ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-MOPRI008

A COMPACT 2.45 GHz MICROWAVE ION SOURCE BASED HIGH FLUENCE IRRADIATION FACILITY AT IUAC, DELHI

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Abstract

A compact 2.45 GHz microwave ion source based low energy ion been facility has been developed for performing various experiments in material science and for studies related to plasma physics. The design of the compact microwave source is based on a tunable permanent magnet configuration and is powered by a 2 kW magnetron [1,2]. The double walled, water cooled stainless steel plasma chamber and ridge waveguide have been fabricated using the latest 'LaserCUSING' technique. The electron energy distribution functions have been measured in a similar low frequency ion source and validated by model calculations [1]. Extraction of the beam can also be performed at very low voltages in the order of hundreds of volts with high intensities by nullifying the space charge effects with the secondary electrons. The facility will be used for ion implantation, phase formation, surface etching and pattering experiments. The design aspects of the microwave ion source and low energy beam transport system will be presented.

INTRODUCTION

Microwave ion sources are well known for their stability, ruggedness and for their long lifetime due to absence of electrodes. Microwave ion sources operating at 2.45 GHz in the off-resonance mode are being utilized for various applications in many laboratories as high current ion implanters [3], and for ion beam deposition [4]. A microwave ion source operating at a frequency of 2.45 GHz has been designed and developed at IUAC, New Delhi [1, 2]. This ion source was able to deliver relatively intense beams of lower mass singly charged ions that were used for ion implantation and ion deposition experiments. A new facility has been designed and developed with a few modifications in plasma chamber, microwave coupling system and beam extraction system. Ion beam characteristics are deeply dependent on plasma density due to which design of these microwave ion sources cavity and coupling of microwaves to the cavity are area of current interest in ion source design [5].

DESIGN AND INSTALLATION OF THE ION SOURCE AND FACILITY

At IUAC, we have designed and developed a 2.45 GHz microwave ion source based high flux facility [1]. In earlier designed ion source, the plasma chamber used was a single walled cylindrical cavity cooled by compressed air. Standard WR340 waveguides were used for microwave coupling to the plasma chamber. A standard "three- electrode" system operated in "Accel-decel" mode was used for the extraction of beam [1]. The total current of proton beam obtained from the system was about 1.8 mA.

In this present work, to improve the performance of the source, we designed, developed and installed a 4-step ridge waveguide for better coupling of microwave to the plasma chamber. The new facility is shown in figure 1.

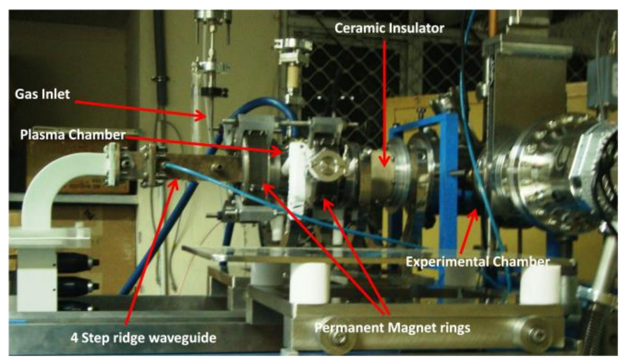

Figure 1: View of 2.45 GHz microwave ion source based high flux facility.

For better cooling of plasma chamber, a double walled water cooled plasma chamber is designed to protect the magnetic properties of the two magnetic rings. This plasma chamber is fabricated using 'LaserCUSING' technique. Two diagnostic ports are incorporated for viewing the shape of plasma and characterizing the plasma properties using Langmuir probe shown in figure 2.

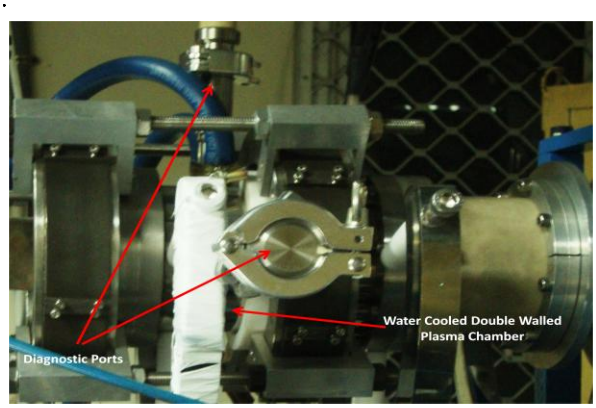

Figure 2: View of new plasma chamber along with two diagnostic ports.

