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# A Study on Effect of Error Field on Toroidal Discharge in Air

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**ABSTRACT**

Breakdown threshold voltage of an electrode less toroidal discharge has been studied using H- type solenoid coil excited by a 13.56 MHz radio frequency power in absence and in presence of a toroidal error field with different pressures, and axial magnetic field for dry air. The breakdown threshold depends on various filling parameters e.g. error field , and magnetic field. Again the floating double probe technique was used to measure the plasma temperature and density in presence of error field using the equivalent resistance method [1,2,3,4,5] for dry air. all measurements were made in a 13.56 mhz inductively coupled radio frequency plasma discharge at different pressures ranging from 0.07 torr to 0.20 torr and magnetic field was varied between 0g to 75g.

***Keywords**:* Breakdown threshold, toroidal field , error field

## 1. Introduction

This work uses a set of simple and easy to make torii. Many such torii can be used with wide variation in all geometrical parameters [major radius (R), minor radius(r) and the aspect ratios ($\sigma$ =R/r)].Working gases, pressure and magnetic field can also be varied within the available limits. In the overall picture it is evident that discharge depends on the competition between the processes that generates ionising electrons and the loss mechanisms. The pressure of the gas affects the electrons to pick up energy from the electric field due to collision with ions and other electrons. This phenomenon happens in straight and simple way in the DC field but takes place in a more complicated manner for an RF field. Gas pressure also controls the diffusion losses since it invariably helps to restrict perpendicular diffusion of charged particles to the wall of the torus. Then there is a host of atomic parameters which come into play even in a simplified model of the start-up phase of a toroidal machine and for the development of discharge in a toroidal machine.

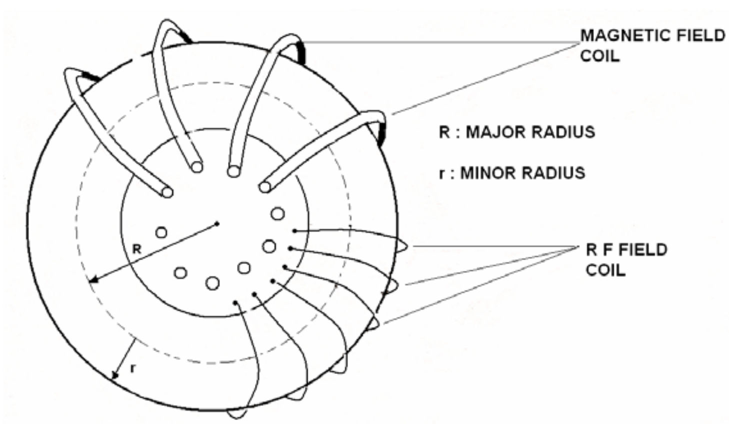
The Langmuir probe method is one of the standard methods of measuring the plasma parameters such as electron temperature and electron density in a gaseous discharge. Johnson and Malter **[1]**, Burrows **[2]**, Dote**[3]**, Sadhya etal **[4]** has described and developed Langmuir probe technique and proposed the floating double probe technique by an equivalent resistance method to obtain plasma parameters. Later on further modification Dote**[3]**, Yamamoto and Okuda **[5]**, and Yong-ik Sung etal **[6]**, established a new method to determine electron temperature through floating double probe characteristics. In the present scenario we repeated the same procedure but in presence of a calibrated error field which stands perpendicular to the toroidal chamber.

**2.1. Experiment 1** Our primary objective for the experiment and the analysis of the data obtained is to get a trend of the variation of different parameters concerned.
Initially the Toroidal chamber is evacuated to about $10^{-3}$ torr and was filled with dry air at different pressures varying from 0.001 to 0.1 torr. The pressure was measured with a Mcloid gauge.
An axial magnetic field was supplied and was varied from 0 G to 80 G. for a constant value of magnetic field, the pressure is raised and the threshold breakdown voltage is measured under varying perpendicular error field as shown in figure 1 & 2.

**2.2. Experiment 2** The apparatus used in this experiment is shown in figure 3 & 4.The cylindrical double probe was placed near the maximum of an plasma density and each probe being of platinum wire with 0.2 mm diameter and 5 mm length parallel and perpendicular to the discharge axis for axial modes of magnetic field. All the measurements were made

a) at a different set of constant pressure between 0.07 to 0.175 Torr with varying magnetic field.

b) at a different set of constant magnetic field between 0 to 70 gauss with varying pressures.



