DEVELOPMENT OF PENNING ION SOURCE FOR 50 keV ION ACCELERATOR

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Abstract

A penning ion source was fabricated, assembled & tested for development of a 50 keV ion accelerator. The source consists of cup shaped mild steel (MS) cathode body, 3.5 kG permanent magnet, aluminium cylindrical anode and MS face plate with a conical frustum. The anode is supported by a 1 mm diameter Al wire connected between the feed-through and anode through a hole in cathode body. The source is assembled inside a nylon cylindrical shaped housing with PU tube inlet for gas entry & MS feed through for anode & cathode power supplies. The source current is optimized by fabricating various sizes of cathode faceplate frustum.

The plasma discharge starts at around 1 kV of anode voltage. It gives a continuous beam of positively charged helium ions. The source was tested for delivering a stable current of 350 micro amp at 9.5x 10^{-5} mbar. at 28 kV cathode voltage. Common power supply with resister divider network was used for anode & cathode biasing. The voltage was raised & tested for up to 50 kV with 20:1 voltage divider providing 2.5 kV to anode.

INTRODUCTION

Penning ion source works with cold or heated electrodes to establish a high-voltage, low-pressure plasma discharge. In a penning ion source the electrons oscillate between two cathode electrodes inside an anode ring. The plasma production is improved by using an axial magnetic field. The permanent magnet has a surface field density of around 3.5kG. The magnetic force of the magnet itself helps it to stay in place. The cathode faceplate is made from the same material used to make the cathode body.

The penning ion generator was fabricated and installed inside a nylon cylinder. The nylon cylinder was installed horizontally on the vacuum chamber. The helium gas was connected by making a hole in the cathode body and connecting a 1/8 inch diameter PU tube. The anode was supported by 1 mm diameter aluminium wire connected between the feed through and anode. Practically the anode hangs on the aluminium wire, which also provide the anode voltage to it. Finally, the cathode faceplate is placed over the cathode body. The magnetic force created by the permanent magnet holds the faceplate in place. In addition to the magnetic force the cathode face plate was held by putting a vacuum grade Aluminium tape. The plasma discharge starts at around 1kV of anode voltage.

Ions formed in the plasma can be extracted in the form of a beam and accelerated by the strong electric field. The ion beam is formed from the plasma and extracted through cathode face plate orifice by applying a high voltage to the cathode body.

VARIOUS PARTS OF THE PENNING ION SOURCE

Penning ion source consists of mainly following parts.

- Cup shaped MS Cathode body
- Aluminium cylindrical anode
- MS Cathode face plate with frustum
- Feed-throughs
- Gas inlet pipe
- Cup shaped nylon cylindrical source body
- Power supplies
- Needle valve
- Aluminium extractor
- Permanent magnet

Fig-1: Various Components   Fig-2: Assembled View

ASSEMBLY AND CONFIGURATION

Various parts as shown in Fig-1 are assembled together and mounted in nylon cylindrical housing. Anode is hung axially inside the cathode body and held by solid 1 mm thick aluminium wire. This wire is taken out from cathode body through a side looking 3mm diameter hole and tightened to the anode feed-through. Teflon tape is wound on the wire to insulate it from the cathode body. Permanent magnet is placed in the centre of the cathode body base and it held on its own by its magnetic force. The cathode face plate is put on the cathode face and held by magnetic field itself. Vacuum grade aluminium tape is also put on to hold the cathode face plate. PU tube of 1/8 inch diameter with a precision needle valve is inserted through the nylon body up to the cathode body hole and fixed by using araldite for supplying the gas to the source. The complete assembled view in shown in Fig-2.

BIASING THE SOURCE

The whole assembly is mounted on to the vacuum chamber along with 40 mm thick aluminium extractor. The source is biased by using 50 kV power supply and 20:1 resistor network for biasing the anode & cathode from the single power supply. 100 kilo ohm resistor is also connected in series with the anode to current limit the discharge. Fig-3 shows the overall arrangement of the assembly and biasing of the source.

