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New Vaporizing Assembly for Q-Plasma Sources

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ABSTRACT

The design and operation of a new vaporizing assembly used for Q-plasma sources are described in this letter. The vaporizing system, consisting of two ovens and an effuser, is used to vaporize and direct atoms onto a hot ionizer plate. The hot plate, which may be of tantalum, tungsten or rhenium, singly ionizes the atoms on contact. The main advantages of this new assembly, compared to previous designs, are the production of higher plasma densities and the control of the radial plasma profile. The heaters of the two atomic beam ovens are independently controlled and monitored so that the gradients of the radial plasma profile can be modified. Plasma production with two ion species can also be performed.

I. INTRODUCTION

Q-machines have received attention during the past 30 years because of their usefulness in fundamental research in plasma physics[1]. The quiescent plasma generated by the device is necessary in order to distinguish the phenomena being investigated from the usually turbulent state generated by other types of plasma production mechanisms. More recently, interest has increased because of the use of the non-pertubative diagnostic of laser induced fluorescence (LIF) [2] in conjunction with barium plasmas.

In Q-machines, the plasma is generated by surface ionization of vapor, barium on rhenium in our case, at the hot plate surface, which is heated to 2200°-2500°K. Residual neutrals are condensed on the chilled vacuum chamber walls in the source section. As a consequence, an almost fully ionized plasma drifts along the confining magnetic field, in a background vacuum pressure in the range of 10^{-7} Torr. Electron and ion temperatures are of the order of the ionizing plate temperature, about 0.2 eV. Plasma densities in the range of 10^{9} to 10^{11} cm^{-3} are currently produced. In the LMP-Q machine[3], the plasma is immersed in a magnetic field of up to 3 kGauss, with good spatial and temporal homogeneity (maximum ripple of 0.3%).

The necessity of increasing the plasma density by a factor 10 when performing certain ion-wave particle interaction studies, gave rise to the idea of the development of the new vaporizing assembly which we present here. This development has at least two additional consequences: 1) it makes it possible to modify the plasma radial profile and 2) it enables the production of a plasma with two atomic species.

II. DESCRIPTION OF THE VAPORIZING ASSEMBLY

The source described here used a rhenium coated tungsten plate, prepared following a special procedure described in [4], in conjunction with barium vapor. The most significant change in the method of heating the vaporizing oven is to attach it to the front of the effuser as shown if Fig. 1a. This arrangement has the advantages of considerably shortening the length of the delivery tube (the neck) and of exposing the oven to the heat radiated by the hot plate, thereby considerably improving the efficiency of heating. A second oven (Fig. 1a) was added in order to increase the vapor production and also to enable the radial density profile to be modified according to experimental requirements. Another source of thermal loss through the oven cap, has been reduced by adding two stainless steel thin foil reflectors electrically welded to the oven top (Fig. 1b). Heat confinement in the useful volume of the oven is thereby optimized. In this way the cooling and deposition of the barium vapor on the internal part of the cap is considerably reduced. In the previous design, the barium vapor had the tendency to condense on the cap, the coolest part of the oven, causing some difficulties.

Heat shields , as shown in Fig. 1a, were added to the effuser because direct radiation from the hot plate to the ovens is at too high a level to allow control of the oven temperature. In this way effective heating control of the ovens comes solely from the the resistive coaxial heater wire (Aerocoax - ARI industries Inc), surrounding the main cylinder of the oven. The heater wire is fed by a maximum current of 2.5A and total power of 200W. Figure 1a shows the oven-effuser arrangement, and Figure 1b the grooved wall of the oven which integrates the heating wire. The heater wire is held in place by a rolled thin sheet of stainless steel (.1mm thickness). The stainless steel retainer also acts as a heat shield and enhances the temperature of the oven by approximately 10% to 20%.

Figure 1c shows the relation between the internal temperature of the oven and the applied power. With this groove configuration the wire does not need to be brazed to the stainless steel oven as was necessary in the previous arrangement. This reduces time and cost of construction and replacement in case of damage.

