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System upgradation for surface mode negative ion beam extraction experiments in ROBIN

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ABSTRACT

Operational commissioning of ROBIN forms an important milestone in the Indian programme on the R&D on negative ion beams. The commissioning activity has been effected in sequence, in synchronisation with the availability of High voltage Power Supply (HVPS) systems and routine operation has now been established in the cesiated, surface mode. Significant efforts have been placed in upgrading the system to initiate the surface mode operation. These include incorporation of a temperature controlled Cesium (Cs) delivery system, spectroscopic diagnostics for detection of Cs lines, installation of plasma grid heating and closed loop warm water circuit for source components heating and Doppler Shift Spectroscopy (DSS) system. The specific design and integration features for these upgrades are discussed and preliminary results obtained from the operation of ROBIN in the surface mode are presented.

1. Introduction

The Indian programme on the development of negative ion beam sources is a 3 step process. The first step is that of setting up the single driver source ROBIN [1,2] followed by a two driver, Twin source and the final step is that of establishing the operation of an 8 driver source, which, in principle characterises the DNB source for ITER [3,4].

In the first step of ROBIN, the first phase has established the inductively coupled RF (Radio Frequency) plasma production, negative hydrogen ion beam extraction and optimisation, in the volume mode in which negative ions are produced through dissociative electron attachment process of vibrationally excited molecules [5]. The operation in volume mode was first carried out with a limited number of apertures, to ensure compatibility with the available power supply at that time, which had limited current rating (10 kV, 400 mA). Subsequently, based on the availability of the high voltage (HV) power supplies, negative ion beam extraction experiments were carried out in volume mode with 73.38 cm^2 extraction area having 146 apertures of 8 mm diameter each and using three grid (plasma grid, extraction grid, ground grid) extraction system. The HV power supply system consist of EPSS (Extraction Power Supply System) (11 kV, 35 A, DC), and APSS (Accelerator Power Supply System) (35 kV, 15 A, DC) power supplies. Beam current, which is the current flowing through the grounded positive terminal of the APSS, of a few hundred milliamperes (mA) has been achieved at 22 kV (10 kV EPSS + 12 kV APSS) with 73.38 cm^2 extraction area in volume mode. The operation in the volume mode has established the procedure of conditioning of the ion source, operation of the installed diagnostics, proper functioning of the electrical [6] and data acquisition and control system [7]. These ensure readiness to operate ROBIN, in the surface mode in which negative ions are produced on a low work function surface through surface conversion process of neutrals or positive ions [5].

Fig. 1 shows the schematic of the RF negative ion source ROBIN. Cs is introduced to achieve low work function on the surface. Operation in the surface mode necessitated a system upgradation due to the need for the integration of a Cs delivery system and a closed circuit and temperature controlled hydraulic flow system, to maintain the temperature of the source body at 40 °C. Additionally, provisions were activated for the heating of the plasma grid up to 150 °C. An additional diagnostics, in the form of a differential calorime-

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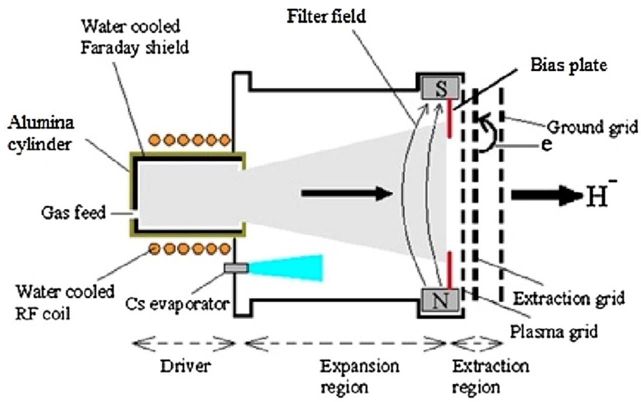

Fig. 1. Schematic of the negative ion source; ROBIN.

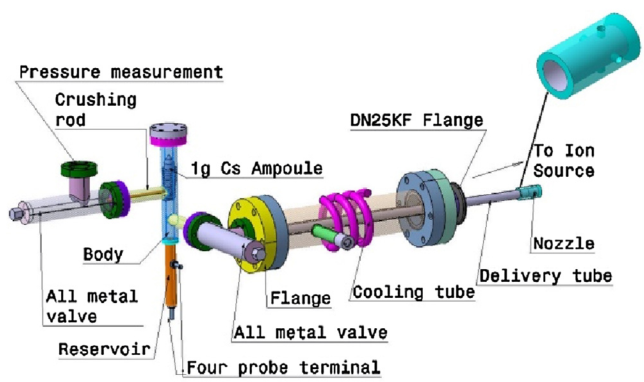

Fig. 2. Schematic of Cesium delivery system.

ter, was also incorporated. The measurements of the differential calorimeter were thermocouple based and this measurement system has been integrated with the data acquisition system.

