Project of the Superconducting ECR Ion Source DECRIS-SC2

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Abstract A new compact version of the “liquid He-free” superconducting Electron Cyclotron Resonance Ion Source, to be used as an injector for the U-400M cyclotron, is presently under construction at the FLNR in collaboration with LHE (JINR). The axial magnetic field of the source is created by the superconducting magnet, and the NdFeB hexapole is used for the radial plasma confinement. The microwave frequency of 14GHz will be used for ECR plasma heating. The DECRIS-SC2 superconducting magnet is designed for the induction of a magnetic field on the axis of the source of up to 1.4T (extraction side) and 1.9T (injection side) at nominal current of 75A. Cooling of the coils is carried out by GM cryocooler with cooling power of 1W at the temperature 4.5K. The basic design features of the superconducting magnet and of the ion source are presented. The main parts of the source are in production. The first beam test of the source is expected in the beginning of 2007.

Key words ECR, superconducting

1 Introduction

A “liquid He-free” superconducting ECR ion source DECRIS-SC[1—3] has been designed and manufactured at the FLNR in collaboration with LHE (JINR). Since April 2004 the source is in operation at the CI-100 cyclotron[4]. Using the experience obtained during construction and operation with the source the new source DECRIS-SC2 was developed.

The source is planned to be used at the U-400M cyclotron[5] to replace the conventional ECR ion source DECRIS-2[6], which is in operation since 1995. The main goal of the DECRIS-SC2 source is the production of more intense beams of heavy ions in the mass range heavier than Ar. For ECR plasma heating the existing microwave system (14GHz) will be used. Taking this into account the magnet system of the source should be designed with the minimum magnetic field about of 0.4T, maximum magnetic field about of 1.4T and 1.9T in the injection and the extraction side correspondingly.

2 The source design

The design of the superconducting magnet system of the new source differs essentially from the previous source. To decrease the weight and dimensions of the system it was decided to produce the vacuum vessel from chromium plated soft steel, so it will simultaneously serves also as a magnetic yoke. The magnetic field will be formed by a set of four coils, magnetic yoke and iron plugs.

The computational model of the magnet and calculated axial magnetic field distribution at nominal

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current of 75A are shown in Fig. 1 and Fig. 2.

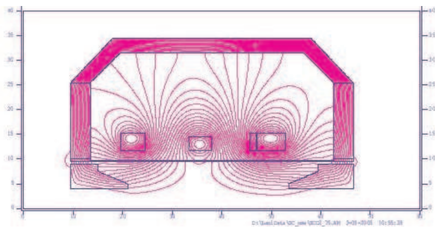

Fig. 1. Computational model of the magnet system.

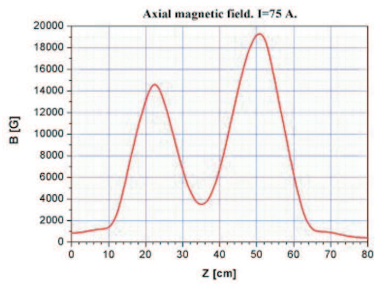

Fig. 2. Calculated axial magnetic field distribution.

The design of the source is shown in Fig. 3, left – superconducting magnet, and right – the "warm" part of the source, which is inserted in the room temperature bore of the magnet.

The magnet contains a set of four solenoid coils. The coils are posed on the framework, fashioned from non-magnetic stainless steel which is free-floating fixed inside a vacuum casing with the help of two supports. The support consists of two stainless steel rings and eight glass textolite rods.

The vacuum vessel is produced from chromium plated soft steel and simultaneously serves also as a magnetic yoke. The magnetic field is formed by magnetic yoke and iron plugs. Combining of the magnetic yoke and vacuum vessel functions allows one to decrease significantly the dimensions and weight of the magnet.

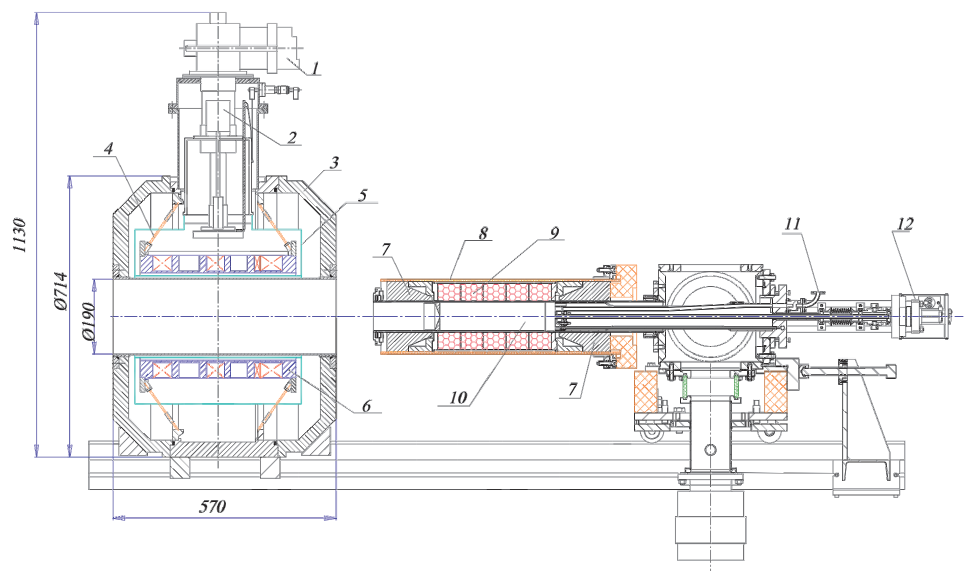

Fig. 3. A cross sectional view of the DECRIS-SC2: 1 – cryocooler head; 2- current leads; 3 – vacuum vessel; 4 – support of the cold mass; 5 –heat screen; 6 – framework with coils; 7 – iron plugs; 8 – plastic insulator; 9 – hexapole; 10 – plasma chamber; 11 – u.h.f. injection; 12 – biased electrode remote drive.

