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Operating Characteristics of the Low Energy Accelerator

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Abstract

The main purpose of this work is to describe the construction and operation of low energy accelerator with energy in the range from (zero to 100 KeV.). This accelerator includes an ion source of the cold cathode Penning type (with pierce geometry for ion beam extraction), an accelerating tube (with 8 electrodes) and Faraday cup for measuring ion current. A vacuum system which gives vacuum of the order 3.0×10^{-8} Torr is used. A palladium tube is used to supply the source with pure hydrogen atoms. It was possible to operate this accelerator with an energy 50 KeV at minimum hydrogen pressure. 6.3×10^{-6} Torr. The total resistance applied between the accelerating electrodes R_T= 31.5 MΩ. These data includes the influence of the pressure in the accelerating tube, the magnetic field of the ion source, the extraction potential and the accelerating potential on the collector ion current. It was possible to accelerate protons with an energy 50 KeV with current about 100 μA at pressure 6.3×10^{-6} Torr, the source magnetic field = 1100 gauss (I_B= 2A), the arc current = 0.4 A and the extraction potential = 10 K.V.

INTRODUCTION

The growth of nuclear physics has depended upon the development of methods for producing beams of high energy particles. Radioactive substances can emit α-particles, β-particles and γ -rays which have been and still used for nuclear projectiles. However particle accelerators[1] greatly extended the range of intensities, energies and types of particles which are available for researches and applications. The low energy d.c accelerators[2] are characterized by its simple design and use in many fields of applications. The low energy deuteron accelerator[3] is widely used to produce 14 MeV neutrons. These neutrons are used in activation analysis techniques[4] for petroleum well logging and medical applications also the low energy accelerators are used in ion implantation technique and ion beam sputtering.

This work includes the construction of low energy accelerator of energy 100 KeV. An ion source of the cold cathode Penning type is used for producing protons. The operational characteristics of this accelerator is studied under the influence of the discharge parameters and pressure inside the acceleration tube.

APPARATUS

This device is a low energy accelerator (fig. 1) whose components are constructed in the nuclear research center-Inchas. It consists of cold cathode Penning ion source[5], an acceleration tube and the beam measuring system.

The Penning Ion source: This source consists of a cylindrical anode (st. steel) and two aluminum cathodes. The anode is insulated from the cathodes by ceramic ring. The anticathode is fitted with an expansion cup. The source