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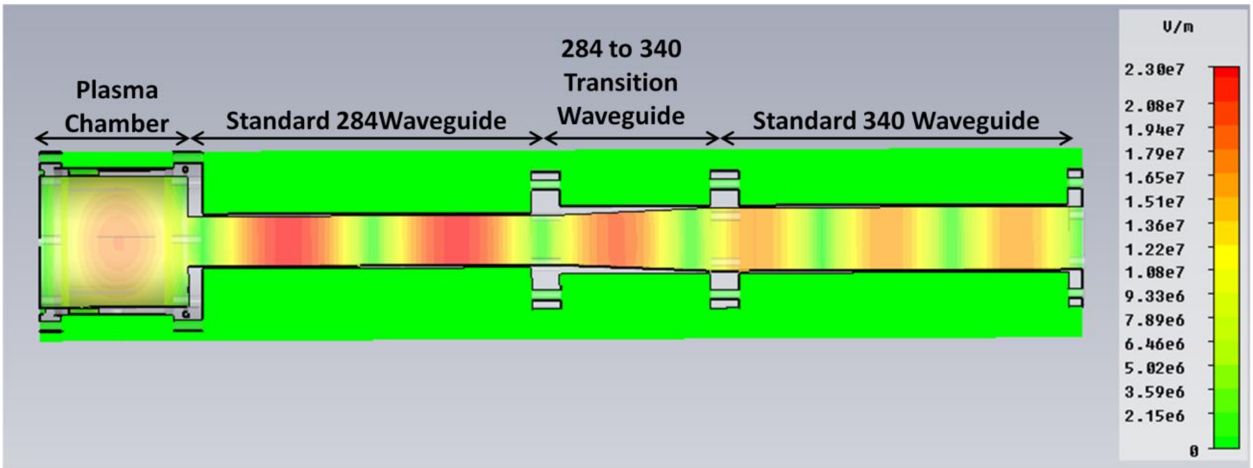

Figure 3: Simulated electric field distribution with standard waveguide system used for microwave coupling to the plasma chamber for 1W input power.

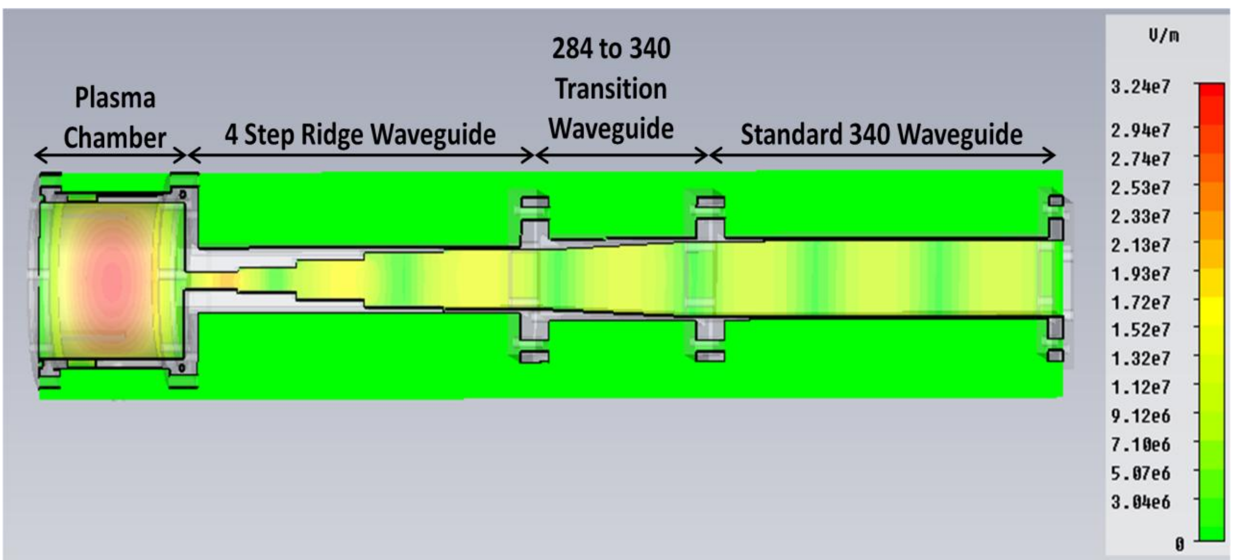

Figure 4: Simulated electric field distribution with 4-step ridge waveguide system for microwave coupling to the plasma chamber for 1W input power.

Figure 3 & figure 4 shows the electric field simulations for normal waveguide system and 4-step ridge waveguide system respectively. The enhancement of electric field at the centre of cavity in case of ridge waveguide system as compare to normal waveguide system is shown in figures 3 & 4. Simulated absolute electric fields along the axis of the system are shown in figure 5. The field distribution is superimposed by the cross sectional view of the two systems indicating the field distribution at different locations of system along the axis.