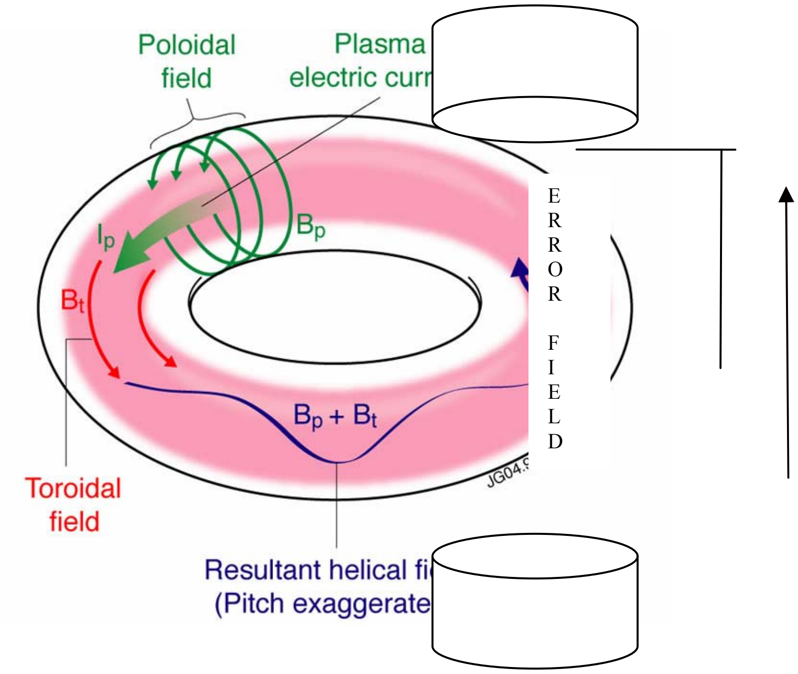



Figure 1 : Schematic diagram of the production of error field on the torus at threshold breakdown voltage.

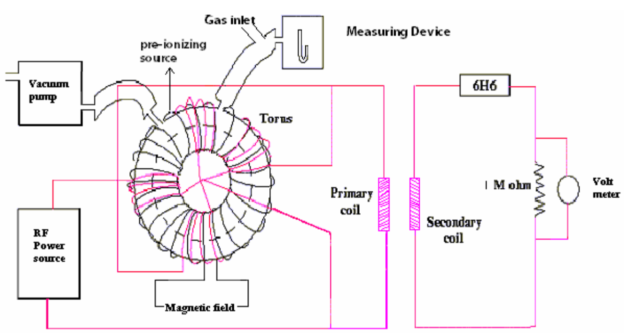



Figure : 2 The schematic diagram for experimental set up for measuring the threshold breakdown voltage