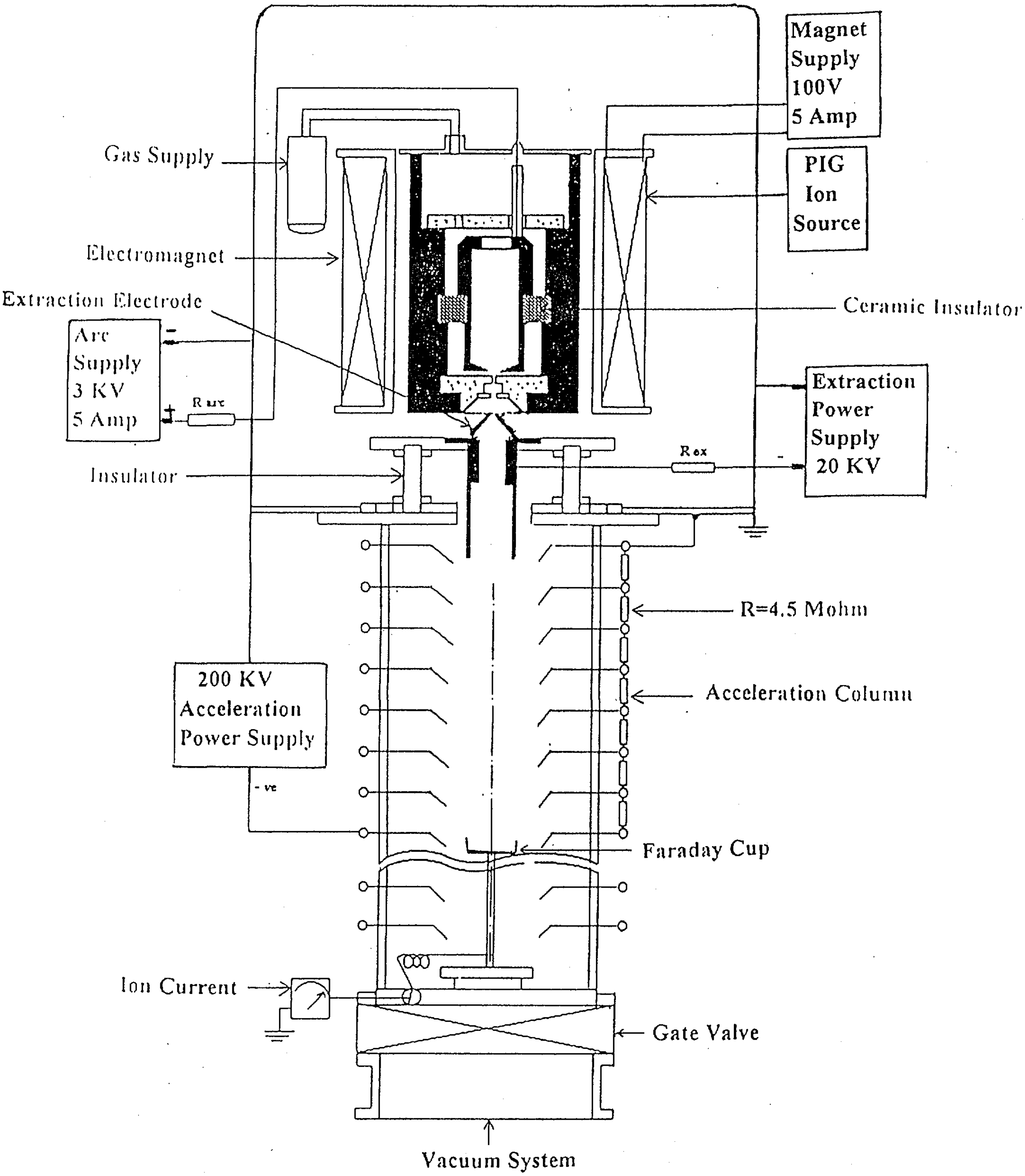


Fig (1)Block Diagram of The Low Energy Accelerator With Power Supplies is surrounded by an electromagnet which is made of an insulated copper wire of diameter 1mm and number of turns = 900. The maximum magnetic field/amp at the anode center is 550 gauss/ amp. The extractor is made of copper with an aperture of a diameter of 2mm and is fixed near the base of the anticathode. The power supplies for ion source operation are: the arc supply (3kV-5A), power supply (20 kV-50 m A) with negative polarity is used for ion beam extraction and an electromagnet power supply (100 V-5A).

The Acceleration Tube : This tube (fig. 2) is used for the acceleration of ions after their extraction from the source. This tube is constructed in Russia and consists of multi-sections of stainless steel electrodes (of 120 mm inside diameter) which are separated by porcelain rings of 25 mm hight. The total hight of the acceleration tube is 1100 mm. At the upper end of the acceleration tube, there are the ion source, its electrical connections and the gas injection system. At the lower flange of the acceleration tube, the faraday cup is mounted below the lower accelerating electrode (fig.1). A corona dischargers are used between the accelerating electrodes to avoid breakdown problems. The potential is distributed by using a resistance 4.5 MΩ between every two electrodes.

The High Tension Supply: This power supply gives negative output voltage (0-100KV) with current 15mA. A high voltage cable is connected between the copper spherical dome of the generator and one of the electrodes of the acceleration tube. In this work the high tension is applied across a part of the accelerating tube of 45 cm length and the rest of the tube is considered as a drift tube. The accelerating part includes 8 electrodes and the faraday cup is fixed at distance 2cm below the eighth accelerating electrode.

