GAS FEED SYSTEM IN NEGATIVE ION SOURCE EXPERIMENTAL FACILITY AT IPR

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Abstract

An inductively coupled RF based (100 kW, 1 MHz) negative hydrogen ion source test bed, ROBIN, is being set up at IPR under IPR-IPP (Germany) technical collaboration contract. The ion source can deliver a negative ion beam of ~10 A with a current density of ~30 mA/cm^2 and accelerated to 35 kV through a 3-grids electrostatic ion accelerator system.

A gas feed system based on remotely controlled calibrated needle valves is designed, developed and used to provide a required gas puff, interlocked with the RF switch ON time, to ensure plasma ignition and then to maintain the desired operational gas pressure over the pulse duration. The gas feed system is capable to setup the source pressure in the range of 0.1 – 1.5 Pa in a step of 0.1 Pa. Fibre optic isolation based control system is used to operate the gas feed system, especially, during ion beam extraction experiments.

A mass flow controller based gas feed system is also being developed to have more flexibility in the operation pressure and ease of operation.

INTRODUCTION

At present, negative hydrogen ion sources are the only choice for having high energy neutral beams suitable to fusion reactors due to the higher neutralization efficiency of negative ions compared to that of positive ions [1]. At IPR, a negative ion program has been initiated which will enhance the international negative ion source operational database and will support the ITER-DNB [2] activities as the DNB is one of the procurement packages, India is supposed to deliver in ITER.

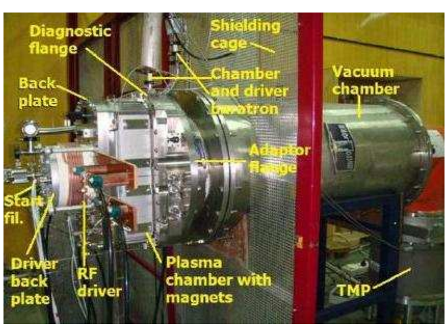

Figure 1: Experimental setup of ROBIN ion source.

A single driver RF based (100 kW, 1 MHz) negative ion source test bed, ROBIN, is being set up at IPR under a technical collaboration with IPP, Germany [3]. ROBIN test bed is similar to BATMAN [4] test bed at IPP and can deliver 10 A negative ion beam with a current density of 30 mA/cm^2 at 35 kV. The operation of ROBIN has been planned in two phases. In the first phase the plasma production and in second phase the beam extraction has been planned. The first phase experiments have already been started. The ROBIN test bed is shown in fig. 1. ROBIN is supported by a dedicated hydrogen gas feed system which is described in the following sections.

GAS FEED SYSTEM

Design

The typical pulse length and operating pressure of the ROBIN ion source are 5 s and 0.3 Pa with pure hydrogen gas or sometimes with a mixture of hydrogen and noble gases like argon. The baseline of the designed gas feed system is BATMAN's gas feed system and is capable of providing the source pressure in the range of 0.1 – 2.0 Pa. Figure 2 shows the schematic of the used gas feed system. The gas feed system consists of two lines with pre-calibrated needle valves and pneumatic valves backed by solenoid valves which are operated remotely. Out of two lines, one line is used for the gas puff and the other line for maintaining the operational pressure e.g. 0.3 Pa, 0.4 Pa etc., in the source during the pulse. The gas puff is essential to ignite the plasma and to avoid discharges across the coil when the RF power is applied. During the gas puff, the pressure in the source is maintained at about 1.5 Pa for about 300 ms. A vacuum pump evacuates the gas lines before source operation.

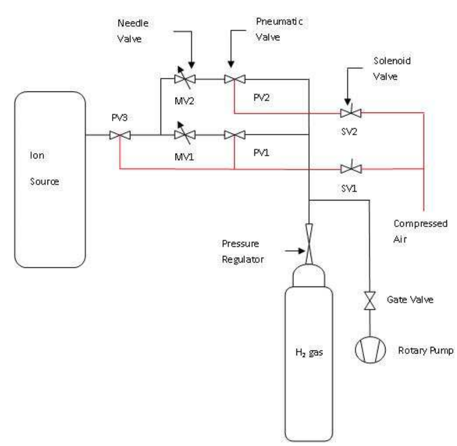

Figure 2: Schematic of two line gas feed system.