III. PLASMA PARAMETERS MEASUREMENTS

Axially and radially movable Langmuir probes are used to measure plasma density. In addition LIF is used to measure ion temperature and drift velocity, as well as wave propagation characteristics. The source start-up procedure is identical to the one described in Ref. [3]. Ion density and temperature profile measurements by LIF are shown in Fig. 2. The density profile can be produced in such a way that radial symmetry is not maintained (Fig. 3a). The central value of plasma density can also be varied without modifying the shape of the profile, by simply acting on the hot plate power (Fig. 3b). Measurements of plasma parameters indicate slight variations with respect to the previous arrangement. In particular the parallel drift velocity is reduced by about 25% and the ion perpendicular and parallel (with respect to the static magnetic field) temperatures are equal to 0.19 eV and 0.15 eV respectively instead of 0.22 eV and 0.19 eV obtained with the previous assembly. The electron temperature remains of the order of 0.2 eV, as inferred from measurements of sound wave dispersion. Direct observations of ion diffusion coefficients[5] indicate an enhancement of collisionality and transport consistent with the changes in plasma characteristics.

IV. CONCLUSION

The variety of radial density profiles and the large range of plasma density obtained in the LMP-Q device demonstrate that the machine is well suited, when equipped with the new type of barium vaporizing assembly, to study fundamental plasma phenomena. The ability to create plasmas easily with two ions species offers new opportunities for study.

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Figure captions

FIG. 1a) The new LMP two oven-effuser assembly, heat shields are cut in order to see the bayonet locker which is inserted between the sheaths of stainless steel.

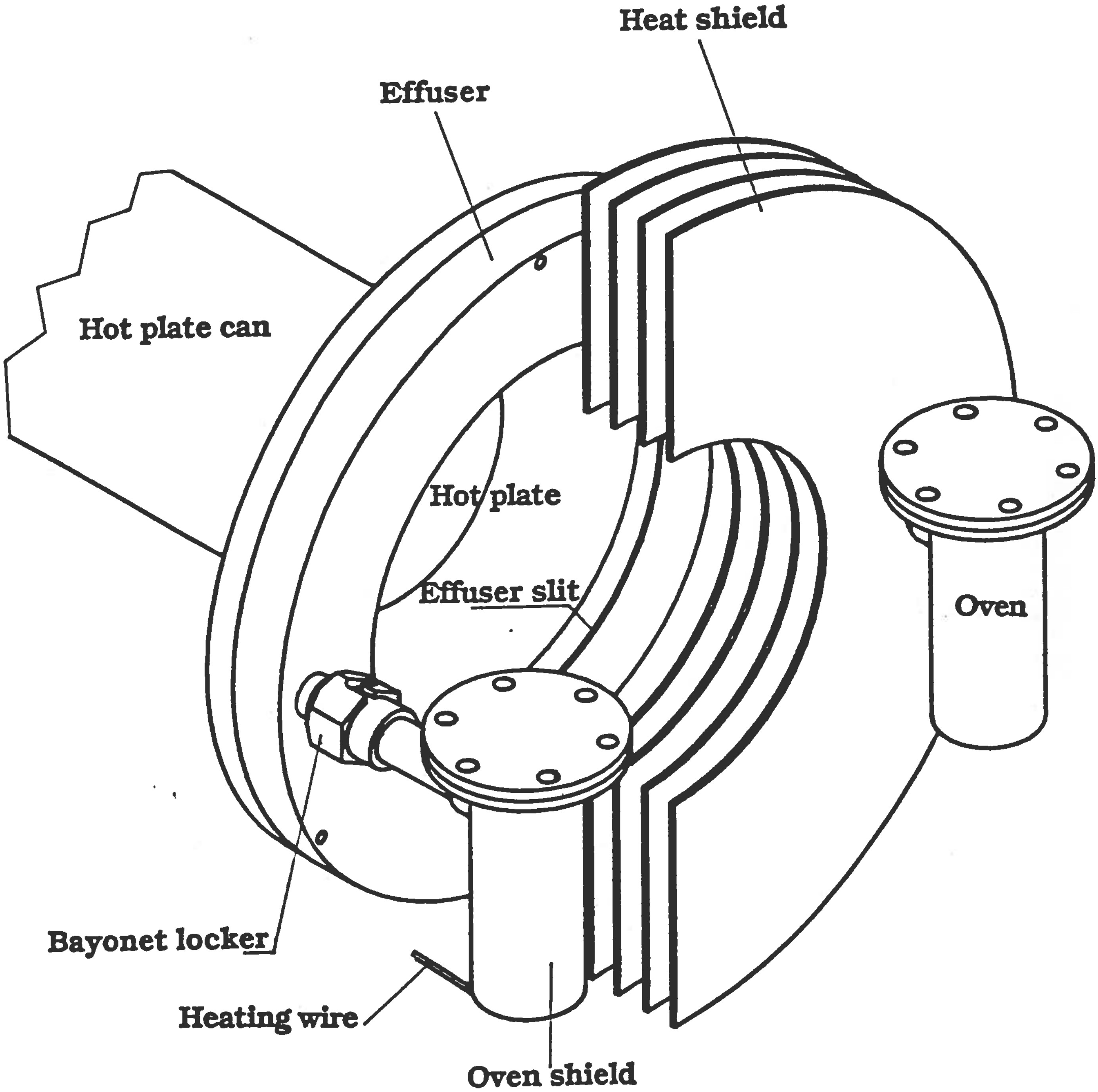
FIG. 1b) Detailed construction of one vaporising oven.

