Chapter 4

Plasma parameters and system characterisation

4.1 Introduction

The complete experimental setup with various sub-systems and the diagnostics is discussed in chapter 2. The initial experiments with ECR breakdown and estimation of various breakdown parameters are presented in chapter 3 at different experimental parameters. In this chapter, the complete description of plasma parameters such as floating potential, plasma density, and plasma temperature is presented in both radial as well as in axial direction. These parameters have a variation with the operating gas pressure and input microwave power also. The radial and axial profiles of these parameters forms the basis for the estimation and identification of various cutoffs and resonances in the plasma system. The information regarding plasma parameters is also necessary to set the initial conditions for any experiment.

In this chapter, the EM wave propagation in waveguide is discussed with the wave electric and magnetic field patterns. The quality factor for the cylindrical plasma system is estimated. The theoretical estimation of plasma parameters is made for this experimental system. The variation in plasma parameters with operating parameters is presented with the explanations. Various resonance and cutoff locations are identified using the radial profiles of plasma parameters and the magnetic field. The electric field generated in plasma is also discussed.
4.2 Field distribution in waveguide

The microwave power in the experimental system is launched through a WR340, 86 mm x 43 mm rectangular waveguide which has a characteristic frequency range 2.20 – 3.30 GHz with 1.7357 GHz cutoff frequency. It has a return loss of more than -50 dB over a frequency range 2.40 – 2.50 GHz. The insertion loss is better than -0.01 dB for the waveguide and it has a VSWR (voltage standing wave ratio) less than 1.02 over the desired frequency range.

The waveguide is selected so as to support \( TE_{10} \) mode propagation. The subscript 10 means the half-period wavelengths in \( x \) and \( y \) directions respectively. An attempt has been made to obtain the electric and magnetic field distributions inside the waveguide. The cartesian co-ordinates associted with three sides of the rectangular waveguide are shown in figure 4.1.

![Figure 4.1: The co-ordinates and dimensions of a rectangular waveguide.](image)

The distribution of the electric and magnetic fields inside the waveguide in three different planes are shown in the figures that follows. The arrows in the figures show the direction of the respective field. The electric field exists only at the right angles to the direction of propagation, whereas the magnetic field has a component in the direction of propagation as well as a normal component. The electric field is maximum at the centre of the waveguide for \( TE_{10} \) mode and drops off sinusoidally to minimum zero intensity at the walls. The magnetic field is in the form of closed
loops, which lies in planes normal to the electric field i.e. parallel to top and bottom of the waveguide.

In figure 4.2, the electric and magnetic field distribution in the AB plane of the waveguide is depicted at the input plane, central plane and the output plane. The field distributions at the input and the output planes is identical due to symmetry.

Figure 4.2: Electric and magnetic field distribution in AB plane.

In AB plane, the electric field is maximum at the centre at all the observation places. It is also to be noted that the magnitude of the wave electric field is high at the centre than at the edge. Similarly, the magnetic field maxima is at the centre on the openings and at the centre of the waveguide. The magnitude of wave magnetic field increases as it reaches the centre but remains less as compared to the wave electric field at that position.
The electric and magnetic field distributions in the BC plane of the waveguide is depicted in figure 4.3, at the edge and at the centre.

Figure 4.3: Electric and magnetic field distribution in BC plane.

In $TE_{10}$ mode, the wave electric field should be minimum near the waveguide walls as shown in figure 4.3(a). The wave magnetic field becomes oscillatory at the edges as shown in figure 4.3(b). At the centre, the magnetic field becomes minimum and the electric field starts oscillating as shown in figures 4.3(c) and 4.3(d) respectively.

In figure 4.4, the electric and magnetic field distributions in the CA plane of the waveguide is depicted at the central plane. The field distributions at the two sides and at the central planes are identical due to symmetry. As seen from figure 4.4(a), the electric field is minimum at the centre. Figure 4.4(b) shows that the magnetic field also has a minima at the centre but it increases towards the edge planes.
Figure 4.4: Electric and magnetic field distribution in CA plane.

The electric field distribution in the cylindrical chamber is shown in figure 4.5 which shows a maxima at the geometrical axis of the experimental chamber.

Figure 4.5: Electric field distribution in cylindrical chamber.

