ECR ION SOURCE BASED LOW ENERGY ION BEAM FACILITY

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Abstract

A unique low energy ion beam facility is set up at Nuclear Science Centre (NSC) for providing low and medium energy ions for atomic physics and materials science research. The important feature of this facility is the availability of large curents of multiply charged ions from an electron cyclotron resonance (ECR) ion source placed entirely on a high voltage platform. All the electronic control devices of the ECR source including high power UHF transmitter placed on the high voltage platform are controlled through optical fiber communication in multiplexed mode. Some details of the source performance and experimental facilities are also described.

1 INTRODUCTION

Over the past two decades or so, electron cyclotron resonance (ECR) ion sources [1,2] have created a tremendous impact and given a major boost to technology and science in the production of high intensity multiply charged ions. A project was undertaken to develop a research facility consisting of an ECR source along with all its peripheral electronics and vacuum components placed on a high voltage platform for obtaining multiply charge ions in a widely varying energy range from a few kilo electron volts (keV) to a few million electron volts (MeV). In order to meet these demands and to conform to some stringent conditions on available space and high voltage operation, a NANOGAN type of ECR source which is based on a fully permanent magnet design was chosen [3]. The development and operation of this facility is a first step towards the design and development of a high current injector for the LINAC accelerator consisting of a high performance ECR source on a 300kV platform, radio frequency quadrupoles and low velocity superconducting resonators.

2 DESCRIPTION OF THE FACILITY

2.1 General Layout

The 10 GHz ECR source placed on a 200 kV high voltage platform along with its extraction system and part of the acceleration tube is shown in Fig. 1. A schematic of the low energy ion beam facility is shown in Fig. 2. All the vacuum and electronic control devices of the ECR source including the UHF transmitter are placed on the high voltage platform. These are controlled through optical fiber communication in multiplexed mode. An indigenously made isolation transformer consisting of 300 kV isolation and a power rating of 10 kVA is used for powering all the electronic components, pumps and UHF transmitter. The high voltage platform, experimental chambers and beam-line components like electrostatic quadrupole triplet, all metal double slit, beam steerers, faraday cup, and all-pneumatic straight-through valve have been developed for this purpose.

Figure 1: ECR source, extraction system, vacuum pumps, gas bottles, UHF transmitter on high voltage platform.

2.2 NANOGAN ECR source

The compact ECR source consists of a fully permanent magnet (NdFeB) structure bought from PANTECHNIK S.A., France. The source is coupled to a pumping tank which houses an einzel lens. A turbo molecular 250 l/s pump is mounted on this tank on high voltage platform. The einzel lens and the following accelerating tube focusses the beam at the object waist position of the analysing magnet.

2.3 Analysing system and control software

The analysing system consists of a 90^{o} bending magnet having a bending radius of 0.6 m and maximum field of 1.4 T. It consists of an additional 15^{o} port which is planned to be used in future for cluster physics and atomic physics related experiments. The analysed beam currents are measured using a calibrated current integrator. The control software has been written to incorporate flexibilitities and ease of operation in our system. Using this software, all source related parameters can be controlled remotely and operational parameters can be stored and analysed online. Since the ECR source is raised to a variable high voltage, all control and communication are done via fiber optic cables. All the interfaced components are connected using RS-232 serial ports of the computer. The control on the high voltage deck is divided into two major blocks: a) analogue and digital control and sensing of the source and b) RF subassembly.

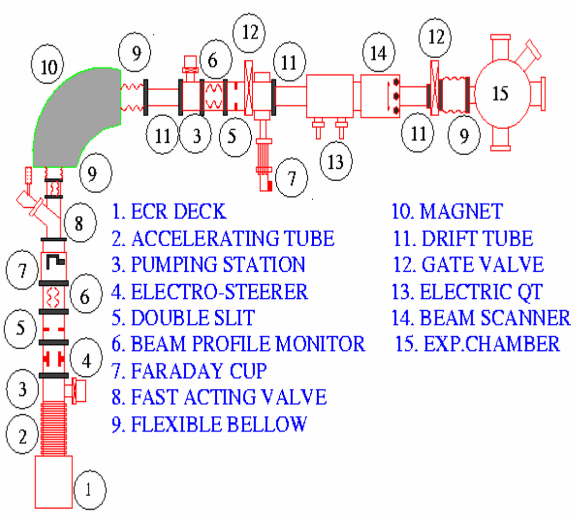

Figure 2: Schematic of the low energy ion beam facility

The source voltages, pressures etc., are controlled and monitored by 'field point' modules from National Instruments (NI) directly via the serial port. This subassembly includes both software and hardware interlocks to guard against various accidents like overheating, overpressure and electrical shock to the operators during maintainance of the system and components on the high voltage platform. The RF subassembly consists of a 10 GHz oscillator that is connected to the input of an RF amplifier. The RF subassembly is controlled by GPIB commands through a GPIB-RS232 converter connected via fibre optic cables to the control computer. Other sections of the facility are also controlled directly through serial ports of the same computer. These include the analysing magnet, Hall probe, steerers, faraday cups, scanners and electrostatic quadrupoles. All these individual hardware are controlled by software written using LABVIEW which provides an integrated control system. A typical screen shot is shown in Fig 3.