FIG. 1c) Heating power dependence of the oven temperature.

FIG. 2 Radial profile of the perpendicular and parallel ion temperature obtained via LIF.

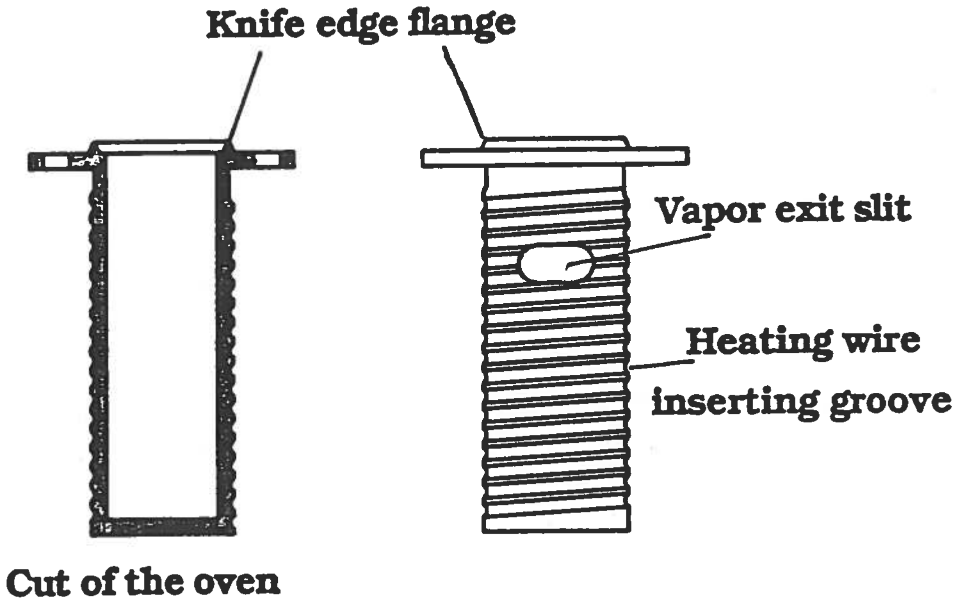
FIG. 3a) Modification of density profile obtained by unbalanced heating of the two ovens, for a constant hot plate power (a): oven 1 temperature 390°C, oven 2 temperature 585°C; b): oven 1 and oven 2 at equal temperature; c) oven 1 temperature 335°C, oven 2 temperature 620°C). Measurements done by biased electrostatic probe.

FIG. 3b) Variations of total plasma density with hot plate power (a): 2.69 kWatts, b): 2.74 kWatts, c): 2.83 kWatts and d) 2.94 kWatts). The shape of the profile is conserved. Measurements done by biased electrostatic probe.



Heat shield
Effuser
Hot plate can
Hot plate
Effuser slit
Oven
Bayonet locker
Heating wire
Oven shield

Fig. 1a)



Knife edge flange
Vapor exit slit
Heating wire
inserting groove
Cut of the oven

Fig. 1b)