4.3 Quality factor, $Q$

The cylindrical plasma system is analyzed for a resonant cavity to estimate the quality factor. The quality factor, $Q$ of a resonant cavity is given by

$$Q = \frac{2}{\delta} \left( \frac{V}{S} \right)$$  \hspace{1cm} (4.1)
where $V$ is the volume of the cavity, $S$ is the internal surface area and $\delta$ is the skin depth given by

$$\delta = \frac{1}{\sqrt{\pi f \mu_c \sigma_c}}$$ (4.2)

here $f$ is the launched microwave frequency, $\mu_c$ is the permeability of the conductor and $\sigma_c$ is the conductivity of the conductor.

The volume $V$ and internal surface area $S$ of the cylindrical cavity is given by

$$V = \pi r^2 l$$
$$S = 2\pi rl + 2\pi r^2$$ (4.3)

here, $l$ is the axial and $r$ is the radial length of the cylindrical cavity. This gives

$$\frac{V}{S} = \frac{rl}{2(r + l)}$$ (4.4)

For this cylindrical system, $l = 10 \text{ cm}$ and $r = 12.8 \text{ cm}$, the ratio comes out to be

$$\frac{V}{S} = 0.0195$$ (4.5)

For $f = 2.45 \text{ GHz}$, $\sigma_c = 10^7/6 (\Omega \text{m})^{-1}$ (for SS304) and $\mu_c = 9.029 \times 10^{-7} \text{ N/A}^2$, skin depth $\delta$ comes out to be

$$\delta = 9.26 \times 10^{-6} \text{ m}$$ (4.6)

From equations (4.1), (4.5) and (4.6), the quality factor comes out to be

$$Q \approx 4200$$ (4.7)

which shows that this cylindrical system is a poor resonator for the operating frequency 2.45 GHz. This system (diameter = 12.82 cm, length = 10 cm) will resonate at a frequency 1.426 GHz. For a frequency of 2.45 GHz, the system should have dimensions, diameter = 4.53 cm and length = 10 cm or diameter = 12.82 cm and length = 7.38 cm.

### 4.4 Estimation of plasma parameters

1. Plasma density, $n_e$
The plasma density is estimated by assuming plasma as a fluid. The electron fluid velocity is given by

\[ v_{\text{fluid}} = \frac{eE}{m_e \nu} \left( \frac{\nu^2}{\nu^2 + \omega^2} \right) \]  

(4.8)

where \( e \) is the electronic charge, \( E \) is wave electric field, \( \nu \) is the elastic electron-neutral collision frequency, \( m_e \) is electron mass and \( \omega \) is the launched wave angular frequency. For \( \nu \ll \omega \), the above equation reduces to

\[ v_{\text{fluid}} \approx \frac{eE\nu}{m_e \omega^2} \]  

(4.9)

The average oscillating energy \( \mathcal{E} \) of the electron in wave is given by

\[ \mathcal{E} = \frac{\eta P_{RF}}{4\pi^2 m_e^2 c^2} = 2 \times 10^{-5} P_{RF} \]  

(4.10)

where, \( \eta \) is the free air impedance \( \approx 377 \, \Omega \), \( P_{RF} \) is the launched microwave power and \( c \) is the velocity of light in free space. For \( P_{RF} = 800 \, W \), it is

\[ \mathcal{E} = 1.6 \times 10^{-2} \, eV \]  

(4.11)

This is the energy gained in each collision which is less than the ionization energy for hydrogen \( (E_t \sim 13.6 \, eV) \). The average oscillating energy or \( RMS \) energy, \( \mathcal{E} \) is converted into random energy through elastic collisions which finally results in the electron heating. The number of such elastic collisions \( (N_{\text{coll}}) \) required to achieve \( E_t \) is given by

\[ N_{\text{coll}} = 13.6/1.6 \times 10^{-2} = 850 \sim 1000 \]  

(4.12)

According to electron fluid model, the average energy transfered to the electrons is

\[ \frac{d\mathcal{E}}{dt} = -e\vec{E} \cdot \vec{v} \]  

\[ \frac{d\mathcal{E}}{dt} \approx 2\nu E_{\text{RMS}} \]  

(4.13)

where \( \vec{E} \) is the wave electric field, \( \vec{v} \) is the electron thermal velocity and \( \nu \) is the electron collision frequency. The power coupled from electrons to neutrals through inelastic collisions is

\[ P \approx n_e V \nu_{in} E_t \approx n_e V f \nu_e E_t \]  