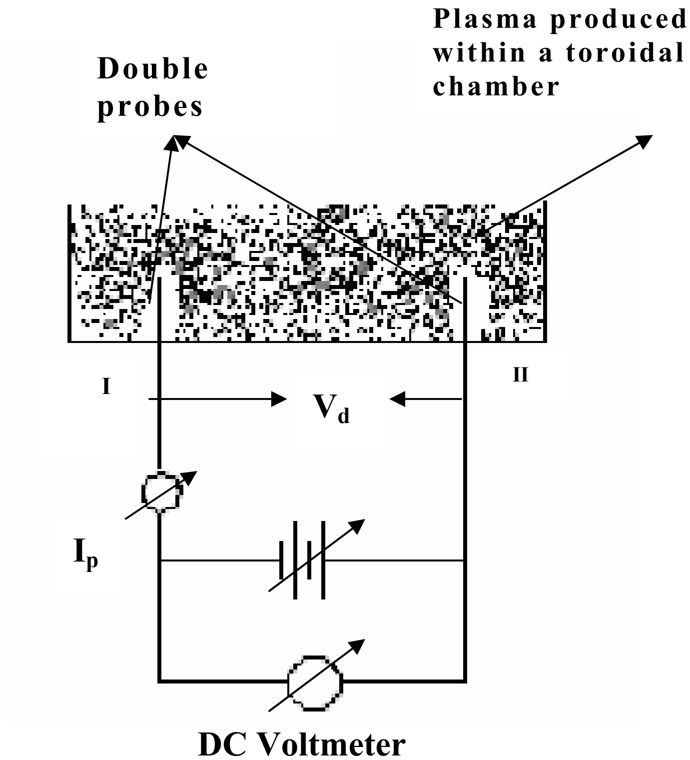



Figure 3: Set up of the Floating Double Probe

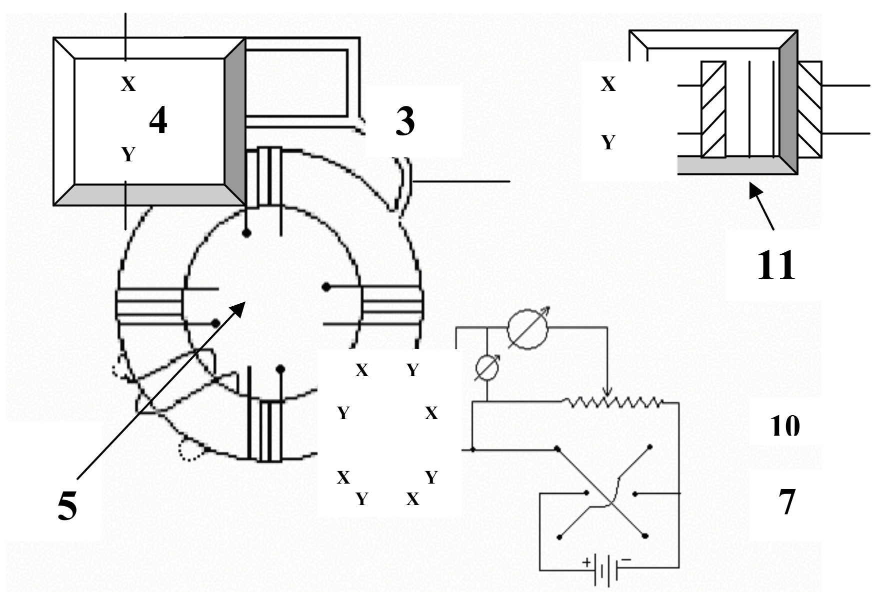
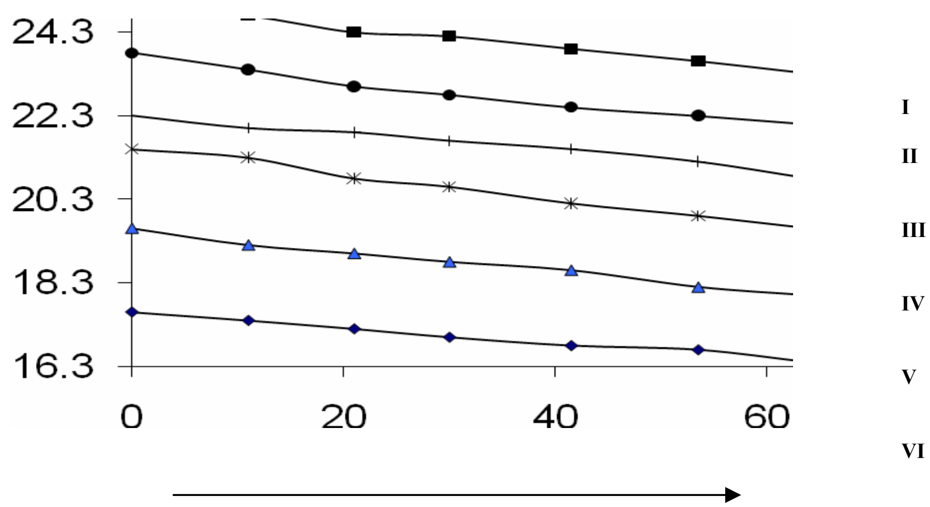



Figure 4: Circuit diagram for parameters studies

1. Annular coils for axial magnetic field
2. Annular H type solenoid coil
3. Gas inlet with measurement of filling pressure
4. Radio frequency power source
5. The toroidal chamber
6. Double probes
7. D.C Voltage source for probes
8. Single resistor for measuring positive ion current or electron current
9. D.C voltmeter for measuring probe voltage
10. D.C μ ammeter for measuring probe current
11. Tuning coil with Primary and Secondary




**Toroidal Mag. field in gauss**

Figure 5 : Variation of threshold breakdown voltage ( $V_{th}$ ) with toroidal Mag. Field ( H ) at aspect ratio 4.14 for dry air (a) with pre-ionisation : filling pressure I : P = 0.1 torr ; II : P = 0.15 torr ; III : P = 0.2 torr ( b ) without pre-ionisation : filling pressure IV : P = 0.1 torr ; V : P = 0.15 torr ; VI : P = 0.2 torr under the error field of 10 gauss