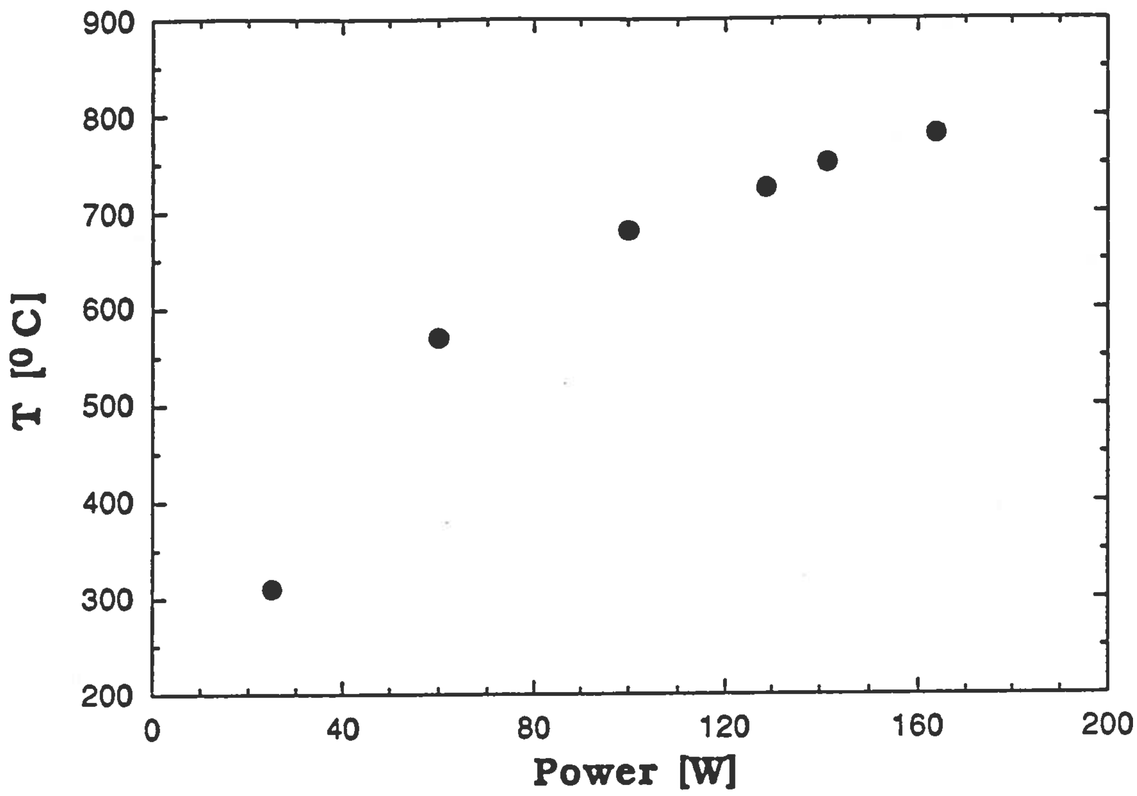


Fig. 1c)