(4.14)
For
\[ \nu_n = n_n < \sigma_n v > \]
\[ \nu_e = n_n < \sigma_e v > \]  
(4.15)
\[ f \approx \nu_n / \nu_e \]

From the electron balance equation
\[ n_n n_e < \sigma_e v > = n_e / \tau_p \]
\[ \nu_e = 1 / \tau_p \]  
(4.16)

where, \( n_n \) is the neutral density, \( n_e \) is the electron density, \( < \sigma_e v > \) is the rate constant of ionization and \( \tau_p \) is the plasma confinement time. From equations (4.14) and (4.16), we have
\[ P = n_e V f E_i / \tau_p \]
(4.17)
\[ n_e = P \tau_p / V f E_i \]

In this experiment, \( P_{coupled} = 400 \text{ W}, E_i = 13.6 \text{ eV}, f = 10 \) (typically), \( \tau_p = 2.5 \mu \text{sec} \) and \( V = 1.29 \times 10^{-3} \text{ m}^3 \). Plasma density comes out to be
\[ n_e = 3.6 \times 10^{10} \text{ cm}^{-3} \]  
(4.18)
This matches well with experimentally measured plasma density, \( n_e = 3.2 \times 10^{10} \text{ cm}^{-3} \) in the system.

2. Plasma temperature, \( T_e \)

Plasma temperature is estimated from the electron balance equation
\[ n_n n_e < \sigma_e v > = n_e / \tau_p \]
\[ n_n \tau_p = 1 / < \sigma_e v > \]  
(4.19)
where, \( n_n \) is the neutral density of hydrogen. For atomic hydrogen
\[ < \sigma_e v > = \frac{2 \times 10^{-13}}{6 + T_e / E_i} \left( \frac{T_e}{E_i} \right)^{\frac{1}{2}} \exp \left( \frac{-E_i}{T_e} \right) \]  
(4.20)
here \( < \sigma_e v > \) is the rate constant for ionization and \( T_e \) is the electron temperature. Equation (4.19) and (4.20) gives
\[ n_n \tau_p \sim 10^{13} \left( 3 + \frac{T_e}{2E_i} \right) \left( \frac{E_i}{T_e} \right)^{\frac{1}{2}} \exp \left( \frac{E_i}{T_e} \right) \]  
(4.21)
For $\tau_p = 2.5\ \mu\text{sec}$ and $n_n = 3.3 \times 10^{19} \text{ m}^{-3}$ for an operating pressure of $10^{-3}\ \text{mbar}$, the plasma temperature can be estimated from the figure 4.6 as

$$T_e \approx 10\ \text{eV} \quad (4.22)$$

Figure 4.6: Theoretical estimation of plasma temperature.

The experimentally observed plasma temperature, $T_e$ is between $9 - 15\ \text{eV}$ which is in agreement with the theoretical estimation.

### 4.5 Spatial profiles of plasma parameters

Plasma parameters obtained in hydrogen plasma are measured in the experimental system with two Langmuir probes, placed in the axial and radial directions as discussed in Chapter 2. During all these measurements, the working pressure is kept constant at $1 \times 10^{-3}\ \text{mbar}$ and the input microwave power is fixed at $800\ \text{W}$. All the plotted values are averaged over three measurements. The errorbars in figures indicate the spread in the plasma parameter estimates.

1. Floating potential, $V_f$

   The floating potential variation in the axial direction is shown in figure 4.7 which shows that $V_f$ peaks at the centre at $\sim 4.5\ \text{V}$ and has a negative value near the walls because of high electron mobility.
Chapter 4: Plasma parameters ...

Figure 4.7: Axial variation of floating potential.

The floating potential variation measured in the radial direction is shown in figure 4.8.

Figure 4.8: Radial variation of floating potential.

Similar to axial profile, this profile also peaks at $\sim 5 \, V$ and $V_f$ value drops near the walls

2. Plasma density, $n_e$

The axial profile of plasma density is shown in figure 4.9.
As shown in figure, plasma density is constant at centre and falls down near the walls. The radial variation of plasma density is shown in figure 4.10.

As shown in figure, plasma density is higher towards the source from centre than on the opposite side. ECR breakdown occurs at the centre and plasma starts diffusing in radial direction across the magnetic field. The fraction of incident microwave power which is not absorbed in the first pass gets reflected and starts moving back towards the source and contribute in further ionization.
3. Plasma temperature, $T_e$

The axial variation of plasma temperature is shown in figure 4.11.

