STATUS OF THE ION SOURCES AT ESS-BILBAO

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Abstract

Currently there are two types of ion sources under development and testing at ESS-Bilbao, the first one is a Penning type source based on the ISIS/RAL source, modified to use permanent magnets to generate the Penning field. The second source is an off-resonance ECR source that is being developed in-house. The Penning source is in the late stages of commissioning, and a beam has been extracted from it. Currently the main work on that source is in the optimization of the operating parameters. The ECR source on the other hand is in the early stages of the commissioning, all parts have been fabricated, and Vacuum tests are underway. Testing of the RF and control systems will follow, and finally the whole system will be tested. The control system for both ion sources was developed under LabView, and runs on a real time system. While for testing the timing sequences run locally, the system is being developed so that it can run using a central timing system.

INTRODUCTION

As part of the ongoing development of the ESS-Bilbao project, work on two different ion sources is being carried out. The ESS-Bilbao in its first, and current, stage calls for a linear accelerator capable of accelerating protons to 50 MeV. To achieve this, the protons form the source go into a Low energy beam transport that feeds a Radio Frequency Quadrupole that accelerates the protons from 70 kV to 3 MV. From there a Medium Energy Beam Transport passes the particles to a Drift Tube Linac, that takes care of accelerating them to the final 50 MeV energy. At their final energy the protons will be used to generate neutrons by impacting them against a target, or to directly irradiate samples for biological studies, cosmic radiation simulation or fusion applications [1].

Given the nature of the accelerator, there is strictly no need for an H^- beam to be produced, however work is being carried out on the development of a slightly modified version of the Penning source in use at ISIS in the United Kingdom. This is a source of proven reliability in the production of a high intensity beam. As far as the accelerator is concerned the slight difference in mass between H^- and H^+, is of no consequence. If the need for short pulses should ever arise, the ease with which electrons can be stripped from H^- can prove advantageous.

The second type of source under development is an in house design of an off-resonace Electron Cyclotron Resonance (ECR) proton source. This is intended to be the main source for the accelerator, since its operation is

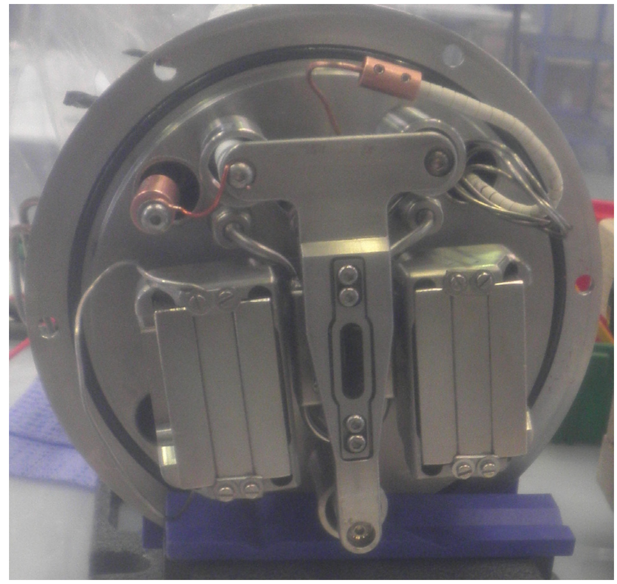

Figure 1: Front view of the modified ISIS source, permanent magnets can be seen on both sides of the extraction electrode.

simpler than that of the Penning sources. However as with any new development there is an inherent risk that expectations will not be meet right away.

H^- SOURCE

As was mentioned in the introduction, the negative source under development at ESS-Bilbao is based on the ISIS penning source [2], which itself is based on the original design by Dudnikov [3]. The basic design of the source is identical to the ISIS version, but permanent magnets were added to generate the Penning field. As a result, the source in this case is mounted horizontally instead of vertically. The source then has to be slightly tilted to compensate for the beam deflection caused by the field of the permanent magnets. Figure 1 shows a frontal view of the penning source, the two groups of rectangles visible on the left and right of the “T” shaped extraction electrode are the FeNdB magnets that generate the Penning field.

