DESIGN, CONSTRUCTION AND COMMISSIONING OF THE NEW SUPERCONDUCTING ION SOURCE AISHA

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Abstract

At INFN-LNS a new superconducting ECRIS named AISHa has been designed with the aim to provide highly charged ion beams with low ripple, high stability and high reproducibility, also fulfilling the needs of hospital installations (e.g. L-He free, easy to use, etc.). It is a hybrid ion source based on a permanent magnet hexapole providing 1.3 T on plasma chamber walls and four superconducting coils for the axial confinement. The axial magnetic system is very flexible in order to minimize the hot electron component and to optimize the ECR heating by controlling the field gradients and the resonance length. The design of the hexapole aimed to minimize the demagnetization due to SC coils. The magnetic system measurement confirmed the effectiveness of the adopted solutions. Innovative solutions have been also implemented as it concerns the RF system design. It will permit to operate in single/double frequency mode, supported by variable frequency high power klystron generators, thus exploiting at the same time the FTE – Frequency Tuning Effect and the Two Frequency Heating. The source has been assembled at the INFN-LNS site and the commissioning phase already started.

INTRODUCTION

The **A**dvanced **I**ons **S**ource for **Ha**drontherapy (AISHa) was designed in 2012 by taking into account the typical requirements of hospital-based facilities, including the minimization of the mean time between failures (MTBF) and the maintenance operations.

In 2013 the proposal of AISHA construction was approved by the Regional Government of Sicily and it was funded within the framework of the program of Sicilian Government named PO FESR 2007-2013 and a pool of Sicilian SME was associated with INFN for its construction. Today the AISHa source is entirely assembled and its complete commissioning is scheduled by the end of 2016.

Figure 1 shows an overall view of the source together with the components of the beamline.

The compact AISHa source has been designed to be an intermediate step between the 2nd generation ECRIS, unable to provide the requested current and/or brightness and the 3rd generation, too complex and expensive.
It is a multipurpose device with the aim to provide highly charged ion beams with low ripple, high stability and high reproducibility.

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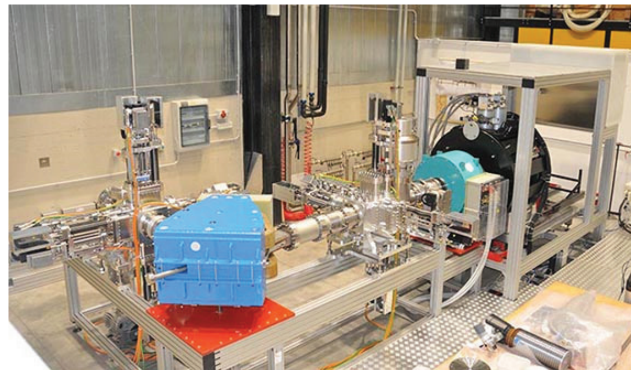

Figure 1: An overall view of the Ions Source and LEBT of the AISHa project.

Furthermore, the introduction of an oven for metallic ion beams will permit the production of new beam for hadrontherapy and for other applications in radiobiology. The main source characteristics are described in Table 1.

Table 1: Major Source Parameters

Radial field (max)	1.3 T
Axial field (INJ/MID/EXTR)	2.6 T / 0.4 T / 1.7 T
Plasma Chamber diameter	92 mm
Operating frequencies	18 GHz
Operating power (max)	1.5 kW
Extraction voltage (max)	40 kV
Cryostat length	620 mm
Cryostat diameter	550 mm
L-He	Free

MECHANICAL DESIGN

The majors mechanical improvements of the AISHa with respect to the usual layout of similar sources concern the use of the carbon fibers and composite materials to realize the hexapole containment chamber and the HV insulation.

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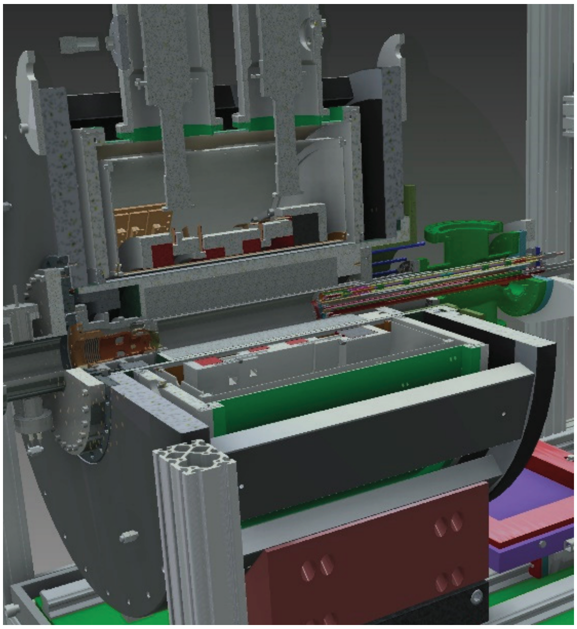

Figure 2: A rendering of core of the AISHa source.

The plasma chamber is made of stainless steel and it was designed to operate at a maximum power rate of 2 kW by using a multi-channel water-cooling system [1].

A laminar water flow into to the plasma chamber allows to not exceed the safe temperature for the permanent magnet hexapole avoiding any possible damage. By optimizing the design of the grooves, the maximum temperature on the outer surface of the plasma chamber is in the order of about 30°C.

The insulation was adapted to 40 kV operation by means of a 20 mm thick Glass Fiber / Carbon Fiber tube surrounding the hexapole, keeping the superconducting magnets and the yoke at ground potential.

Furthermore, the movable extraction system will permit to adapt the AISHa source to other facilities, such as the high voltage platform already present at INFN-LNL.