![Figure 4.11: Axial variation of plasma temperature.](image)

The figure shows the increase in temperature near the walls because of electron trapping at those positions due to higher magnetic field. The radial variation of plasma temperature is shown in figure 4.12.

![Figure 4.12: Radial variation of plasma temperature.](image)

Plasma temperature, in radial direction, varies between $10 - 18$ eV. It can be
seen from the figure that the temperature profile is also asymmetric about the centre and it is higher towards the microwave source side.

4.6 Temporal evolution of plasma parameters

The evolution of plasma parameters such as the floating potential and plasma density with time in the axial and radial positions is obtained in the ECR plasma system with Langmuir probes in the respective directions. During this measurement, data is acquired on a high sampling rate.

1. Floating potential, $V_f$

The time evolution of floating potential at different locations in the axial direction of the system is shown in figure 4.13. The figure clearly shows that floating potential peaks at the centre and attains a slight negative value at the extreme axial positions. The spikes in the figure are the pickups from different noise sources. Due to high magnetic fields at the edges, the signals have less noise near the walls.

Figure 4.13: Time evolution of axial floating potential.

The time evolution of the floating potential at different radial locations in the plasma system is shown in figure 4.14.
Figure 4.14: Time evolution of radial floating potential.

Similar to axial profile, the radial profile of floating potential also has a maximum value at the centre as can be seen from the figure.

2. Plasma density, $n_e$

The time evolution of ion saturation current, which is a measure of plasma density, at different locations in the axial direction is shown in figure 4.15. The Langmuir probe is given a bias voltage of -80 V to collect ions from plasma.

Figure 4.15: Time evolution of axial ion saturation current.
Chapter 4: Plasma parameters ...

The figure shows a constant plasma density in the central region. The time evolution of the ion saturation current at different radial positions is shown as in figure 4.16.

![Figure 4.16: Time evolution of radial ion saturation current.](image)

As evident from the figure, plasma density is higher at the two resonant surfaces and low in the other regions. The central peak can be clearly seen from the radial profile above.

4.7 Plasma parameter variation with experimental parameters

The variation in basic plasma parameters such as plasma density and temperature is measured with a variation in the operating conditions prior to the experiment. Hydrogen is used as the fill gas. The errorbars in the figures indicate the spread in plasma parameter estimates.

1. Plasma parameter variation with input microwave power

Plasma density variation with input microwave power is shown in figure 4.17. During the measurement, the operating pressure is kept constant at $1 \times 10^{-3} \text{ mbar}$. 
As can be seen from the figure, the plasma density increases with the increase in input microwave power and almost a linear relationship exists. The electron production is less at low power. The increased power increases the ionization and hence the plasma density.

The variation of plasma temperature, $T_e$ with the input microwave power is shown in figure 4.18. During the measurement, the operating pressure is kept constant at $1 \times 10^{-3}$ mbar.

Figure 4.17: Plasma density variation with input microwave power.

Figure 4.18: Plasma temperature variation with input microwave power.
The figure clearly shows the increase in plasma temperature as the input microwave power is increased. The increased input power contributes towards the increase of average kinetic energy with which the newly generated electrons are produced. Hence, the plasma temperature as a whole increases.

2. Plasma parameter variation with working gas pressure

The variation of plasma density with the working gas pressure is shown in figure 4.19. The input microwave power during the experiment is fixed at 800 W.

![Figure 4.19: Plasma density variation with working pressure.](image)

As evident from the figure, the plasma density increases linearly with the increase in operating gas pressure. The increase in neutral population at higher operating pressures increases the plasma density at the same degree of ionization.

The plasma temperature variation with the operating pressure at a constant input microwave power is shown in figure 4.20. From the figure, it can be inferred that when the operating pressure is more, the plasma temperature reduces because the plasma density increases and so is the collision frequency.