The operation of gas feed system is controlled by a Siemens make PLC. The commutation of signals between the gas feed system and PLC is done through optical fibres.

Experimental Results

A typical plot showing the behaviour of the gas feed system is shown in fig. 3. The source pressure is measured at the driver and diagnostic flange locations using capacitance manometers. The first peak in the figure relates to the trapped gas in the gas line between the cylinder and the valve in between two gas pulses. The second peak relates to the gas puff followed by the constant gas flow in the source during the pulse. It is noticed that the gas pressure does not remain steady and tends to drop during the pulse length. This is probably due to the lack of precise balance between gas throughput into the source and evacuation of the source by vacuum pumps.

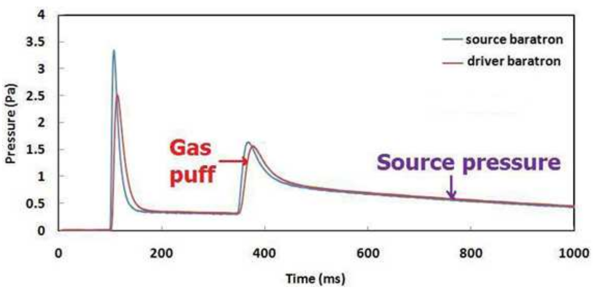

Figure 3: Typical shot of a gas pulse.

MFC BASED GAS FEED SYSTEM

It is difficult to change the gas throughput to maintain a constant pressure in the source during plasma operation and therefore, an automatic system which can adjust the throughput as required is necessary. To fulfil this requirement, a mass flow controller, MFC, based gas feed system is being developed where MFC can automatically adjust the valve opening to maintain the set gas throughput and therefore a stable operating source pressure can be achieved. A MFC of 200 sccm is sufficient to provide the desired source pressure. One GUI schematic of MFC based gas feed system with remote operation by PLC is shown in fig. 4. The pneumatic valve between the source and MFC is installed to avoid any leakages into the source through MFC.

Figure 5 shows the experimental result of the MFC based gas feed system. As shown in the figure, the source pressure is quite stable after the gas puff. This result suggests that MFC based gas feed system can provide a stable source pressure during plasma operation. More experiments are being carried out to fully characterize the MFC based gas feed system.

SUMMARY

The MFC based gas feed system shall be used till the completion of the first phase for experiments. For the second phase related to the beam extraction experiments, the gas feed system will float at the source potential of 35 kV and therefore, the gas feed system will be isolated from ground potential components. The power into the gas feed system components such as flow meter, pressure gauges etc. will be fed from a high voltage deck through an isolation transformer. Hydrogen gas detector along with an exhaust fan will be installed to detect hydrogen gas leakages.

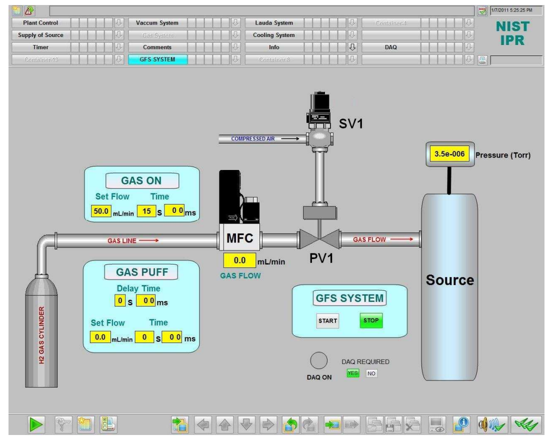

Figure 4: GUI for remote operation of gas feed system.

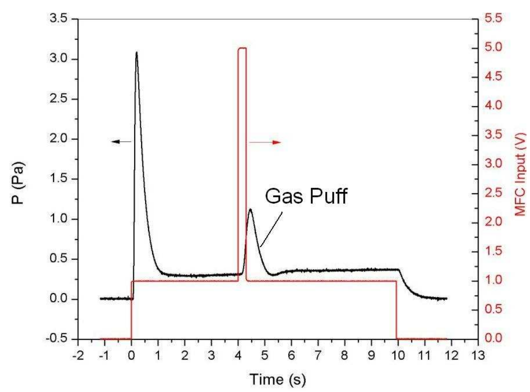

Figure 5: Typical shot of a gas pulse with MFC based gas feed system.

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