Current Status

The installation of the test stand for the Penning source has been completed, and it is still in its commissioning stage. The main elements of the setup consist of a high tension platform that can be floated up to -100 kV with respect to earth. The power supply used to provide the platform tension was custom-built by Jema in Lasarte

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(Spain). A set of Isolation transformers supply power to the platform. The power supplies used to generate the extraction pulse is located on the platform and can generate pulses of up to +25 kV referenced to the platform, and of up to 2 ms length. These two power supplies have been tested and adjusted and work according to specification. The power supplies that are used to generate the current to warm up the source to the point where there is sufficient thermal emission from the cathode and the pulsed power supply that is used for the actual operation of the source are also on the platform. The DC power supply has been fully adjusted and works properly. The pulsed power supply, is still a work in progress, it has been successfully tested with a resistive load, however when connected to the ion source the response is not yet quite right. The gains are not properly adjusted, and when the supply tries to regulate during the current pulse into the ion source the pulse becomes unstable and cannot be sustained. However with other settings but a more restrictive set of alarms, a few pulses could be achieved before an alarm tripped the supply. The control system for the ion source is based on National Instruments hardware, and runs on two PXI systems, on on the platform and one on ground linked via a fiber optic cable. The system reads all the control temperatures, and controls the temperature of the Cesium oven, it also generates the internal timing sequence triggered by an external timing signal. The internal timing sequence controls the following events that occur in the following order: The piezo-valve opening to control input hydrogen in the system, the current pulse into the system and the extraction voltage pulse.

All the control signals as well as the readings from the sensors and diagnostics go into an EPICS system and are stored so they can be analyzed later on. This is the basis for the control system that will be used at the ESS-Bilbao accelerator, and is being tested out at the sources, because they are the first elements of the accelerator to come online.

During one of the short periods where everything worked correctly a beam was extracted from the source and was recorded by the DC current transformer. The beam intensity is rather low, but expected since none of the parameter had been optimized at that point. The graphs showing the current pulse that generates the plasma, the voltage pulse that extracts the beam and the measured beam are shown in Fig. 2.

Future Work

Work is ongoing to get the pulsed plasma generation power supply into working order. Once this step is completed, work will begin on the beam characterization and optimization for the conditions needed for the accelerator. In addition to that even during short runs we have notized that the temperature of the permanent magnets raises above what is generally recommended for FeNdB magnets, their temperature has exceeded 90° C, for that reason new Sm2Co17 magnets have been purchased and will be tested.

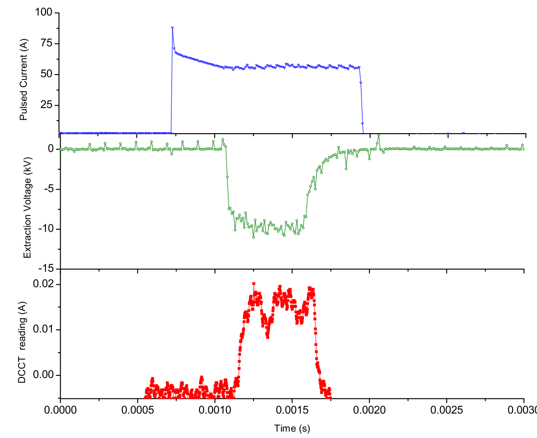

Figure 2: Graph showing the extraction voltage pulse (top), the current pulse into the source (middle) and the extracted beam current measured at the DC current transformer (botom).

Their maximum opperating temperature is above 300°, and should prevent the magnetic field from dropping too far during operation.

H^+ SOURCE

As was mentioned in the introduction, the accelerator at ESS-Bilbao is intended to use an ECR H^+ source. The production of positively charged hydrogen ions is far simpler than that of negatively charged ones, since there is no need to add electron donors [4]. ECR sources are relatively simple, especially when compared to Penning sources, they can be turned on almost instantaneously and have shown a long lifetime.