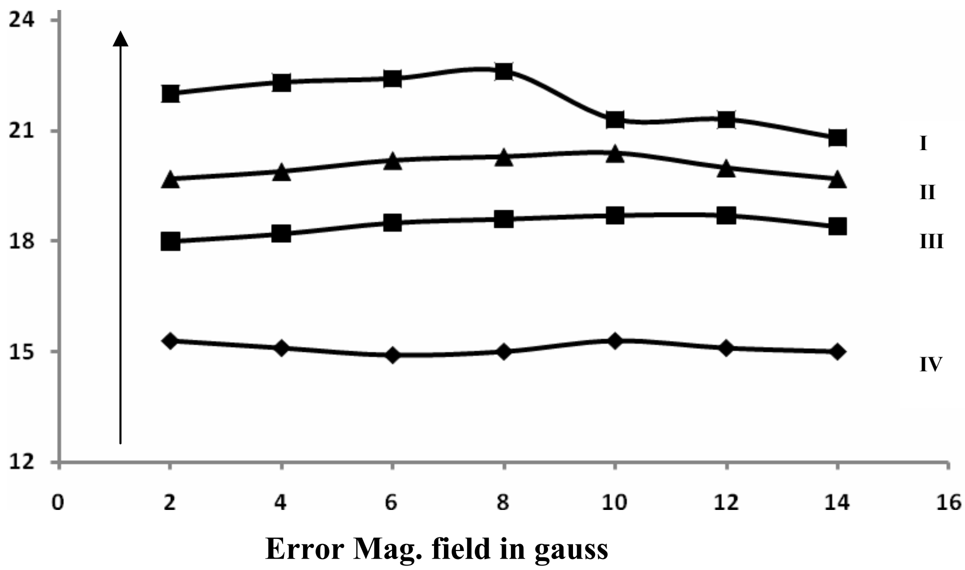



Figure 6: Variation of threshold breakdown voltage ( $V_{th}$ ) with Error field( $E_H$ ) for dry air without pre-ionisation : filling pressure I : P = 0.1 torr ; II : P = 0.125 torr ; III : P = 0.15 torr; IV : P =0.2 torr under the toroidal field of 50 gauss

***1.*** **Results And Discussions**

As a whole the experimental results show that the I-V characteristics curve is symmetrical because the probes have the same cross section. The maximum current that circulates for the double probe is similar to the ion saturation current and, therefore, the maximum current is lesser than that of the single probe and can assure a smaller plasma perturbation. These results imply that plasma particles correspond well with the Maxwellian distribution by using the theoretical curve to determine the basic parameters of the plasma.

From the result it is observed that at weak fields the I-V curves are approximately symmetric, but by increasing the field strength they become asymmetric. The magnetic field can have considerable effects on the ion current collection even though the ion gyro radius is much larger than the probe sizes.

The lack of ion saturation is slowly increasing due to an expansion of sheath thickness as the probe goes increasingly negative with respect to the plasma.