In this facility, the old "three electrode" extraction system is replaced by a newly designed five electrode extraction system in order to minimise the beam loss. The new extraction system comprises of the plasma electrode and additional four electrodes which can be tuned independently. The extraction optics simulated for 1 keV protons with 1mA of beam current is shown in figure 6 using IGUN [5].

RESULTS AND DISCUSSIONS

From the electric field simulation, we have observed that by using ridge waveguide system for microwave coupling, the absolute electric field at the centre of plasma chamber is increased by a factor of 1.79 as compared to situation where normal waveguide system was used.

The enhancement in the electric field is quite encouraging. We observed that stored energy in plasma chamber is only ~24.7 % of the total stored energy in system in case of normal waveguide system. The rest of 75.3% stored energy is dissipated in the waveguides. In case of ridge waveguide, the stored energy in plasma

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chamber is ~70.4% of the total stored energy in the system.

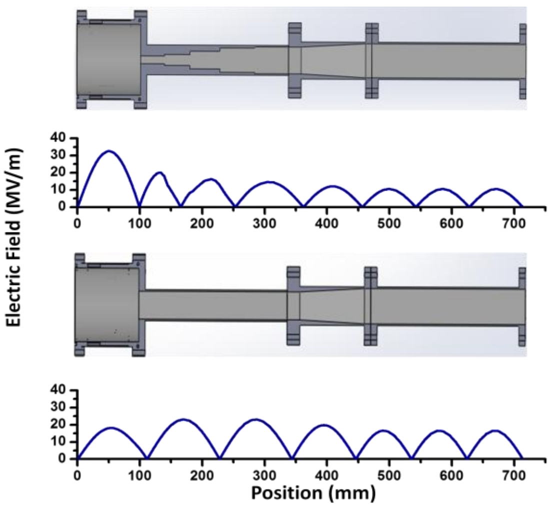

Figure 5: Simulated electric field along the axis of the system for normal and 4-step ridge waveguide.

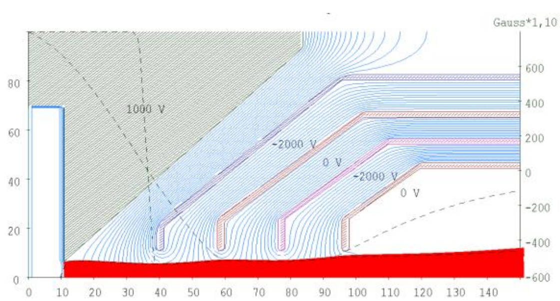

Figure 6: Calculated optics for transporting 1 mA of 1 keV protons in newly designed multi-electrode geometry (1 unit = 4.6E-04 mm).

We observed that use of 4-step ridge waveguide system is better than normal waveguide system in terms of maximizing the electric field at the centre of plasma chamber. This improved electric field will help in enhancement of plasma density.

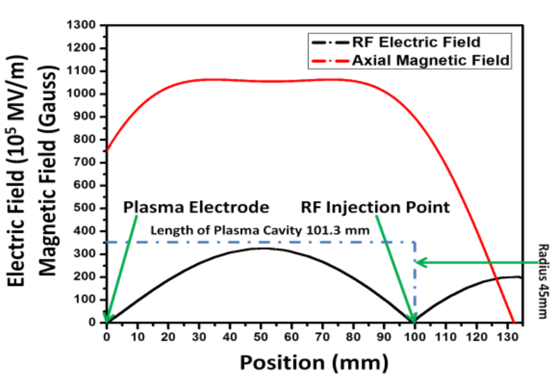

Figure 7: Design of axial magnetic field with respect to RF electric field along the chamber axis.

In Figure 7, the axial magnetic field with respect to the RF electric field along the axis of the chamber is shown. We have observed that the microwaves can be launched into the chamber at resonance field 875 Gauss where electric field is very low.

CONCLUSION

A 2.45 GHz microwave source together with the low energy beam transport (LEBT) has been successfully designed, developed and commissioned at IUAC, New Delhi, India. The design of microwave coupling and extraction system is capable for production and transport of very low energy ion beams (energy range from a few hundreds of eV to a few tens of keV) with high beam current (order of a few mA).

ACKNOWLEDGMENT

One of the authors (N. Kumar) is grateful to University Grant Commission (UGC), India for financial support through Senior Research Fellowship (SRF). Travel support by DST, India is acknowledged. The authors would like to thank the workshop personnel and other staff members of IUAC for their help.

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