REVIEW OF RESEARCH AND DEVELOPMENT ON RADIO FREQUENCY ION SOURCES

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ABSTRACT

A historical review is given to RF ion sources starting from the simplest low current type utilizing ion beam extraction in the direction of plasma tube axis, so-called axial extraction type, and passing by versions of this type which have been improved for higher beam current and better beam characteristics and ending by the type utilizing beam extraction in a direction transverse to RF field direction, so-called radial extraction type, with its different versions leading to improved, ion source design.

AXIAL EXTRACTION RF SOURCES

The RF ion source is characterized by its simple construction, high proton percentage, large beam current, and low gas consumption. It is used in particle accelerators , in neutron generators and in many fields of research and applications. Before presenting the RF ion source with an injected electron beam and its importance a review of the other types is given.

In the Thonemann[1] type RF source, Fig. 1, ,the ions are extracted along the tube axis in the direction of the electrostatic field. The output current is extracted through an Al-channel and reaches about 500, μA. Many types of axial extraction RF sources were developed using the axial magnetic field as given[2] in Fig. 2. The extracted current reaches 1.2 mA with V_{ex}= 5 kV . An important version of the axial type which delivers high ion current (500 mA) was introduced by U.Tallgren[3] at CERN (1966) , Fig.3.

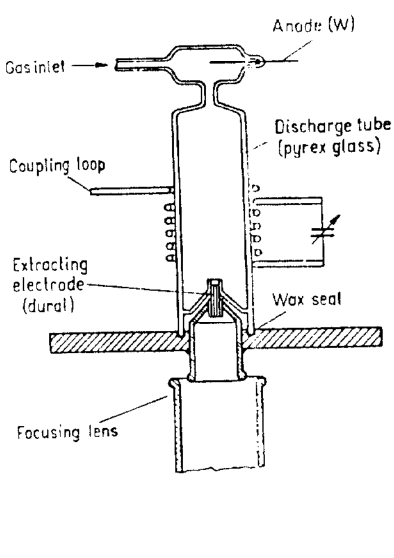

Fig. 1 Thonemann's Axial Type RF Ion Source[1].

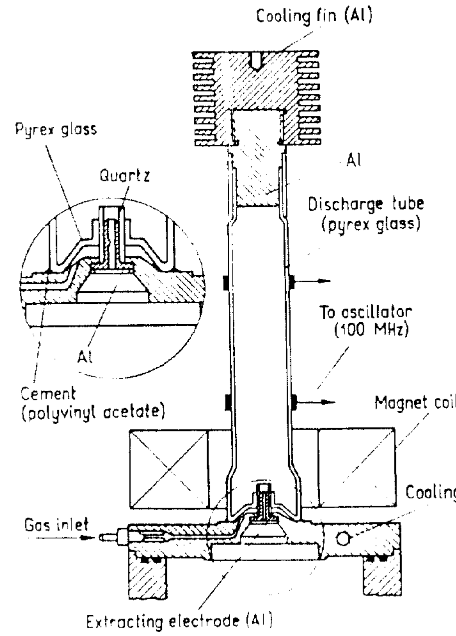

Fig. 2 Moak-Reese-Good's Axial Type RF Ion Source with magnetic field[2].

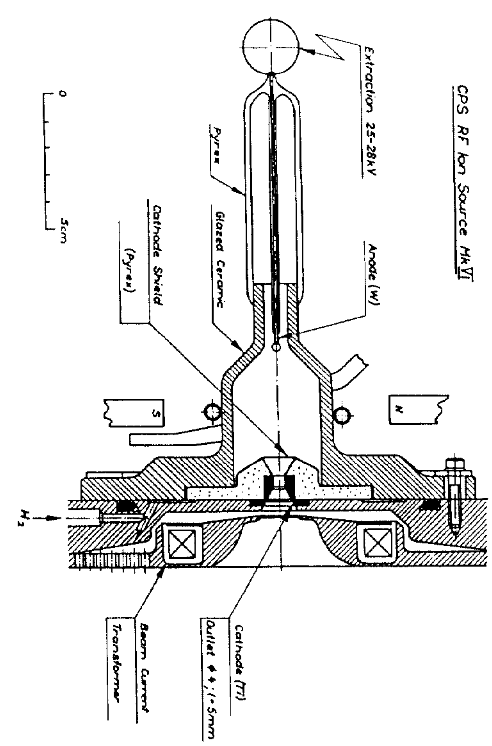

Fig. 3 Tallgren High Current Axial Type RF Ion Source[3].