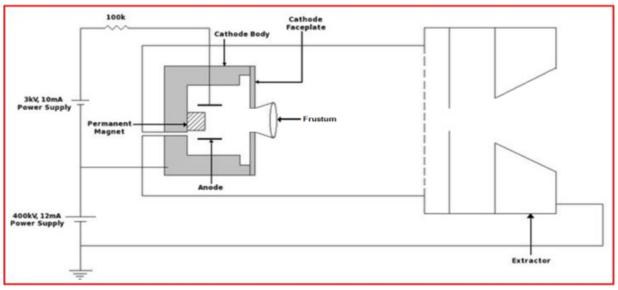

Fig-3: Overall arrangement & Biasing of the Source

The plasma discharge starts at around 1 kV of anode voltage. Ions formed in the plasma can be extracted in the form of a beam and accelerated by the strong electric field. The ion beam is formed from the plasma and extracted through cathode face plate orifice by applying a high voltage to the cathode body.

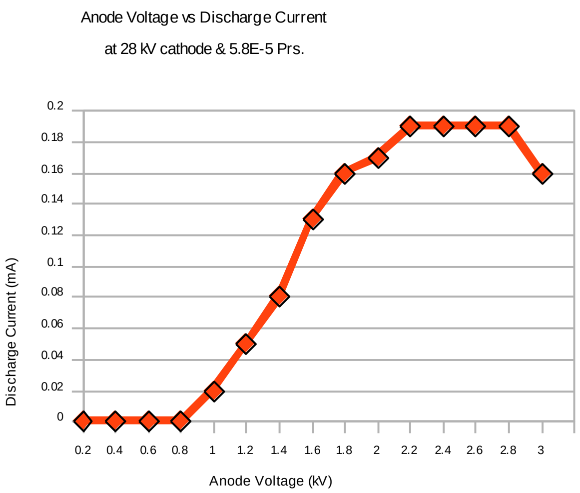

Fig-4: Discharge current vs anode voltage

CURRENT OPTIMIZATION

Source current was measured on a faraday cup with suppressor mounted inside the vacuum chamber. Initially the cathode face plate was only having a hole without any frustum. To optimize the output current through the extractor various sizes and shapes of the frustum were tried. This is basically to focus the beam coming out of the cathode face plate towards the extractor hole. The data was taken for various values of pressures. The chamber pressure was varied from 1.00E^{-6}mbar to 1.00E^{-4}mbar by controlling the helium gas flow through needle valve.

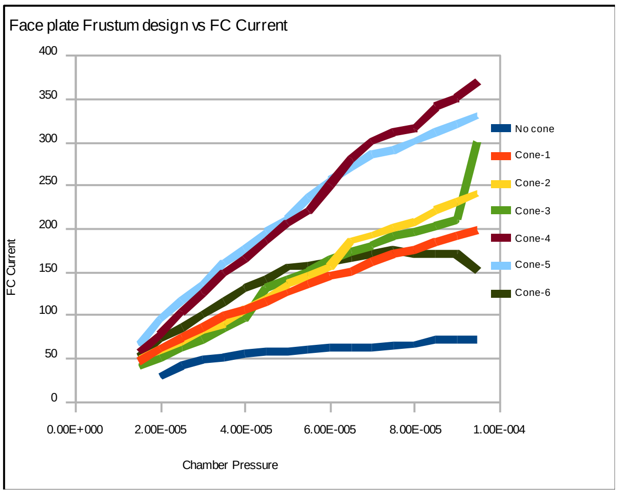

Fig-4: Farady cup current with different shapes of the cathode face plate frustum at 28 kV cathode voltage.

CONCLUSION

The source was designed, fabricated, assembled and tested with helium gas. Cathode & anode were biased with individual power supplies by using isolation transformer for powering anode as well as by 20:1 resistor divider network. The vacuum chamber was evacuated by using turbo molecular pump in combination with rotary pump.

The electrode closest to the source was conical shaped aluminium extractor around 25 mm away. The current was measured at a faraday cup with suppressor at 80 mm away from the extractor.

The source was tested for delivering a stable current of 350 micro amp at 9.5x10^{-5} mbar chamber pressure at 28 kV cathode voltage. The voltage was raised & tested for up to 50 kV with 20:1 voltage divider providing 2.5 kV to anode.

References:

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[2] Joshua L Rovey1, Design parameter investigation of a cold-cathode Penning ion source for general laboratory applications, Plasma sources science and technology, 20 June 2008