnetic field easily reaching values from 10% to 30% higher then $B_{ECR,}$ and also it provides a very good magnetic shielding of the extraction region. This can drastically improve the ion extraction. But the big disadvantage is that magnetic field shape isn't flat. This will probably detoriate microwave absorption and consequently creation of an overdense plasma necessary for the high proton current production.

So we have proposed another solution, shown on the right side of the Fig.1. The plasma electrode and its support part have been made of non-magnetic material and simulation has been done. Magnetic field will be almost constant along the plasma chamber having a value of 100 mT, that is just above the resonance. This will allow for a better plasma formation and higher plasma density, but will increase the magnetic field in extraction region up to 500 mT that will involve a risk of sparks and higher divergence of the extracted ion beams.

Deeper understanding of this problem is necessary and we will perform a detail test of the both proposed solutions in our future plasma laboratory that is already under construction.

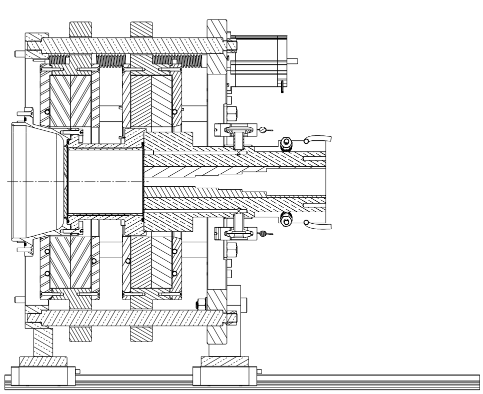

Figure 2: Layout of BLISI.

MICROWAVE SYSTEM

The microwave system of the BLISI consists of commercially available CPI klystron generator of 2 kW, working at 2.7 GHz, bidirectional couplers, circulator, waveguides and four stub automatic tuning unit (ATU) from Sairem company. Waveguide transition for coupling with the plasma chamber, electronics for ATU and electronics for pulsing the klystron amplifier will be designed and engineered by us. The plasma chamber (see Fig.2) will be made of copper in cylindrical shape with diameter 80 mm and length of 97 mm to provide optimal microwave coupling. It will be water-cooled and having at the both ends boron-nitride disks as electrons donors, this is necessary for efficient production of the high current proton beams.

The main reason for using klystron instead of magnetron is because it is easier for maintenance and better for pulse mode operation.

The 2.7 GHz working frequency has been chosen since it will generate higher plasma density.

GAS INLET SYSTEM

A special care has been taken in designing a gas inlet system that includes a PID regulator for creating an automatic control loop. It consists of a gas dosing valve, automatic gas pressure control unit, isolation valve and pressure gauge (see Fig.3). Our aim is to ensure a stable and reliable work for hundreds of hours even in case of long and/or short term changes in outside temperature or some others instabilities that can happen in the vacuum system and plasma fluctuations during a pulse mode operation.

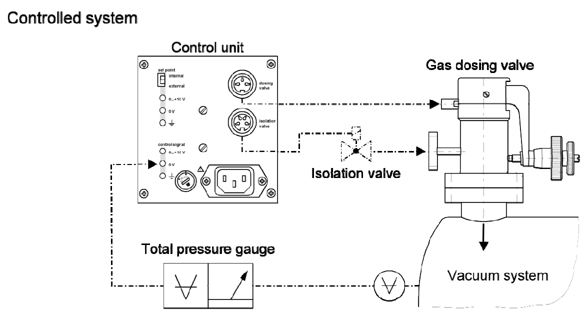

Figure 3: Layout of the gas inlet system.

For experimental determination of the PID parameters of the control unit of the gas regulation system we are building an ion source test stand. A pressure gauge will be directly connected to the plasma chamber that will give us exact knowledge on the pressure inside the chamber. This will open possibility to derive relation (semi-empirical equation) between the magnetic field profile, microwave power (and frequency) and neutral gas pressure and the plasma parameters: ion density, electron temperature and plasma potential.

The gas inlet system will consists of two separates lines for simultaneous introducing of hydrogen (or deuterium) and additional gases like oxygen or even water vapour.

EXTRACTION SYSTEM

The extraction system consists of 4 electrodes (see Fig. 4). The first one is plasma electrode attached to the plasma chamber and ion source body. So it is elevated to the voltage of the HV platform, i.e. 70 kV. Another 3 electrodes are packed in the extraction column and separated via two alumina insulators from the HV platform.

These three electrodes will be remotely movable as an entire group. That means we will keep the fixed distance between them, and change only acceleration gap – distance between them and plasma electrode. In such a way we have opportunity to experimentally optimize acceleration gap according to possible different extraction voltages, ion current density and different ion species (protons and deuterons). It will also allow for comparison of our ion extraction simulations with the experimental results for identical plasma parameters, since we can change the acceleration gap without breaking a vacuum.

The first and the third electrode of this group are grounded and water cooled. They serve for shaping of the ion beam. The second one, so called repeller, shall be on negative voltage of 3kV serving for the electron suppression.

We have paid a special attention to provide a good vacuum condition inside the extraction column, drilling additional wholes on the support parts of the electrodes. For reducing electron production in the HV column, and consequently minimizing X-ray radiation in vicinity of the source a special kofoidal protectors has been installed.

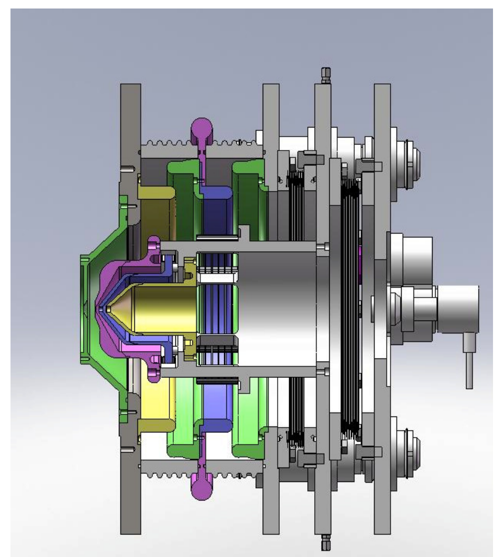

Figure 4: Layout of extraction system.

CONCLUSION

We have presented a preliminary design and status of construction of BLISI, an off resonance microwave source. Improvements have been done in all crucial parts of the BLISI comparing to designs of the similar proton sources [2],[3]. Extensive set of test measurements in the plasma laboratory, that we are building at the same site, will allow us for very a detailed performance check. The main target is reaching the overall reliability of the BLISI of minimum 170 hours.

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