

## आगामी सुविधा

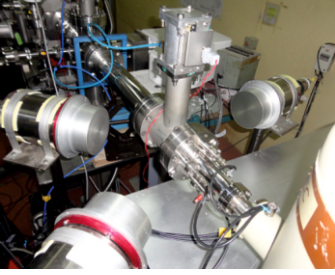
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### भापअ केंद्र में ईसीआरआईएस सुविधा और इसके उपयोग के लिए अनुसंधान कार्यक्रम

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D+D संलयन के लिए स्थापित प्रयोग की तस्वीर।

#### सारांश

वीडीजी भवन, भापअ केंद्र, मुंबई में एक उच्च धारा अतिचालित इलेक्ट्रॉन साइक्लोट्रॉन अनुनाद आयन स्रोत (ईसीआरआईएस) संस्थापित किया गया है। इस आयन स्रोत का उपयोग करके निम्न ऊर्जा वाले नाभिकीय भौतिकी प्रयोग और बहु-विषयक अनुसंधान कार्यक्रम किए गए हैं। भापअ केंद्र-वैज्ञाग में 'ईसीआर आधारित भारी आयन त्वरक' की दिशा में पूर्व-परियोजना अनुसंधान और विकास के लिए इस ईसीआरआईएस को हॉल-9, भापअ केंद्र में स्थानांतरित करने और इसके उपयोग को बढ़ाने की योजना है। पूर्व-परियोजना अनुसंधान और विकास के लिए, यह ईसीआरआईएस भारी आयन रेडियो आवृत्ति चतुर्भुव के बाद अतिचालक रेडियो आवृत्ति नायोबियम गुहिकाओं के लिए एक अंतःक्षेपक होगा। मूलभूत एवं अनुप्रयुक्त अनुसंधान कार्यक्रमों के लिए एकल ईसीआरआईएस का उपयोग करने की भी योजना है। ईसीआरआईएस प्रणाली की संस्थापना के संबंध में, हाल ही में एक आरसीसी हॉल का निर्माण किया गया है और वर्तमान में हॉल-9 में संबद्ध सेवाओं के लिए स्थल की तैयारी का काम चल रहा है। इस लेख में, हॉल-9 में एकल ईसीआरआईएस का उपयोग करके त्वरक आधारित निम्न ऊर्जा नाभिकीय भौतिकी और बहु-विषयक अनुसंधान कार्यक्रमों के लिए अनुसंधान योजनाओं को रेखांकित किया गया है।

## Nuclear Physics

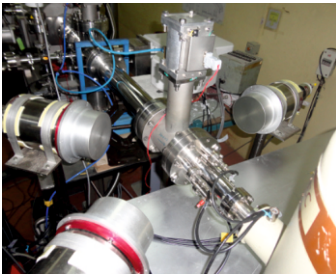
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### The ECRIS Facility at BARC and Research Programs for its Utilization

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Photograph of experiment setup for D+D fusion

#### ABSTRACT

A high current superconducting Electron Cyclotron Resonance Ion Source (ECRIS) has been installed at the VDG building, BARC, Mumbai. Low energy nuclear physics experiments and multidisciplinary research programs have been carried out using this ion source. It is planned to relocate this ECRIS to Hall-9, BARC for pre-project R&D towards the 'ECR based Heavy Ion Accelerator at BARC-Vizag' and also to enhance its utilization. For the pre-project R&D, this ECRIS will be an injector for heavy ion Radio Frequency Quadrupole followed by superconducting Radio Frequency niobium cavities. It is also planned to utilize the stand-alone ECRIS for basic- and applied-research programs. With respect to setting up of the ECRIS system, a RCC hall has recently been constructed and site preparation works for associated services are currently underway at Hall-9. In this article, the research plans for accelerator based low energy nuclear physics and multidisciplinary research programs to be carried out using the stand-alone ECRIS at Hall-9 are outlined.

KEYWORDS: Electron Cyclotron Resonance Ion Source (ECRIS), Low-energy Nuclear Physics.