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RADIAL EXTRACTION RF SOURCES

It has been shown [4] that in low pressure RF plasma, the radial density distribution follows the equation : $n_r = n_o J_o(2.405\ r/R)$ and reaches maximum value at the tube axis. In the RF source with radial extraction , Fig. 4, the extraction cathode is placed near the tube center and the extraction potential is applied transverse to the tube axis. The extracted ion current from this type is

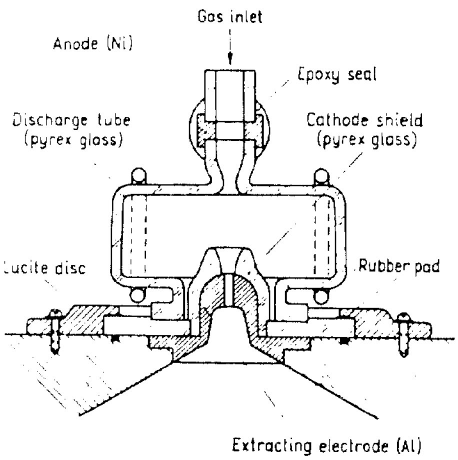

Fig.4 ABD EL AZIZ High current Radial Extraction Type RF Ion Source[4].

found to be much higher than the equivalent axial type.

The ion density n_o at the plasma center[5] is found to be $n_o = I_d/1.36\ evr^2$ where I_d is the discharge current at the tube axis, v is the velocity of the particle in the RF field and r is the tube radius. This equation shows the dependance of n_o on the inverse square of the tube radius.
A design was made of an ion source based on this result by having a reduced radius at the central region of the plasma tube[5], Fig. 5, producing plasma confinement due to mechanical constriction, leading to an increase of the ion current.

In the RF source with injected electrons[6], Fig. 6 , the source is featured by having hot filament and accelerating electrode, surrounded by the ferrite core of an electromagnet. Thus more electrons are added to the secondary electrons (emitted from the tube walls) to intensify the plasma . The magnetic field is used to confine both the injected electrons and the plasma at the source center near the region of extraction. Also, the application of magnetic field perpendicular to the RF field will cause the oscillating electrons to absorb high energy from the RF field which increases the plasma intensity[7,8] .

The injection of an electron beam in the RF plasma is an important factor which modify the ion beam characteristics such as :

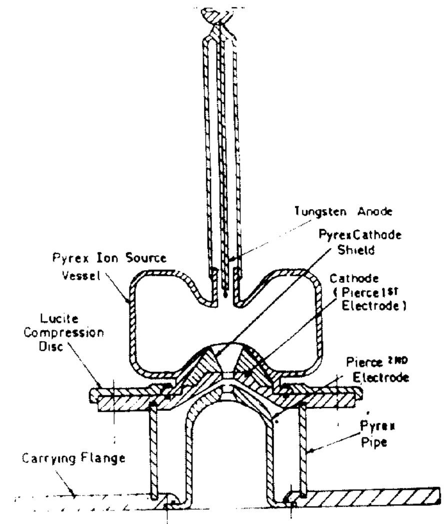

Fig. 5 Radial Extraction with central constriction RFIon Source[5].

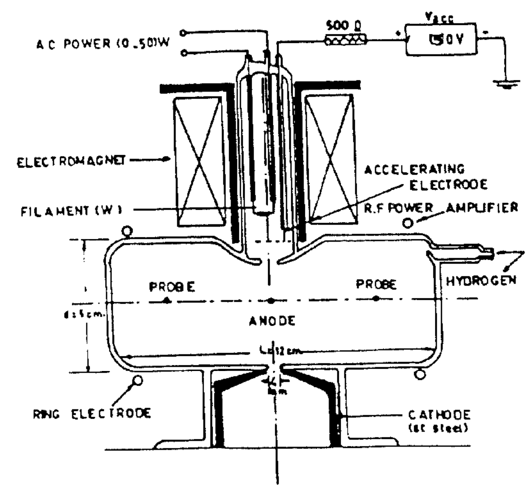

Fig.6 Radial Extraction with Injected Electrons RF Ion Source[6] .