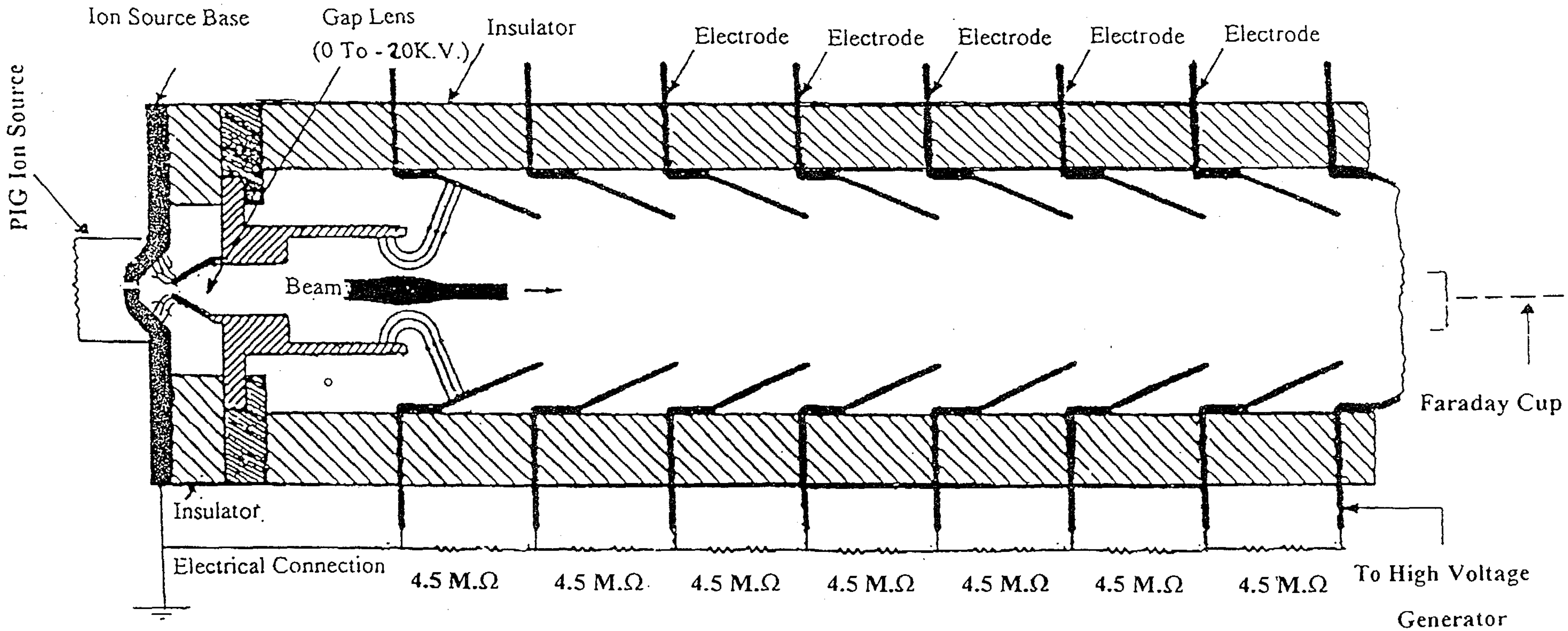


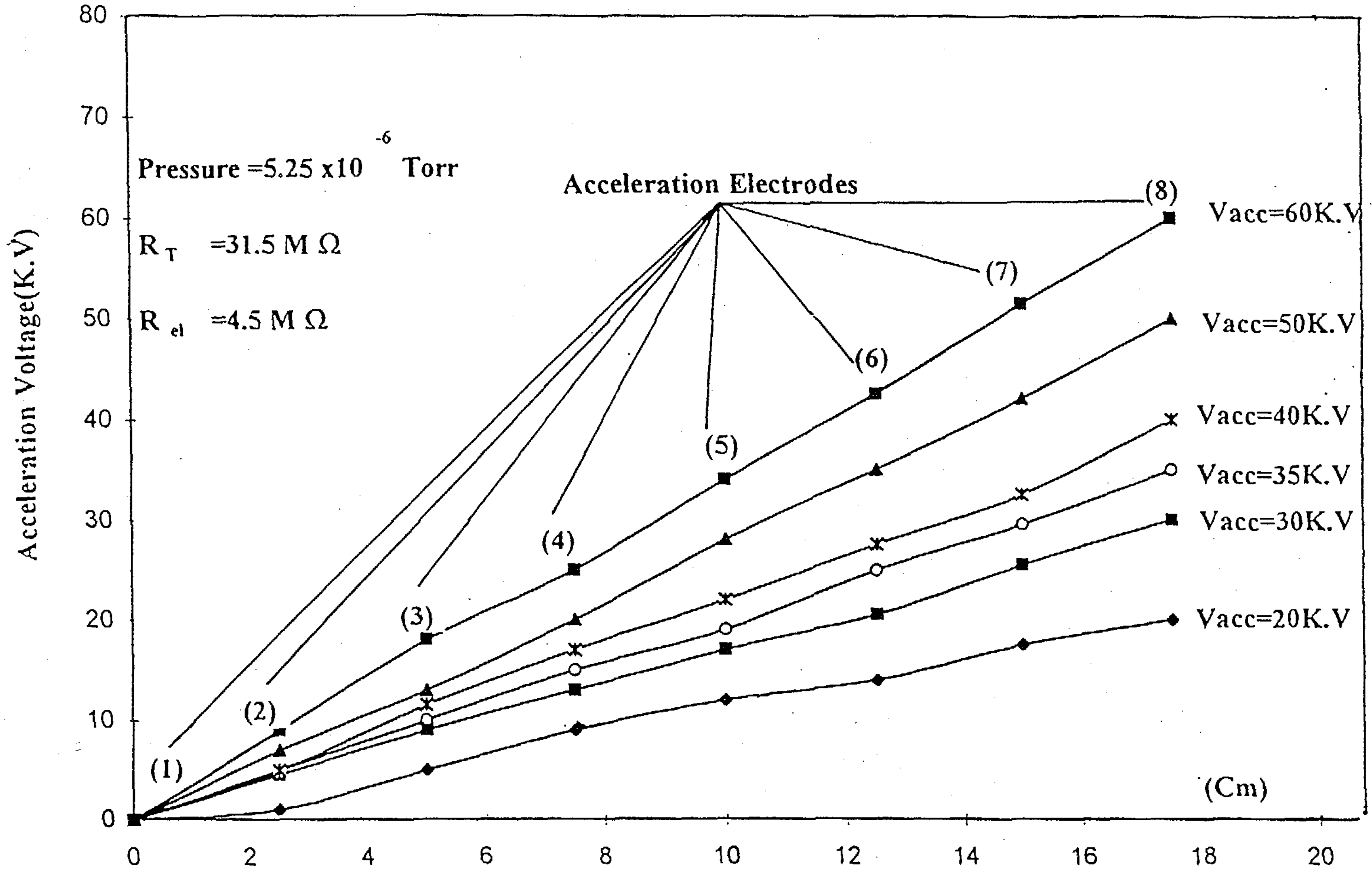
Fig (2) Acceleraing tube and Gap Lens Focusing Action

Gap Lens: The extraction electrode (fig. 2) plays large importance for ion beam focusing[6]. The ion beam is subjected to two focusing actions by this electrode. The first action is between this electrode and the base of the ion source, and the second action is between the base of this electrode and the first accelerating electrode in the acceleration tube. Also the lines of force between the successive accelerating electrodes tend to restrict the beam towards the axis of the acceleration tube.