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## Introduction

A high current superconducting Electron Cyclotron Resonance Ion Source (ECRIS) [1] capable of providing a wide range of ion species has been installed at the VDG building, BARC, Mumbai. This 18.0 GHz superconducting ECRIS has a maximum RF power rating  $\sim 1.7$  kW and is capable of delivering a wide range of ion beams with typical species including p,  ${}^4\text{He}^{2+}$ ,  ${}^{16}\text{O}^{7+}$ ,  ${}^{181}\text{Ta}^{32+}$ ,  ${}^{209}\text{Bi}^{33+}$  etc. produced with  $\mu\text{A}$  - to -  $\text{mA}$  currents. It operates at maximum 30 kV extraction voltage on the maximum 300 kV platform, providing a maximum kinetic energy of 330 keV per charge state of the ion [1]. The schematics of the ECR ion source system is depicted in Fig.1. Accelerator based low energy nuclear physics [2], x-rays emission from ion-atom collisions, and multidisciplinary research programs have been initiated with this ECRIS.

It is planned to relocate the ECRIS to Hall-9, BARC for pre-project R&D towards green field 'ECR based Heavy Ion Accelerator at BARC-Vizag' and also to enhance its utilization as a stand-alone ion source. For the pre-project R&D activities, installation of the superconducting ECRIS system and a room temperature heavy ion RFQ (Radio Frequency Quadrupole) followed by SRF (superconducting Radio Frequency) niobium cavities are being carried out at Hall-9, BARC. This ECRIS will be an injector element for the heavy ion RFQ. With respect to the setting up of ECRIS system, a RCC hall has already been constructed (Fig.2) and site preparation works for associated services are currently underway at Hall-9, BARC.

In this article, some of the low energy nuclear physics and multidisciplinary research programs to be carried out using the stand-alone ECRIS are outlined.

## Research Programs using the ECRIS

### Low-energy nuclear physics: Lattice assisted fusion studies

Nuclear fusion reactions, viz. D+D and D+T are of interest for both basic and applied nuclear physics. These reactions are important for the development of neutron sources, fusion-fission hybrid systems and advancement of nuclear technologies for controlled fusion [3].

In a recent work using the stand-alone ECRIS at the VDG building, we have carried out experiments to investigate the neutron production in D+D fusion during deuterium implantation in palladium at low temperatures [2].

In this experiment, 100 keV accelerated  $\text{D}^+$  ions from the ECRIS impinged on a cooled ( $-76^\circ\text{C}$ ) palladium target (Fig.3) and the neutron emission rate was measured as a function of the number of implanted  $\text{D}^+$  ions. It is observed that the excess of neutrons in a certain region is significantly large (Fig.4) which might be ascribed to the strong matrix effect of the host material at large D/Pd ratios [2]. The phenomenon of neutron production in D+D fusion at low-energies using various host materials in different experimental conditions need to be investigated and further experiments are planned to examine the role of the host matrix in neutron production.

### Characteristic and continuous x-rays studies

The experimental studies of the characteristic X-ray

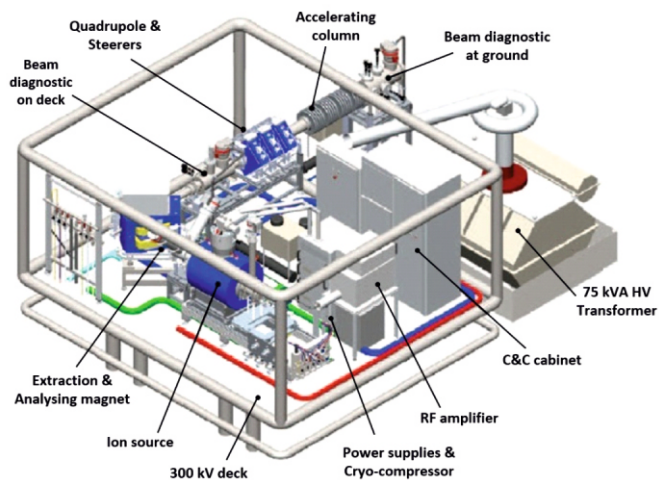


Fig.1: Schematic of the Electron Cyclotron Resonance Ion Source (ECRIS) system.



Fig.2: Newly built hall exclusively for the ECRIS at Hall-9, BARC.

production yield is of interest for understanding basic ion-atom collision processes involving tightly bound electrons [4], and for different applications including elemental composition analysis. Therefore, to test the validity of theoretical models in the low-velocity region, the K/L/M X-rays production cross sections and X-rays relative intensities for different projectile-target combinations will be measured using ion beams from the ECRIS.