MAGNETIC SYSTEM DESIGN

The hybrid magnetic system consists of a NdFeB permanent Halbach-type hexapole magnet and four independently energized NbTi superconducting coils.

The maximum radial field on plasma chamber walls is up to 1.3 T, while the axial gradients is about 13 T/m, enough to burn the plasma in strong gradient regime [2].

A deep analysis in the design phase has allowed to overcoming the demagnetization issue of some sectors of hexapole due to the presence of high values of the radial magnetic field components H_x and H_y generated by the SC coils. To avoid the radial confinement magnetic field decreasing, these sectors have been replaced with others having higher coercivity [3].

The tunable magnetic profile, by changing the current in the two middle coils, allows a fine tuning of the mirror ratio and an improvement of the heating efficiency by suppressing the production of quasi-collisionless high energy electrons.

Figure 3 shows the axial magnetic field measurement that confirmed the design specifications [3].

The peak field at the injection side is around 2.6 T and at the extraction it is about 1.7 T, with a minimum value of 0.5 T, about 60% of the ECR resonance field @ 18 GHz.

The superconducting coils are enclosed in a compact cryostat (it is 620 mm long and 550 mm in diameter), the cold mass is cooled down to cryogenic temperatures with two double-stage cryocoolers. Figure 4 shows the typical cool down data: around 40 hrs are needed from room temperature to reach the operating conditions needed to energise the magnet and the time to reach the maximum coil energisation is 24 min.

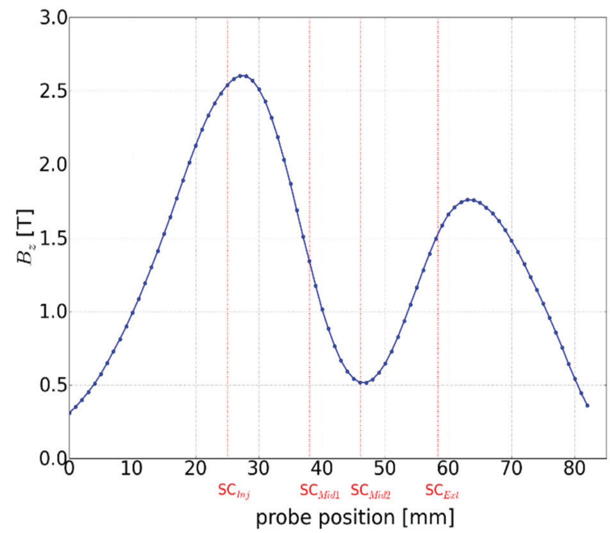

Figure 3: Experimental axial magnetic field measurement.

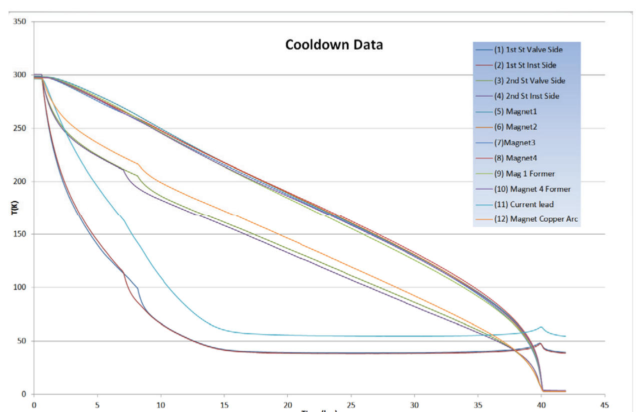

Figure 4: Typical cool down data.

MICROWAVE INJECTION

The source is equipped with two High Power Klystron Amplifiers in order to inject microwave at different frequencies in the chamber, one at 18 GHz and another at higher frequency (~ 21 GHz).

Through a Digital Fast Tuner System (DFTS) it is possible to finely tune the frequency and to exploit the Two Frequency Heating (TFH) and Frequency Tuning Effect to

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generate moderate currents of the highest charge states and optimize the beam brightness.

Figure 5 shows the front side of the injection flange with the different input utilities, the biased-disk and the evaporation oven for metal ion beam production.

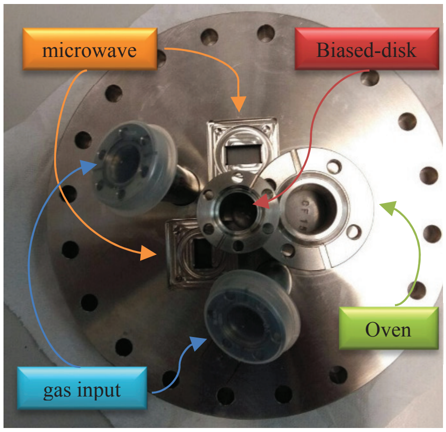

Figure 5: Front side of the injection flange.

Figure 6: Microwave injection system.

Figure 6 shows the plasma injection flange equipped with two waveguides, two different gas inputs, the bias disk and the port for the oven.

In order to insulate the plasma chamber, placed at high voltage, from the microwave amplifier, located at ground, two compact waveguide DC breaks have been designed for the two microwave line to permit reliable operation up to 50 kV.

BEAM LINE

The beamline mainly consists of a focusing solenoid placed downstream the source, a 90° bending dipole for ions selection and two diagnostic boxes. The distance beetwen solenoid and dipole was chosen in oder to minimize the beam losses and increase emittance for the transport of ions with different charge states.

The diagnostic boxes consist of two Faraday Cups, a beam wires scanner and the slits that will allow the characterization of the beam.

Figure 7: Beam line.

CONCLUSION

The assembly and the first tests of vacuum, high voltage and the magnetic system startup with different cycles of cool-down and warm-up has been completed in June. The computer control is going to be finished, this will permit to start the beam commissioning in late September 2016.

ACKNOWLEDGEMENT

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