In the following sections, the design and integration of the upgrades are described for the Cs delivery and plasma grid and source components heating system and beam diagnostic e.g. Doppler shift spectroscopy, thermal differential calorimeter and currents measurements. The initial result obtained from the operation of ROBIN in the surface mode is also presented, along with the representative data obtained from the spectroscopy based diagnostics.

In order to investigate the Cs inventory in the ion source, the atomic spectrum line of the Cs (852.2 nm) is monitored using a spectrometer.

2. Cesium delivery system for ROBIN

Fig. 2 shows the different parts of the Cesium (Cs) delivery system. Principal parts are nozzle, delivery tube, body and the reservoir.

Four nozzles of diameter 2 mm each are equally spaced and placed at 90° angle with respect to the delivery tube axis. The nozzle arrangement is made on a blind tube to avoid the direct spray of the Cs [8] on the plasma grid to avoid high voltage breakdown between the grids. The nozzle fits on the end of the delivery tube which is 8 mm in outer diameter (OD) and is ~300 mm of length. A jacket, coaxial with delivery tube has been placed to take out the heater and thermocouple connections of the delivery tube. The oven, along with the jacketed delivery tube is connected to the ion source with an elastomer seal for vacuum integrity. The seal is sitting on a flange on the jacket (DN25KF), which is cooled by water circulation through the cooling tube. The cooling tube is used to cool down the outer jacket to protect elastomer seal. The whole oven is evacuated through, the delivery tube and the nozzle by the ROBIN pumping system.

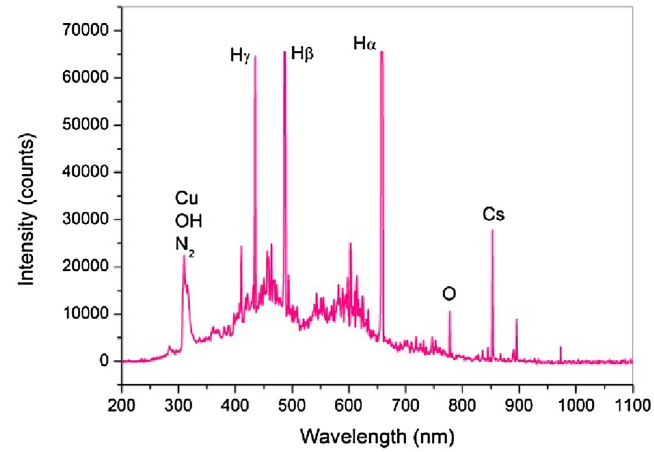

Fig. 3. The typical spectrum of the initial phase of source operation with H2 gas and Cs injection, hydrogen atomic and molecular lines, Cs atomic lines along with some impurity lines are visible.

The Cs is stored in vacuum sealed glass ampoule. During operation, 1 g Cs glass ampoule is crushed by a metal crushing rod in vacuum sealed and heated condition of the oven and then liquid Cs is dropped down in the reservoir due to gravity. The vacuum sealed bellow based actuator (metal valve) acts as crushing rod to crush the Cs ampoule when it moves forward. After crushing the Cs ampoule the metal valve is closed. To restrict broken glass pieces from falling into the reservoir volume a spiral filter is placed inside the oven, otherwise, broken glass pieces may block the Cs vapour flow into the delivery tube. Cs inventory in the reservoir volume is measured using the resistance method (four probe method). An all metal valve (DN 16CF, high conductance) is used in the oven to stop the Cs flux into the source immediately whenever required.

For controlled heating of all parts of the oven, a flexible heater and K type thermocouple are installed on each part of the oven. The temperature of the individual part of the oven is controlled through a Proportional Integral Derivative (PID) temperature controller within ±1 °C. Operating temperature of the Cs oven is kept in the range of 150–250 °C. Several prototype experiments have been carried out at IPR to characterize Cs vaporization, transport and injection through different delivery tubes and nozzles [9,10].

Since the Cs oven is physically connected to ROBIN, its heating power supplies, and thermocouples are also at the source potential (high potential). All equipment of the Cs oven is kept in a shielded cage to avoid RF pickups.

Cs reacts with air and makes compounds [11]. To avoid contamination of the Cs, the source is vented by ultra-high purity (99.999%) argon. A pressure switch is installed on the source to alarm when the pressure threshold (set valve) is reached. Additionally, continuous pumping of the source is planned as an alternative to argon venting in ROBIN to maintain the source vacuum and to avoid Cs contamination.

For safe and successful operation, monitoring of impurity lines along with Cs injection is necessary. Fig. 3 shows the typical spectrum of the initial phase of surface mode experiments in ROBIN. The integration time of the spectrometer has been increased to monitor the Cs line and other impurities and therefore Hα and Hβ lines are getting saturated in the spectrometer.