2.4 Experimental facilities

The experimental facilities consist of two chambers, one for materials science experiments and another for atomic physics experiments. The materials science chamber has facilities in the target ladder for mounting of multiple samples to be implanted without breaking the vacuum. The samples can be maintained at temperatures ranging from 80°K to 700°K. An electrostatic beam scanner allows samples to be uniformly implanted over an area of 50x50 mm^2. It is possible to identify the desorbed and sputtered particles from the samples using a residual gas analyser placed on one of the ports of the chamber. View ports have also been provided to enable fluorescence spectroscopy or reflectivity studies online during implantation. Some preliminary experiments on the preparation of silicon-on-insulator (SOI) and modification the behaviour of spin tunnel junctions have been carried out.

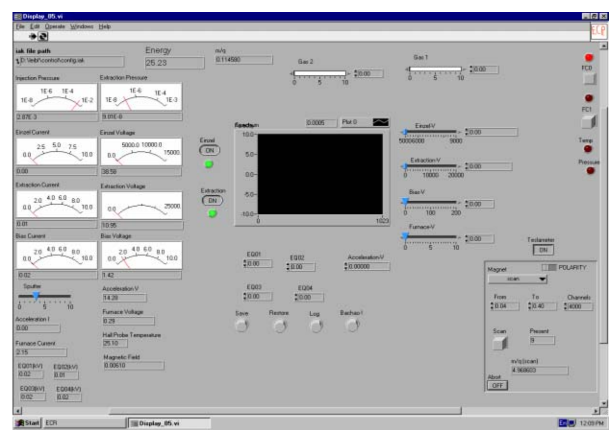

Figure 3: Screen shot of the control software

This facility is very useful for various exciting experimental research programs in materials science on beam induced epitaxial recrystallization (IBIEC), Hetero- and nano- structure formation in semiconductors, modification of surface and near surface properties of materials, rare earth doping of semiconductors, interactions of highly charged ions (HCI) with solid surfaces.

The atomic and molecular physics chamber is equipped with two time of flight spectrometers. The ions extracted from the source interact with a gas jet perpendicular to the beam direction. The two time of flight spectrometers are used to detect simultaneously the electrons and ions formed during the interaction. The electrons are detected by a channeltron detector and provide the timing reference signal. The ions are detected by a position sensitive micro-channel plate detector assembly using delay lines to obtain X and Y position sensitivity along with arrival times. These will be used to study electron capture and emission in highly charged ion-atom interactions and dissociation dynamics in molecular systems.

Interdisciplinary studies of formation of (hollow atoms and ions) when highly charged ions (HCI) capture electron from solid surfaces are planned. The special nature of the hollow ions formed would require expertise in solid state (for the source of the electrons, coulomb explosion on the surface etc) and atomic physics (for the properties, such as the lifetimes and electronic transitions in the hollow ions). The study of hollow ions through the HCI-surface interactions will be pursued by probing and characterizing the X-rays, ions, neutrals and electrons ejected.

3 PERFORMANCE OF THE SOURCE

The ECR source and associated systems mounted on a high voltage platform have been performing satisfactorily. Various beams have been extracted and transported to the experimental stations. By reducing the plasma electrode aperture diameter from 7 mm to 3 mm, the transmission through the high resolution analysing magnet is improved without much decrease of beam current. For obtaining higher intensities of the highly charged ions, the 'gas mixing' technique [4] has been used successfully. Table 1. gives a listing of typical beam currents obtained after analysis by 0.6m radius analysing magnet at 90 degree. Fig 4 shows the charge state distribution obtained for argon in three cases ; pure argon, argon with helium as mixing gas and argon with nitrogen as mixing gas. Helium is seen to be a better mixing gas when compared to nitrogen. Further measurements will be done using ^{16}O and ^{18}O. Studies are underway to improve the source output by performing simulations using the IGUN code [5] and to maximise the transmission to the experimental stations.

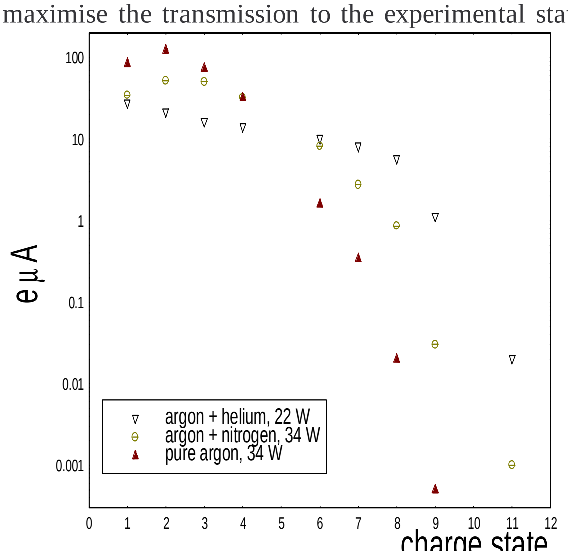

Figure 4: Charge state distributions for argon

An effort is being made to produce metal ion beams of appreciable intensity by adopting the MIVOC (Metal ions using volatile compounds) technique [6]. Preliminary work shows some promising results.

Table 1: Typical analysed beam outputs

Beam	Current (eμA)	Rf power (W)	Mixing gas/bias
Ar^{6+}	25.0	35	bias
Ar^{7+}	17.4	35	bias
Ar^{8+}	8.0	35	bias
Ar^{9+}	1.4	35	bias
Ar^{11+}	0.003	35	bias
O^{5+}	4 .0	12	helium
O^{6+}	1.2	12	helium
O^{7+}	0.02	12	helium
N^{4+}	20.0	21	helium
N^{5+}	3.8	21	helium
N^{6+}	0.056	21	helium

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