Current Status

The ion source is composed of a CPI S-Band 2.7 GHz Klystron amplifier that provides the RF power, the RF signal is generated by an RF generator built in house that can work in pulsed or in continuos mode. The RF amplifier is connected to the plasma chamber via a waveguide composed of a circulator with a load to protect the klystron, followed by a directional coupler, a three stub automatic tuning unit, a second directional coupler and a stepped waveguide transition into the chamber. The chamber is water-cooled and has Boron Nitride disks on both ends to increase the electron density [5]. All the RF components have been tested and fully characterized by the RF group. The ECR field is generated by a set of two coil pair that can be moved to change the shape of the magnetic field profile. The field profile and intensity are also controlled by the current supplied to each coil. This has also been tested, and the magnetic field profile corresponds to the one simulated using a 3D finite element code. The Hydrogen flow into the chamber is controlled by a mass-flow controller from

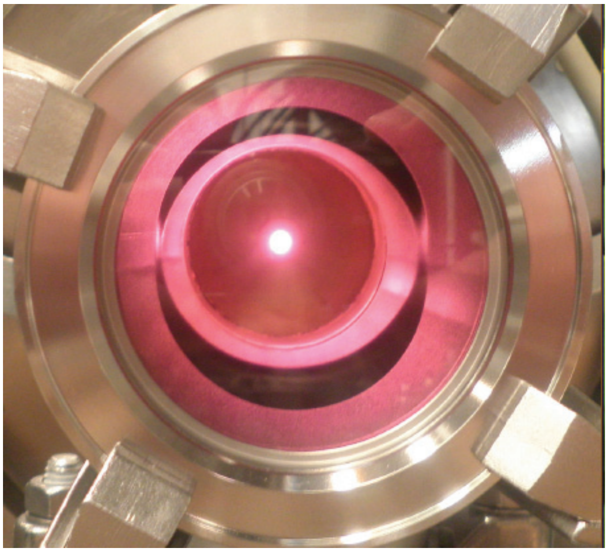

Figure 3: Image of the hydrogen plasma ignited in the chamber viewed through the plasma iris aperture

Omega Engineering. The entire microwave system has been tested in continuos wave mode, and a plasma can be ignited. Figure 3 shows an image of the light emitted by the plasma that is generated. In parallel with the work on the RF line, the high tension platform for the source has been successfully tested up to 70 kV, with the power from the isolation transformer on and the de-ionized water supply to the platform running. Work on the extraction column is also being carried out in parallel. The column was designed so that the distance between the plasma iris and the extraction triode system could be moved while in vacuum. The column has been manufactured and delivered, and final tests on the mechanical elements are underway.

The RF elements are now being re-assembled on the high voltage platform and the control system is being connected. Here the same strategy as with the H^- source will be used, two PXI boxes from National Instruments will be connected by a fiber optic cable, one will sit at ground potential an the other on the platform, they will also control all the local timing sequences of the source. Figure 4 shows a photograph of the high voltage enclosure with the control racks on the ground and on the platform and the RF line.

Current Status

In the near future all the systems will be integrated and it is well within reason to expect that the first beam under continuos wave operation will be achieved by the summer of 2012. The magnetic configuration of the system has to be modified to improve the shape of the field in the plasma chamber, simulations are underway to test possible options. Pulsed operation will also be tested in the near future to achieve the required repetition rate and pulse length for the accelerator. As part of the pulsed operation, the mass-flow controller will be replace by a piezo-valve identical to the used on the penning source.

Figure 4: High voltage enclousure for the H^+ source, showing the control and power racks along with the klystron amplifier and RF line.

SUMMARY AND CONCLUSIONS

Both ion sources at ESS-Bilbao are progressing and are nearing the point where the can become fully operational. Even if the development of the H^+ were to run into unexpected problems, the H^- source should be available to allow for the testing of other accelerator elements as they become available.

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