1. Increases the ion beam current due to the increase of the probability of ionization[6](Fig. 7).

2. Decreases the ion beam emittance and increases the brightness due to space charge neutralization between the ions and the injected electrons[9]. (Fig. 8) .

3. Decreases the diffusion losses[10] across the magnetic field due to decrease of plasma oscillation caused by electron beam plasma interaction (Fig. 9) .

4. Also , it is found that the process of electron injection decreases the mean beam energy[11] due to lowering of the plasma sheath potential .

5. Finally, it is found that the electron injection increases the cross-section for multiple ionization process which allows an increase in the % age of the multiply charged ions[12] (Fig. 10).

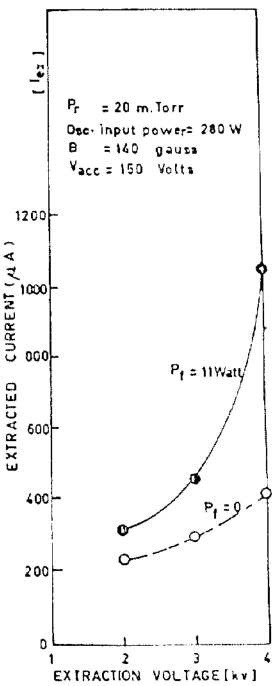

FIG.(7) EXTRACTION CHARACTERISTICS WITH & WITHOUT INJECTION

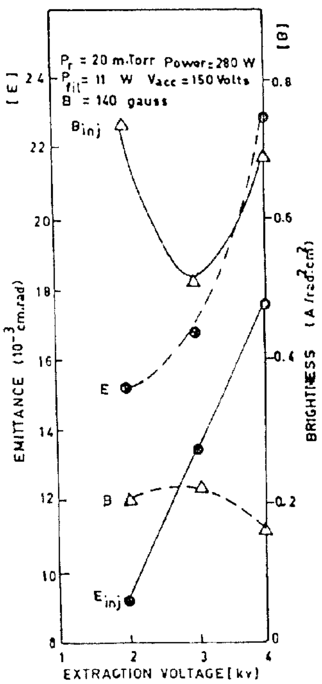

FIG.(8) CHANGE OF EMITTANCE & BRIGHTNESS WITH ELECTRON INJECTION AT DIFFERENT POTEN.ls

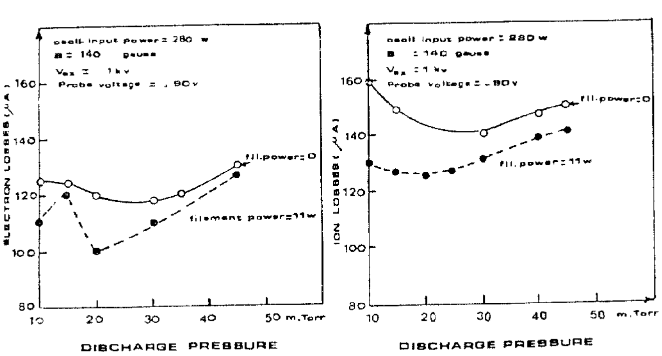

FIG (6) EFFECT OF DISCHARGE PRESSURE ON DIFFUSION LOSSES BEFORE AND AFTER ELECTRON BEAM INJECTION

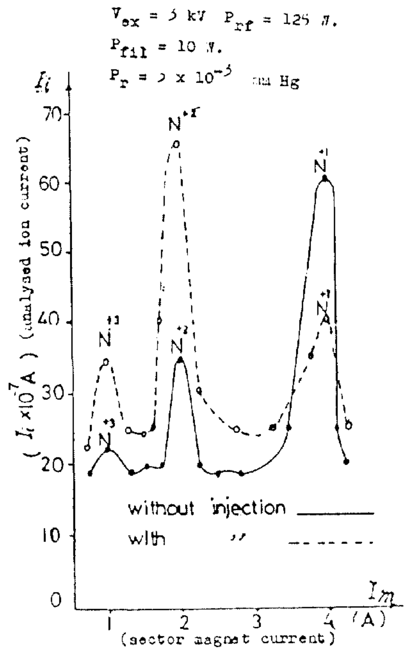

Fig. 10 Nitrogen charge spectrum[12]

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