Vacuum system: This system consists of silicon oil diffusion pump fitted with liquid nitrogen trap. The diffusion pump is backed by a rotary mechanical pump of double stages. This system gives vacuum of the order $3.65x10^{-6}$ Torr in the acceleration tube. The injection of pure hydrogen gas is regulated by using palladium tube and current transformer.

RESULTS & DISCUSSION

In this study the system is evacuated to about $3.65x10^{-6}$ Torr before operation to remove the residual gases before hydrogen gas injection in the ion source. Figure (3) shows the potential distribution along the acceleration electrodes where the first electrode is at zero potential. This figure shows the value of the acceleration voltage of the high voltage on each electrode when applying the acceleration voltage of the high voltage generator on the eighth electrode. This potential distribution is adjusted by using resistance 4.5 MΩ between the electrodes. The total resistance equal 31.5 MΩ. The maximum voltage reaches 60KV at pressure $5.25x10^{-6}$ Torr without breakdown. Figure(4) shows the change in pressure in the acceleration tube after the injection of pure hydrogen gas in the ion source.The ion current on the collector is recorded at extraction potential 10KV and at low acceleration voltage=10KV.From this figure it is clear that at pressure lower than10^{-5} Torr



Fig(3) Potential Distribution Along The Acceleration Electrodes

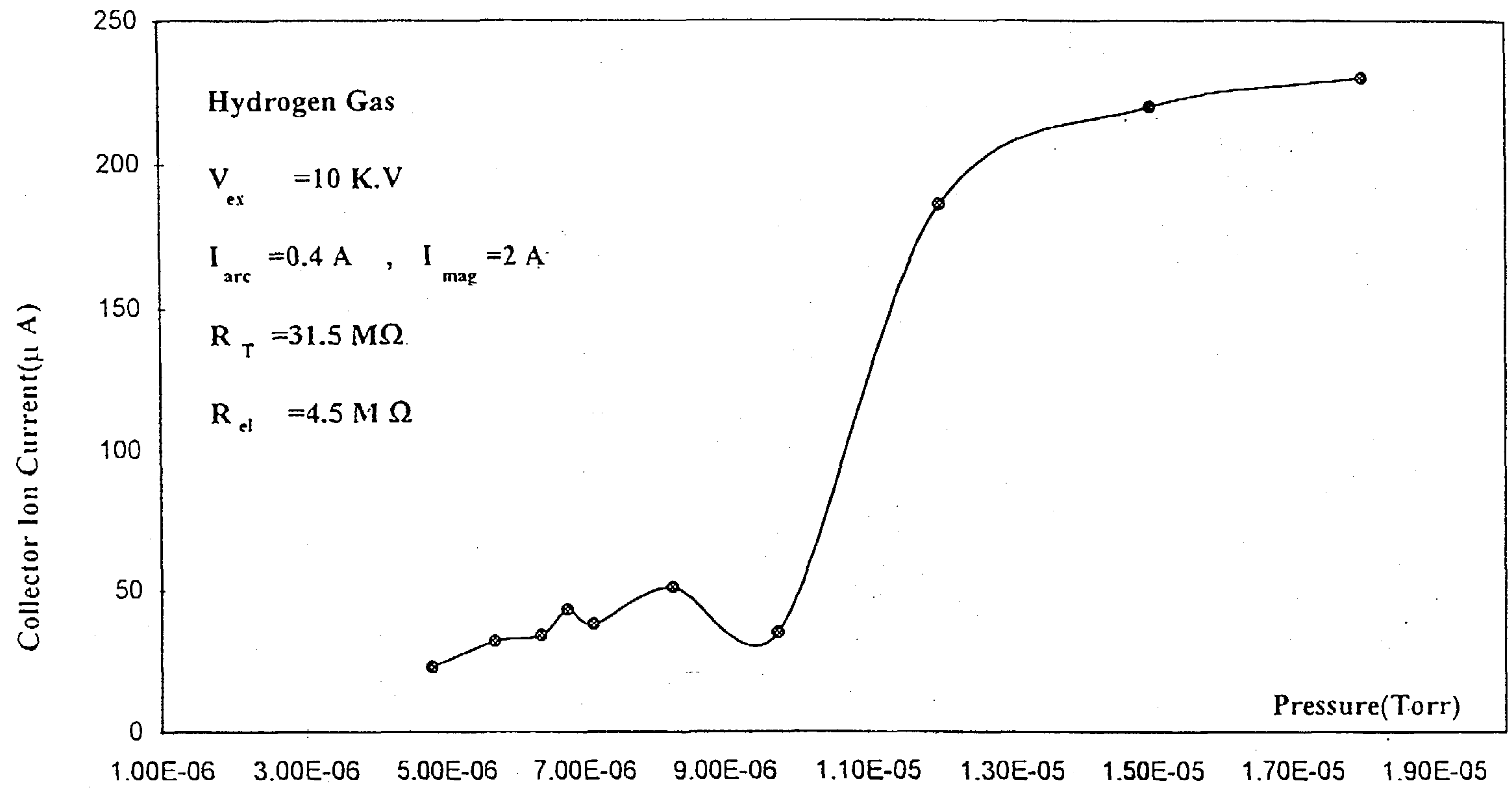


Fig (4)Change Of Collector Ion Current
With Pressure at V_{acc} =10 K.V

the collector current is lower than 50μA while at pressure larger than 10^{-5} Torr the current increases rapidly to about 235 μA at pressure 1.8×10^{-5} Torr. Figure (5) shows the influence of the change of pressure on the arc current. It is clear that the arc current increases with the increase in pressure where I_{arc} changes from 0.2 A to 1.1 A for the change in pressure from 6.3×10^{-6} to 1.65×10^{-5} Torr. The increase in arc current may be due to the increase in ion density inside the source[5]. This increase in arc current is reflected on the value of the collector ion current which agrees with the recorded data at figure (4). Figure (6) shows the influence of the source magnetic field on the collector ion current at acceleration voltage 10KV at pressure 7.1×10^{-6} Torr. The change in magnetic field causes an increase in collector ion current which begins to appear at I_{mag}=1.5 A and reaches peak value at I_{mag} = 1.9 A with maximum ion current 45 μA at extraction voltage 10KV. Figure (7) shows the same experiment at larger pressure (1.8×10^{-5} Torr). The recorded ion current appears at I_{mag}=1.3A and reaches maximum value at I_{mag}= 2.2 A which equals 265 μA. It is clear that the magnetic field has large influence on the ion current in this range of pressure (1.8×10^{-5} Torr). Figure (8) shows the influence of the extraction voltage on the collector ion current for different values of the acceleration voltage applied on the acceleration tube at low pressure. It is clear that the change of extraction voltage (V_{ex}) from 0 to 8KV causes a small change in collector ion current while at $V_{ex} > 9$ KV, this change begins to increase rapidly. The application of the accelerating voltage greater than 30 KV is characterized by large effect on collector ion current.

CONCLUSION

From the study of the operational characteristics of the low energy accelerator it is clear that:

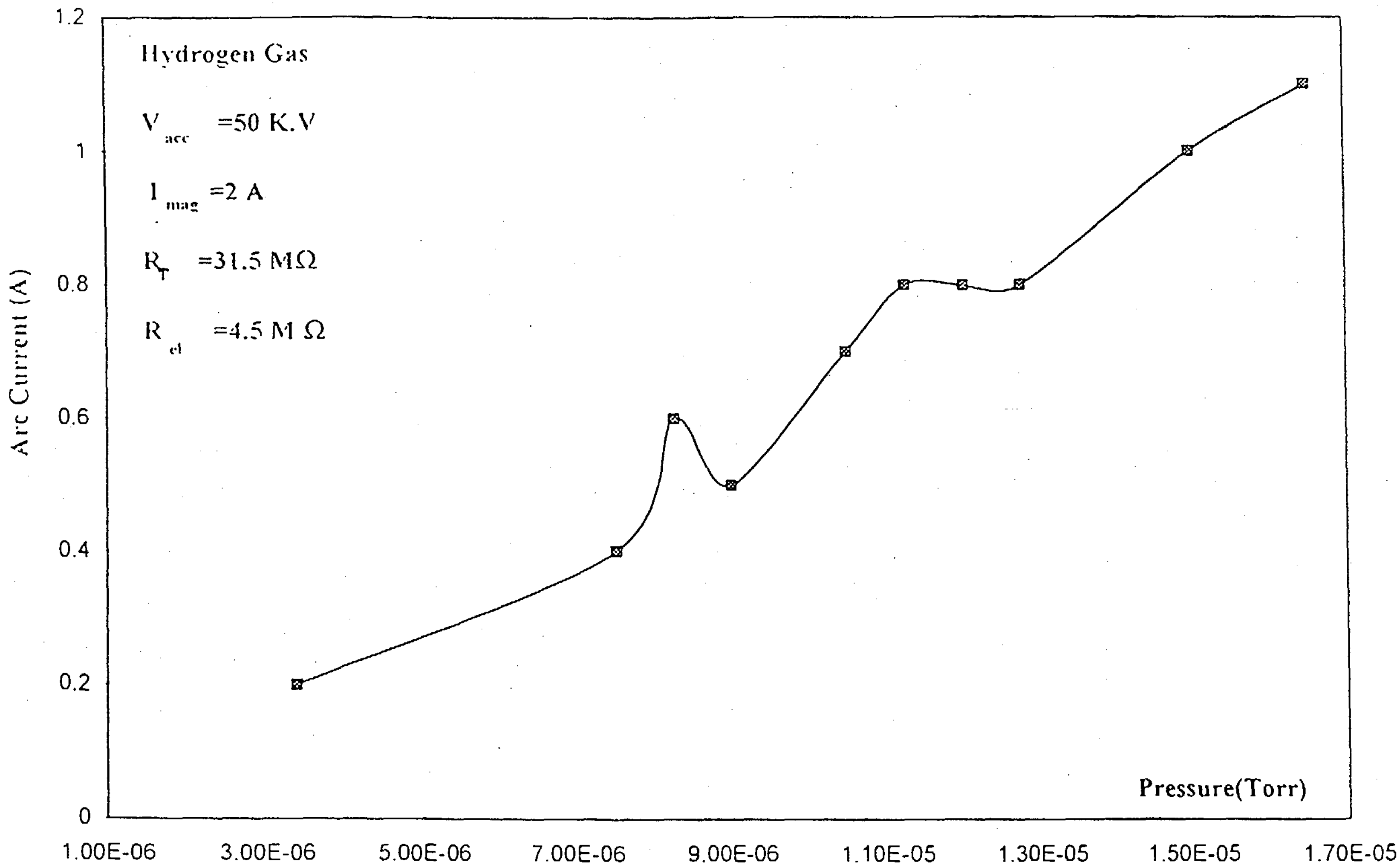


Fig (5)Change Of Arc Current With Pressure

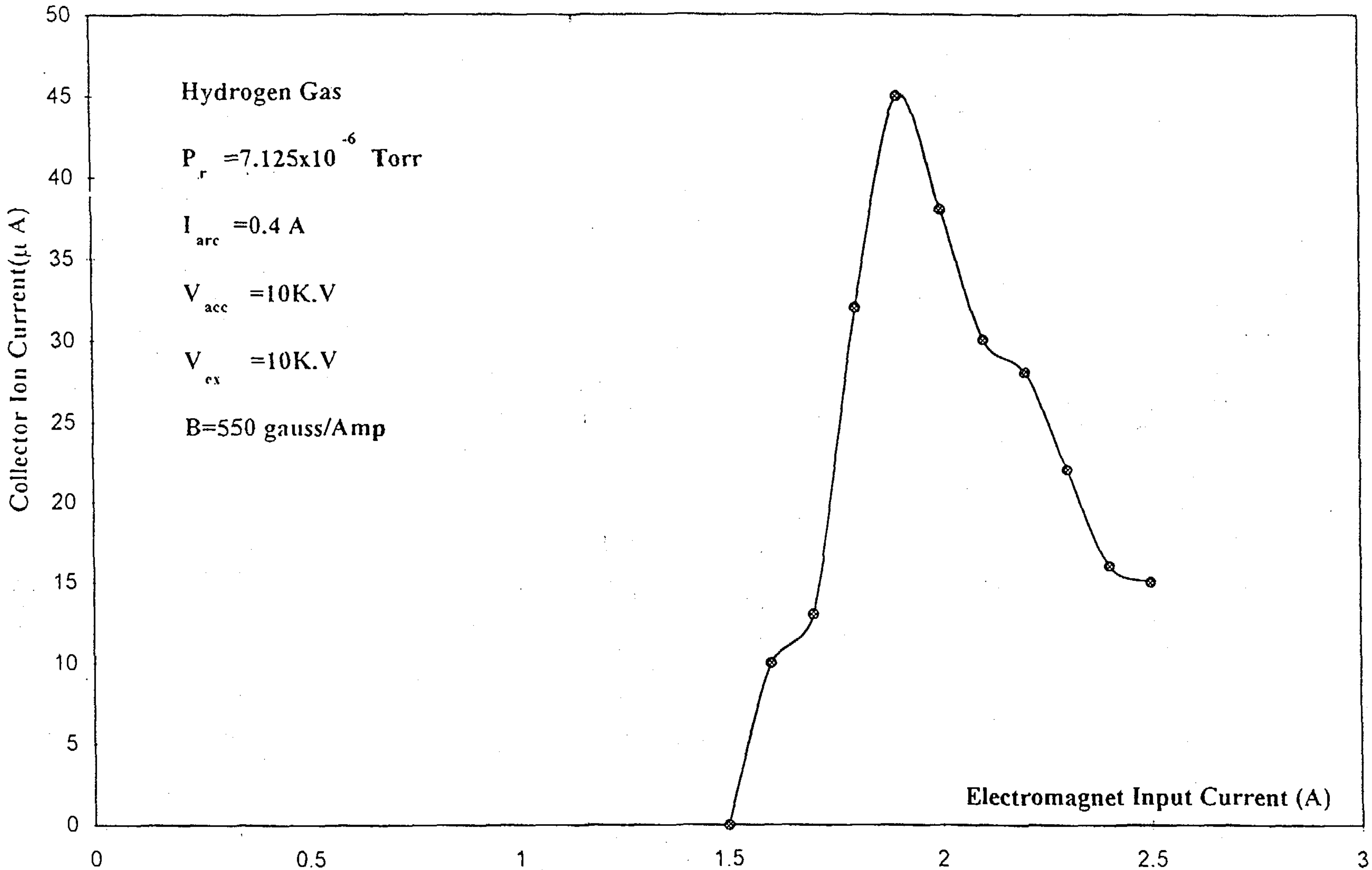


Fig (6)Influence Of Magnetic Field On