For plasma density of $3 \times 10^{10} \text{ cm}^{-3}$, the electron collision rate, $\nu_e$ is $4.85 \times 10^4 \text{ sec}^{-1}$. Hence, the energetic electrons got thermalized and loose their energy.
4.8 Estimation of resonances and cut-offs

A cold inhomogeneous plasma model is assumed in a magnetic field along $z$ direction. The electric field variation is assumed to be

$$ E \sim e^{-\omega t} $$

(4.23)

Inside the plasma, it is given by

$$ \nabla \times (\nabla \times \vec{E}) = \frac{\omega^2}{c^2} \vec{K} \cdot \vec{E} $$

(4.24)

where, $\omega$ is the angular frequency, $c$ is the velocity of light and $\vec{K}$ is the plasma permittivity tensor given by

$$ \vec{K} = \begin{pmatrix} K_\perp & -iK_X & 0 \\ -iK_X & K_\perp & 0 \\ 0 & 0 & K_\parallel \end{pmatrix} $$

(4.25)

where

$$ K_\perp = 1 - \frac{\omega_{pe}^2}{\omega^2 - \omega_{ce}^2} $$

(4.26)

$$ K_X = -\frac{\omega_{ce}}{\omega} \frac{\omega_{pe}^2}{\omega^2 - \omega_{ce}^2} $$

(4.27)
Equation (4.24) gives

\[ K_{\parallel} = 1 - \frac{\omega_{pe}^2}{\omega^2} \]  

Equation (4.24) gives

\[ K_{\perp} n_{\perp}^4 + [(K_{\perp} + K_{\parallel})(n_{\parallel}^2 - K_{\perp}) + K_{X}^2]n_{\perp}^2 + \{(n_{\parallel}^2 - K_{\perp})^2 - K_{X}^2\}K_{\parallel} = 0 \]  

(4.29)

where \( n_{\parallel} = c k_{\parallel}/\omega \) and \( n_{\perp} = c k_{\perp}/\omega \).

For \( n_{\perp} = 0 \), equation (4.29) reduces to

\[ [(n_{\parallel}^2 - K_{\perp})^2 - K_{X}^2]K_{\parallel} = 0 \]  

(4.30)

This equation gives cut-offs for

\[ K_{\parallel} = 0 \]  

(4.31)

The o-mode cutoff

\[ \omega = \omega_{pe} = \omega_{O} \]  

(4.32)

The other part also give cutoff

\[ (n_{\parallel}^2 - K_{\perp})^2 - K_{X}^2 = 0 \]  

(4.33)

The left-hand cut-off

\[ (n_{\parallel}^2 - K_{\perp}) - K_{X} = 0 \]

\[ \omega = \omega_{L} = \frac{1}{2} \left[ \left( \omega_{ce}^2 + \frac{4\omega_{pe}^2}{1-n_{\parallel}} \right)^{1/2} + \omega_{ce} \right] \]  

(4.34)

and the right-hand cut-off

\[ (n_{\parallel}^2 - K_{\perp}) + K_{X} = 0 \]

\[ \omega = \omega_{R} = \frac{1}{2} \left[ \left( \omega_{ce}^2 + \frac{4\omega_{pe}^2}{1-n_{\parallel}} \right)^{1/2} - \omega_{ce} \right] \]  

(4.35)

Equation (4.29) gives resonance for

\[ K_{\perp} = 0 \]  

(4.36)

The upper hybrid resonance as

\[ \omega = \omega_{uhr} = \sqrt{\omega_{pe}^2 + \omega_{ce}^2} \]  

(4.37)
1. Resonances

Two different resonances are observed to be existing in the cylindrical plasma system. The frequencies of first two harmonics of electron cyclotron resonance (ECR) and the upper hybrid resonance (UHR) are calculated using the measured radial profiles of plasma density and the externally applied DC magnetic field.

The radial profile of the electron cyclotron frequency, $f_{ce}$ and electron plasma frequency, $f_{pe}$ is calculated and plotted as shown in the figure 4.21 with the launched source frequency $f_0$ (2.45 ± 0.02 GHz).

![Figure 4.21: Radial variation of $f_{ce}$ and $f_{pe}$.](image)

As can be seen from the figure, the first ECR surface, $B = 875 \text{ G}$, is located at $R = 0 \text{ cm}$, the geometric axis of the system whereas the second ECR surface is residing at $R = 5 \text{ cm}$, near the wall of the plasma system on both sides, towards the microwave power source as well as away from the source due to the symmetry in the magnetic field profile about the centre of the system, $R = 0 \text{ cm}$.

The radial profile of UHR frequency for the hydrogen plasma is shown in figure 4.22 with the launched source frequency $f_0$. As observed from the figure, the UHR layer exists at two locations, because of the radially symmetric externally applied DC magnetic field in the system at $R = 2 \text{ cm}$ towards microwave.
source and at $R = -2 \, cm$ on the opposite side of the microwave source from the geometric centre of the system.