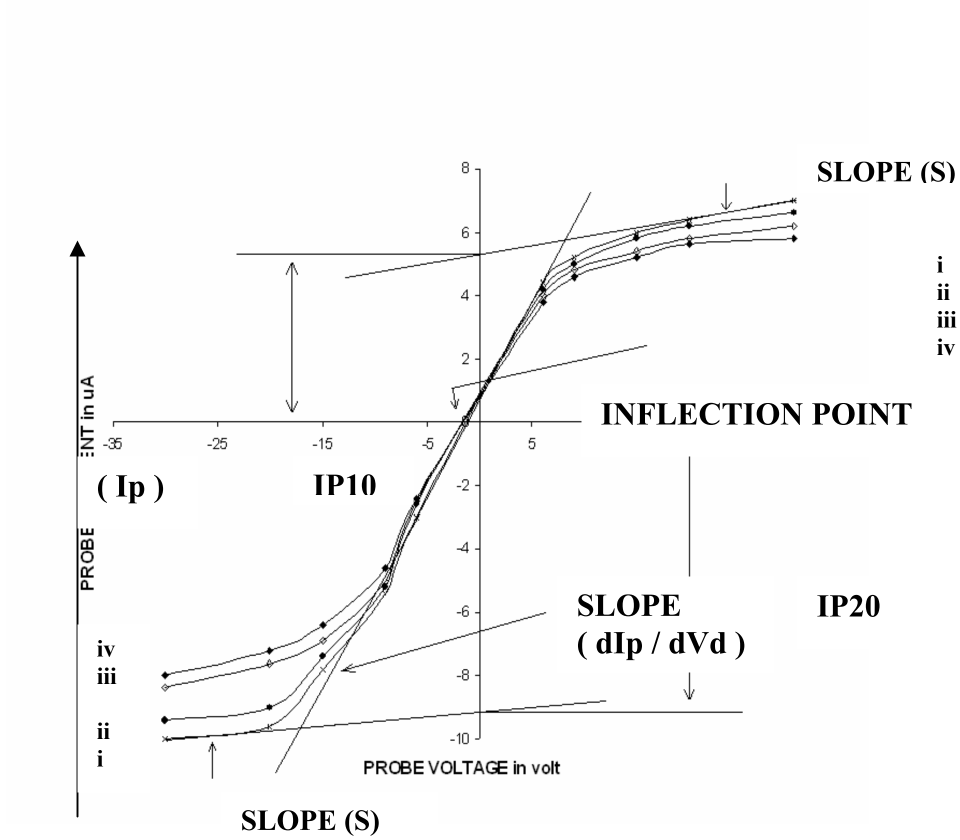



Figure 7: The double probe characteristics in axial to the toroidal magnetic field at (P) =0.1 Torr
(i) H = 0 G, (ii) H = 25G, (iii) H = 50 G, (iv) H = 75 G, at error field of 10 gauss

| **PRESSURE in Torr** | **MAGNETIC FIELD in Gauss** | **ELECTRON TEMPERATURE ($T_e$) in ev** | **ELECTRON DENSITY ($\sigma$) X $10^{26}$ per $m^3$** |
|---|---|---|---|
| 0.125 | 00 | 0.928854 | 1386.056 |
| | 22 | 0.994000 | 1568.272 |
| | 48 | 1.221916 | 1252.158 |
| 0.15 | 00 | 1.501842 | 912.6305 |
| | 22 | 1.644554 | 854.8183 |

| | | | |
|---|---|---|---|
| | 48 | 1.985965 | 728.6746 |
| | 70 | 2.233390 | 707.6937 |
| 0.175 | 00 | 1.254464 | 0758.926 |
| | 22 | 1.450490 | 648.7812 |
| | 48 | 1.552480 | 620.6071 |
| | 70 | 1.927033 | 587.9436 |

Table 1 : Variation of electron temperature and electron density with toroidal magnetic field for different pressures and at constant error field of 10 gauss

| **PRESSURE in Torr** | **Error FIELD in Gauss** | **ELECTRON TEMPERATURE ($T_e$) in ev** | **ELECTRON DENSITY (σ) X $10^{26}$ per $m^3$** |
|---|---|---|---|
| 0.1 | 02 | 1.114224 | 1327.2180 |
| | 08 | 1.370192 | 1239.5890 |
| | 14 | 1.588480 | 1190.9700 |
| 0.15 | 02 | 1.979167 | 1102.5310 |
| | 08 | 1.488189 | 0881.8198 |
| | 12 | 1.784581 | 0823.9957 |
| | 14 | 2.077703 | 0781.0184 |
| 0.175 | 02 | 1.678103 | 0772.4870 |
| | 08 | 1.884993 | 0765.3056 |
| | 12 | 2.119565 | 0756.0834 |
| | 14 | 2.194224 | 701.21800 |

Table 2 : Variation of electron temperature and electron density with error field for different pressures and at constant toroidal field of 50 gauss

**3. Conclusion**

We studied the plasma threshold breakdown voltage of toroidal discharge in presence of toroidal magnetic field and as well as error magnetic field in different sets of pressures. The variation of threshold voltage with magnetic field at a consant error field is gradually decreasing but at a constant toroidal field the variation with error field is almost linear. Again electron temperature and electron number density were determined at different error fields keeping the toroidal field constant and vice versa for different sets of pressures. The variation of electron temperature and number density with error field at constant toroidal magnetic field is are shown in table 1 and table 2.

In this paper we have covered only some aspects of experimental information and its application in equivalent resistance method. These aspects are of much interest at the present time, however, and further development both theoretical and experimental are to be expected.

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