Collector Ion Current at $P=7.125x10^{-6}$ Torr

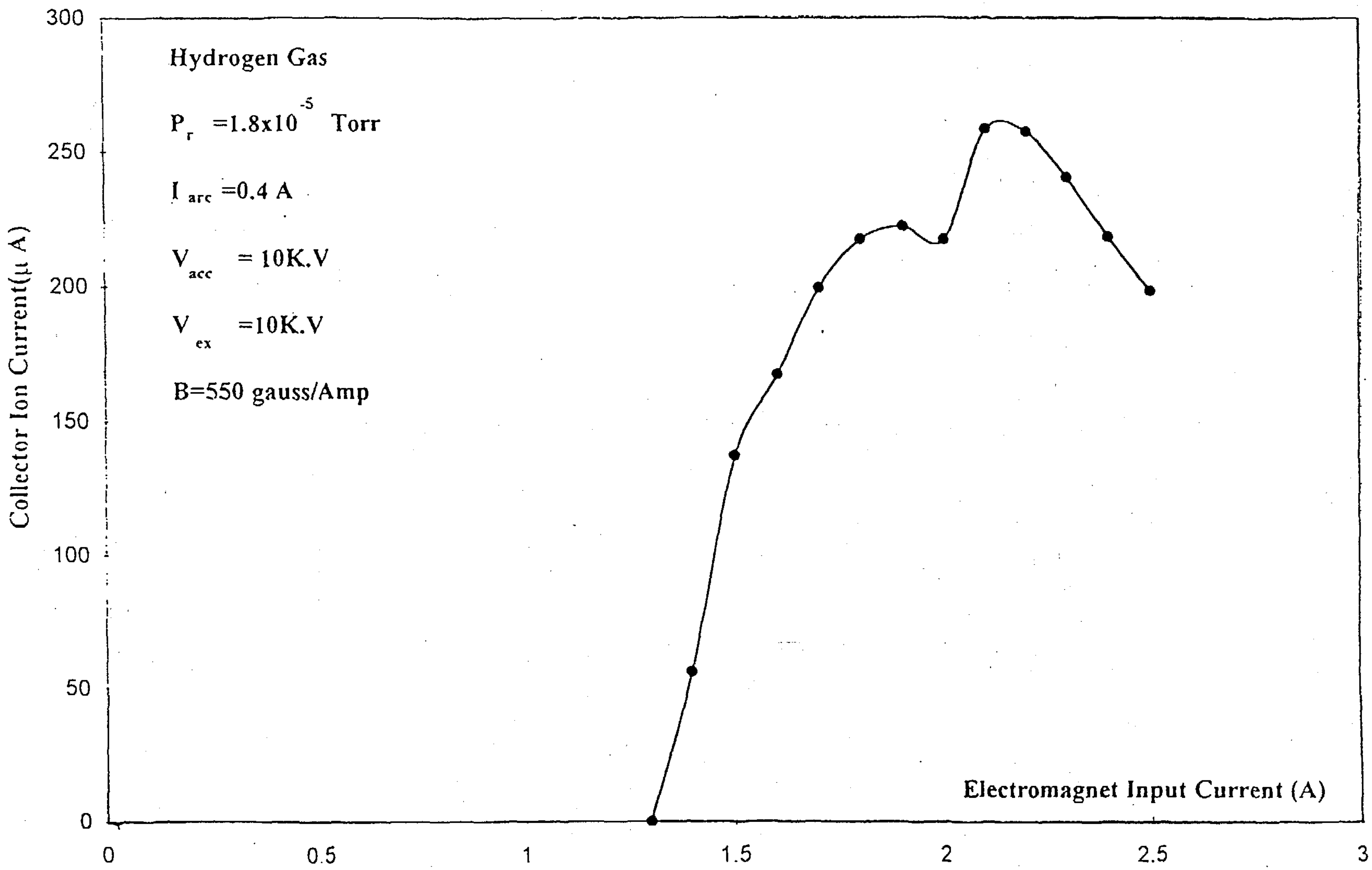


Fig (7)Influence Of Magnetic Field On Collector Ion Current at $P=1.8x10^{-5}$ Torr