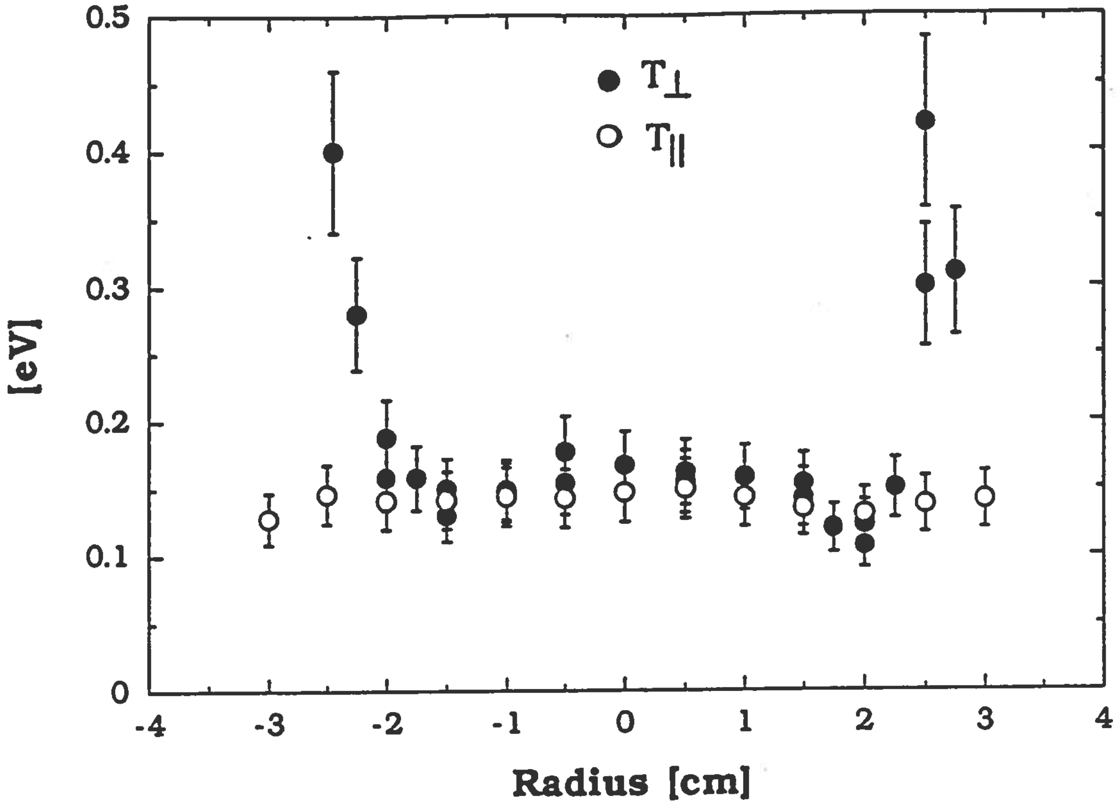


Fig. 2

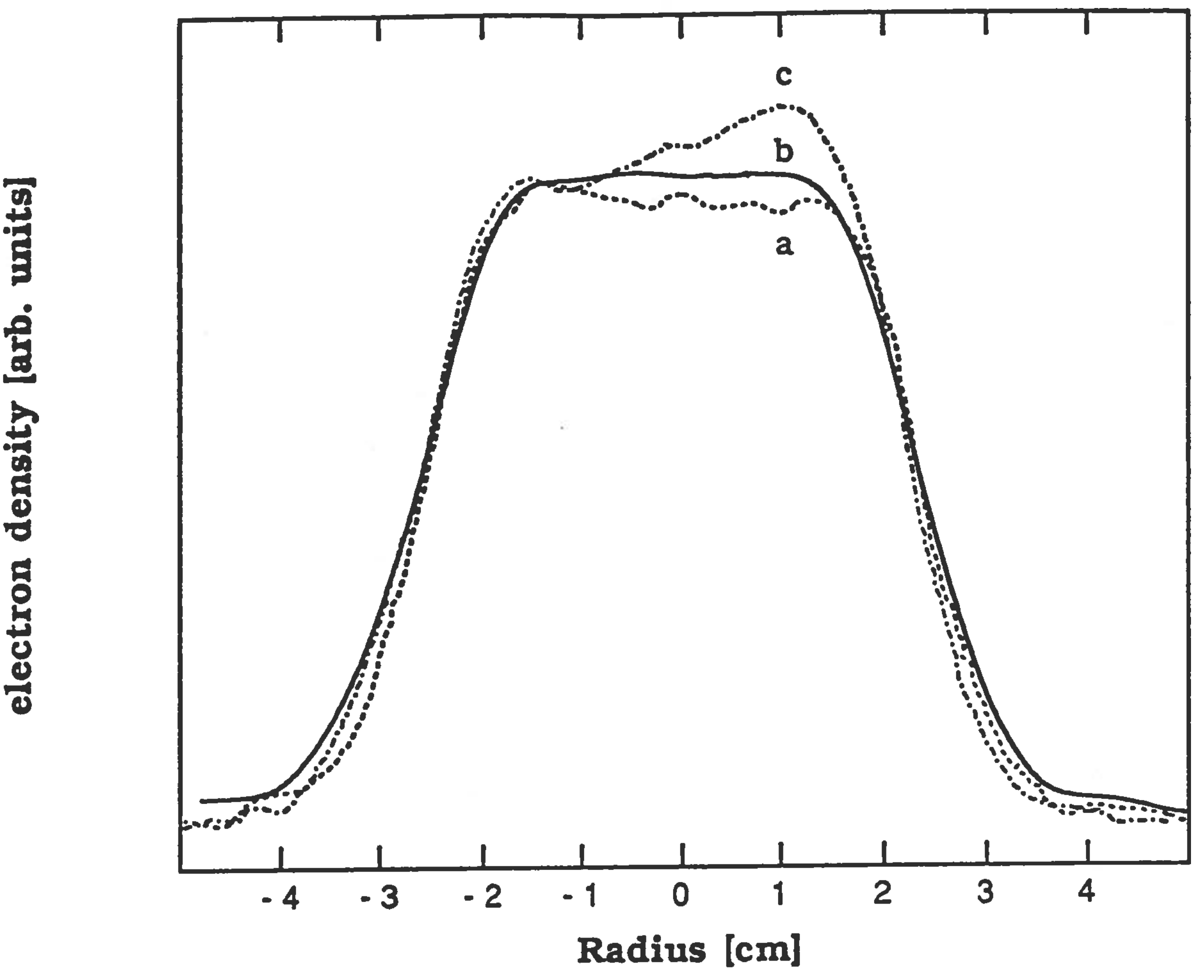


Fig. 3a)