In another research program, the X-rays bremsstrahlung spectrum emitted by the electrons inside the ECR plasma source [5] will be measured for the temperature of the high energy electrons inside the plasma. A systematic study of the X-ray bremsstrahlung spectrum, thus, can bring out the dependence of electron temperature on different operating parameters (e.g. RF power, gas pressure, different gas mixing) that would help in the efficient operation of the ECR ion source at optimum conditions.

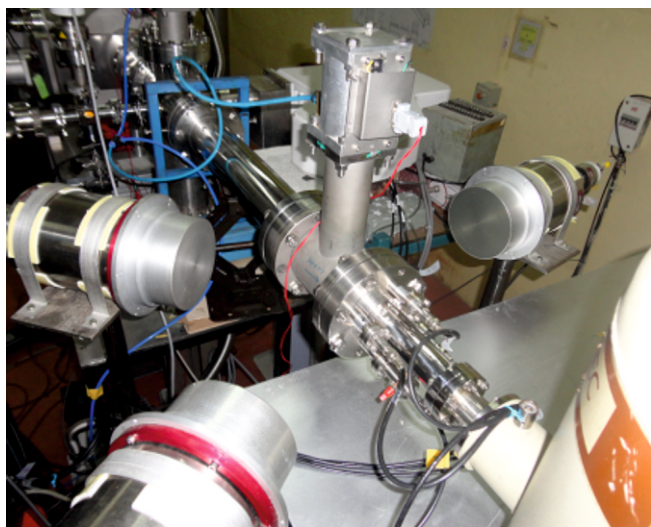


Fig.3: Photograph of the experimental setup used.

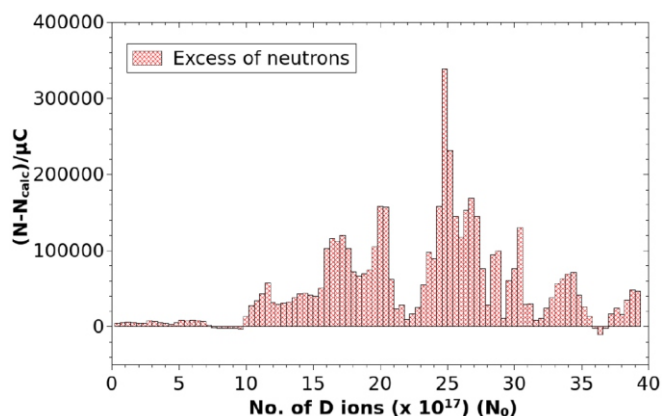


Fig.4: The excess of neutrons with respect to the simulated value as a function of the number of implanted ions ( $N_0$ ).

### Multidisciplinary research programs

In addition to aforementioned research programs, different experiments has been performed using the ECRIS at VDG building, for example, (1) assessment of long term radiation stability of nuclear waste glasses, borosilicate and iron phosphate glasses, due to irradiated by 2 MeV Xe ions and (2) testing of a high-resolution x-ray crystal spectrometer. Apart from NPD's research programs mentioned in previous sub-sections, various researchers from DAE have proposed

research plans for utilization of the ECRIS after its relocation to Hall-9, namely (a) understanding of radiation induced changes in matrices proposed for immobilization of nuclear waste (b) alpha decay induced recoil of trapped radionuclides in crystalline matrices (c) radiation damage study in reactor pressure vessel steel and Zr-Nb pressure tube material and (d) measurement of cross sections and astrophysical S-factors for reactions at astrophysically relevant energies.

### Summary

A high current superconducting Electron Cyclotron Resonance Ion Source has been successfully installed at the VDG building BARC. A number of experiments related to low energy nuclear physics and multidisciplinary research have been performed using this ECRIS. It is planned to relocate the ECRIS to Hall-9, BARC for pre-project R&D towards green field 'ECR based Heavy Ion Accelerator at BARC-Vizag' and also to enhance its utilization as a stand-alone ion source. For setting up of the ECRIS system, a RCC hall has been constructed and site preparation works for associated services are underway at Hall-9. The research plans for low energy nuclear physics and multidisciplinary research programs to be carried out using the stand-alone ECRIS at Hall-9 have been described.

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