![Figure 4.22: Radial variation of $f_{\text{UHR}}$.](image)

2. Cutoffs

Two cutoffs ($f_L$ and $f_R$), on either side of the central axis, exist in this linear ECR plasma system as shown in figure 4.23.

![Figure 4.23: Radial variation of $f_L$ and $f_R$.](image)

As evident from the figure, the right-hand X-mode cutoff resides at $R = 5 \, cm$
Figure 4.25: Contour plot of plasma density.

The figure clearly shows that the contours of equal plasma density are generated at the geometrical centre of the experimental chamber whereas at a distance away from centre radially and axially it exhibits slab geometry.

3. Plasma temperature

Plasma temperature distribution on equatorial plane is shown in figure 4.26.

Figure 4.26: Contour plot of plasma temperature.

The measurements, plotted in the figure reveals that plasma temperature is
minimum at the centre and maximum near the ends of the plasma system.

For a fixed axial position it is constant in the radial direction.

4.10 Electric field in plasma

The space potential, $\phi_s$ for the hydrogen can be measured indirectly from the floating potential and electron temperature [83] as

$$\phi_s = \phi_f + 3.6 \left( \frac{kT_e}{e} \right)$$  \hspace{1cm} (4.38)

where $\phi_f$ is floating potential, $T_e$ is plasma temperature, $k$ is Boltzmann constant and $e$ is the electronic charge. The derivative of $\phi_s$ with respect to the radial and axial distance, the radial and the axial electric field is obtained as given by the equation

$$E_r = -\frac{d\phi_s}{dr}$$  \hspace{1cm} (4.39)

The electric field of plasma in the axial direction is shown in figure 4.27. The electric field is symmetric in the direction as expected.

![Electric field in plasma in axial direction.](image)

The electric field of plasma in the radial direction is shown in the figure 4.28. The figure shows the regions in the form of potential wells where electrons can be be trapped to heat up.
Figure 4.28: Electric field in plasma in radial direction.

The figure shows the regions in the form of potential wells where electrons can be trapped to heat up.

4.11 Conclusion

The wave propagation in WR340 waveguide is analysed by obtaining the electric and magnetic field patterns when microwave power flows in $TE_{10}$ mode. It is observed that the wave electric field is maximum at the central axis once it enters the cylindrical experimental chamber.

Hydrogen plasma is formed in a cylindrical chamber using ECR method. Plasma parameters are measured in the axial and radial directions in experimental system with Langmuir probes installed appropriately. Hydrogen is used as the filling gas at an operating pressure of $1 \times 10^{-3} \text{ mbar}$ with 800 W of input microwave power. A peak plasma density of $3.2 \times 10^{10} \text{ cm}^{-3}$ at first ECR layer and $2.7 \times 10^{10} \text{ cm}^{-3}$ at second ECR layer. Plasma temperature in the experimental system is between 9 – 15 eV. The experimentally observed plasma density and plasma temperature matches well with the theoretically estimated values. The floating potential at the centre of the system in the system is $\approx 5 \text{ V}$. It has been observed from the radial and axial profiles that the floating potential becomes negative near the walls due to
the high mobility of electrons.

The locations of the first and second harmonic ECR and UHR surfaces are identified from the radial profiles of plasma density and externally applied DC magnetic field. The fundamental resonance resides at the centre \( R = 0 \, \text{cm} \) while the second harmonic comes out to be at \( R = 5 \, \text{cm} \) near the wall towards the microwave source. The UHR surfaces lies at either side of the central axis due to symmetric externally applied magnetic field.

The left-hand and right-hand X-mode cut-offs are estimated for the ECR plasma system using the radial profiles of plasma parameters and DC magnetic field. The left-hand cut-off is located near \( R = -5 \, \text{cm} \) from the centre of the plasma system and on the opposite side of the microwave source whereas the right hand cut-off is residing at \( R = 5 \, \text{cm} \) towards the microwave power source.

The equatorial \((y = 0)\) contour profiles of floating potential, plasma density and plasma temperature are measured for the ECR plasma system. These measurements reveal that the contours of equal plasma density and equipotential are generated at the geometrical centre of experimental chamber whereas at a distance away from the centre radially and axially it exhibits slab geometry.

Electric field in plasma is estimated from plasma temperature and floating potential measurements. In the axial direction, the electric field is symmetric whereas it radial direction, it form potential wells where electrons can be trapped for heating.

The designed cylindrical plasma system is thus said to be characterized for advanced basic ECR experiments.