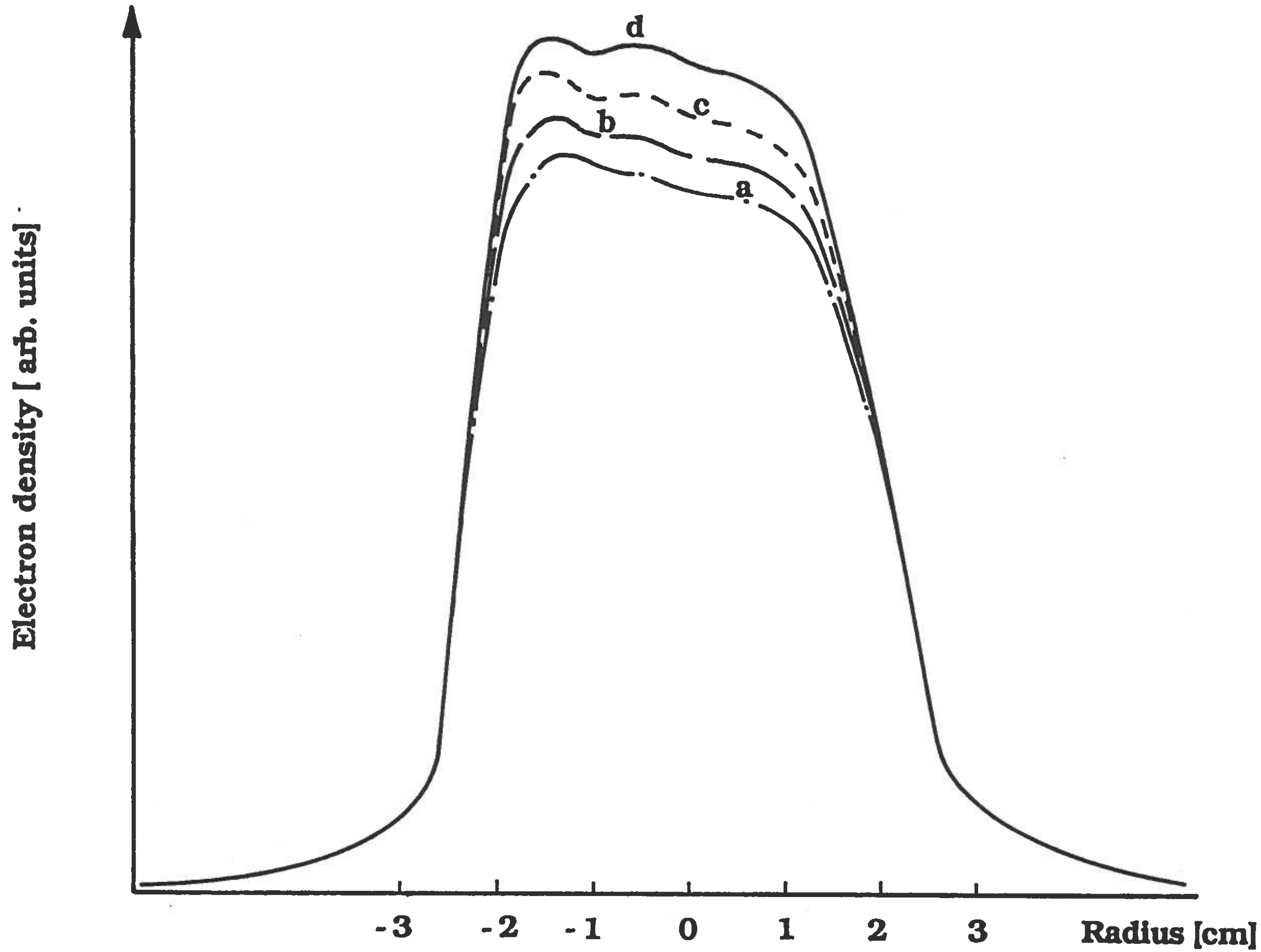


Fig. 3b)