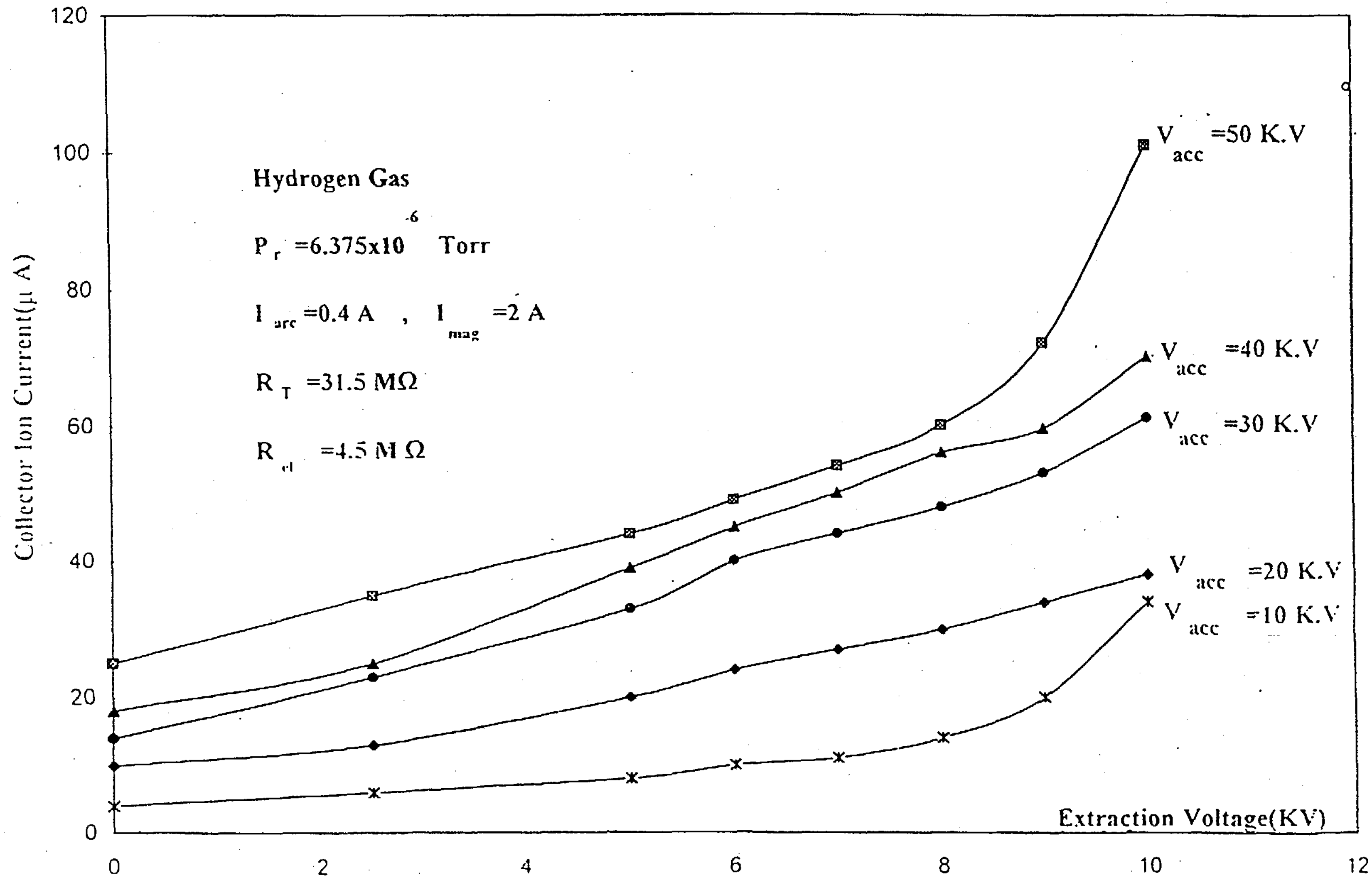


Fig (8)Influence Of Extraction Voltage On Collector Ion Current At different Accelerating Voltages

1- The change of pressure has large influence on the collector ion current. (fig.4) at pressure $< 10^{-5}$ Torr the ion current is less than 50 μA while at larger pressure ($> 10^{-5}$ Torr), the current increases to several hundred of microamperes. ($\simeq$ 235 μA at p= 1.8 x 10^{-5} Torr). It is found that the change in pressure causes an increase in arc current which causes the increase in ion density inside the source.

2- The magnetic field of the source is characterized by large influence on the collector ion current. At pressure 7.1 x 10^{-6} Torr (fig. 6). maximum current reaches 45 μA at I_{mag} = 1.9 A which is characterized by sharp peak. At relatively larger pressure (fig. 7) under the same experimental conditions the current reaches 265 μA. at I_{mag} = 2.2 A. This reveals the increase of ion current by the double effect of the pressure and the magnetic field.

3- At low pressure (6.3 x 10^{-6}) Torr (fig. 8) it is possible to increase the collector ion current to about 100 μA by the application of acceleration voltage $\simeq$ 50KV.

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