The framework with windings is protected by a reflective aluminium shield and copper screen which is cooled by the first stage of the cryocooler. The copper screen is covered with a multilayer screen-vacuum isolation.

A Nb Ti/Cu monolithic superconducting wire (bare diameter - 0.65mm, insulated diameter - 0.7mm) is used in the windings. The working current (75A) is significantly lower critical current (⩾270A at 5T and 4.5K). The reserve of the temperature stability has the value about of 2°K and allows this magnet to operate with increased heat loads.

Compounding of the windings is realized with prepreg, located between layers of wire and thermally treated upon completing the winding and banding of all the solenoids. The aluminium tapes are glued to the external surface of the windings under a binding. These tapes are insulated electrically from the windings and the binding.

The framework and the windings are connected with the second stage of the cryocooler by a high-purity aluminum tape. The copper plates are screwed to the framework. "Cold" diodes are located on the plates. The copper screen is fastened to supports. Six HTSC current leads are posed around the cryocooler head. The pumping of the vacuum casing is performed by forevacuum and turbomolecular pumps.

A block diagram of the power supply and safety system is shown in Fig. 4. External coils are connected in series and the central one is working with a reverse current to ensure a required minimum level line of magnetic field.

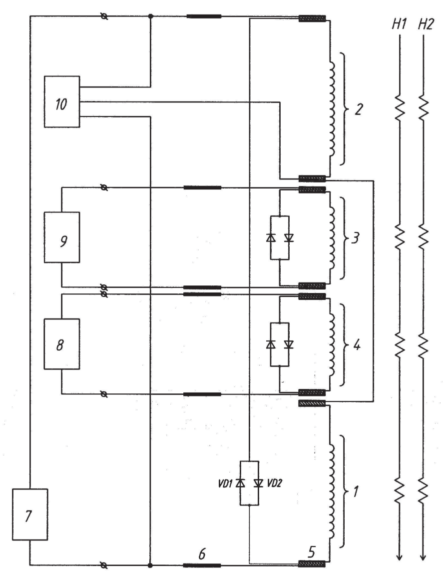

Fig. 4. An electrical circuit of the power supply and protection of solenoids: 1, 2, 3, 4 – windings; 5 – electrical and thermal contacts of the windings ends, current leads conductors and diodes; 6 - HTSC current leads; 7,8,9 - current sources of the windings; 10 – quench detector; H1, H2 – heaters; VD – "cold" diodes.

The safety system consists of the passive and active parts. Comparing the DECRIS-SC source the following changes are introduced in the safety system:

• The windings are not divided into sections.

• The "cold" diodes serve only for the protection of HTSC tapes in current leads. Two diodes, connected in series, opens at ∼1.8V.

• The conductors, connecting windings and the HTSC inserts, are coupled by heat link unit, which allows to transfer the normal zone from one conductor to others, and distribute uniformly the stored energy to all windings.

It should be noted, that the windings are substantially self-protected due to the moderate cross-section dimensions and sufficient thermal conductivity. Besides, the stored energy is not so high (∼40kJ). The estimations have shown that coils temperature after a full quench transition is 40—50K and the maximum temperature of the "hottest" point does not exceed ∼120K.

• An active system contains only one block of quench detector and eight resistive heaters installed in the windings. The heaters allow the simultaneous quench of all windings thus preventing the excessive attracting forces between the windings and magnetic yoke.

• In the cold zone of the magnet 16 thermometers are located. TVO carbon resistors are used as thermometers.

In the design of the "warm" part of the source most of constructional features of the DECRIS-SC and DECRIS-4[7] sources, such as cylindrical plasma chamber, UHF feed by standard waveguide, movable bias-electrode etc., are used (see Fig. 3).

The hexapole for radial confinement of plasma has a Halbach structure. It consists of 24 permanent-magnet identical sectors with the corresponding easy axis direction. The inner diameter, the outer diameter and the length of the hexapole are 80mm, 170mm and 290mm, respectively. The desired radial magnetic field strength on the plasma chamber wall is 1T.

The plasma chamber consists of an aluminium tube and stainless steel flanges. No welding is used in the chamber design. For the hexapole protection six copper cooling pipes are pressed into external surface of the chamber.

3 Conclusion

In the following Table 1 the main parameters of the DECRIS-SC2 are presented.

Table 1. Design parameters of DECRIS-SC2.

UHF frequency/GHz	14
mirror field on the axis:	
extraction side	1.4T
injection side	1.9T
mirror to mirror space	290mm
nominal coil current	75A
radial field at the wall	1.0T
plasma chamber internal diameter	74mm
Max. extraction voltage	30kV

The main parts of superconducting magnet (vacuum vessel, windings, copper screen, supports of "cold" mass, current leads, etc.) are produced and tested. By the end of the 2006 the full tests of the magnet system will be completed. The first beam test of the source is expected in the beginning of 2007.

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