A.2: Numerical and experimental study of multi-cusp magnetic field in a cylindrical plasma chamber for H^- ion source

Multi-cusp magnetic field configuration has been found to be the most suitable technique for plasma confinement in generation of H^- ions through volume production. It has the capability to generate uniform and dense plasma that can produce high and stable negative ion current density in the presence of appropriate filter magnetic field. Two most important parameters of multi-pole configuration that determine the leak width and the uniform density plasma volume in the ion source are the cusp field strength and the diameter of the central field free region ($|B| < 10$ Gauss).

In the present study carried out at Power Supply Division, RRCAT, the vector potential and Fourier decomposition method has been used to determine the magnetic field intensity variation in the cylindrical chamber, which shows a power law radial dependence rather than the exponential form. In fact the exponential fit has been used in past with some correcting factors to predict the behavior of magnetic field in multi-pole arrangement. The expression derived for correctly predicting the absolute value of n^{th} harmonic of magnetic field is

$$B_n = \frac{N}{R} n a_n \left(\frac{r}{R}\right)^{n \cdot N-1} \qquad \text{---------(1)}$$

where 'a_n' is the n^{th} harmonic coefficient, R is the radius of the chamber and N is the number of magnets pairs. For the same arrangement, the exponential dependence is Here, y is the distance measured from the

$$B_n = \frac{N}{R} n a_n \exp\left(-\frac{n.N.y}{R}\right) \qquad \text{--------(2)}$$

surface of the plasma chamber in the radial direction. Accurate cusp magnetic field measurement has been carried out for two sets of permanent magnets to verify above predictions - 12.5mm x 25mm x 50mm; (wide magnets) and 12.5 mm x12.5 mm x20mm; (square magnets) using the Hall-probe method. The experimental set-up is shown in Fig.A.2.3. Hall probe accurately measures the field up to 1G, using a stepper motor system. Fig.A.2.1(a-b) and Fig.A.2.2(a-b) show that the power law predicts the field free region much more accurately as compared to the exponential dependence. This can be understood from the fact that the magnetic field calculations due to above two functional forms would differ substantially in the central region. The power law dependence shows excellent agreement with the actual data and hence the field free region as per Equation (1) would be nearly three times more as compared to the one estimated using Equation (2). In Fig.A.2.2(a-b), contributions up to two harmonics have been plotted for both Equation (1) and (2). The typical magnetic field at the cylinder axis is about 1 G and closer to the plasma chamber wall is about 2.3 kG, for the present configuration of 12 magnets.

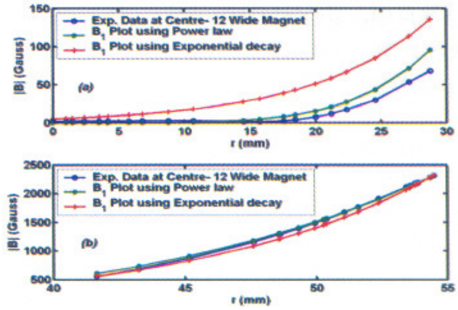

Fig.A.2.1: The plot of magnetic field measurement data (blue curve) compared with exponential form (red curve) and power law form (green curve) for 12 wider permanent magnets surrounding the plasma chamber. In the central region (a) and near the chamber surface(b).

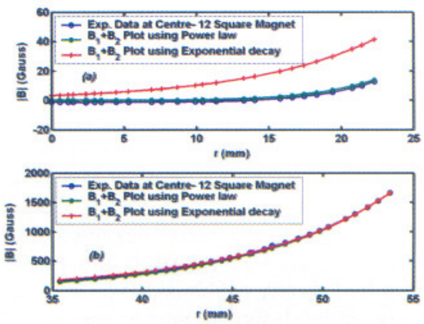

Fig.A.2.2: Same as in FigA.2.1, but for square magnets considering the contributions up to two field harmonics.

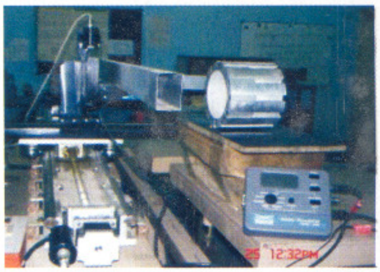

Fig.A.2.3: The experimental set-up to measure the multi-cusp magnetic field using the Hall probe system having 3-D stepper motor control movement for cylindrical plasma chamber used for the H^- ion source.

The knowledge of accurate field free region is crucial for H^- ion source since it is required for several reasons: (i) the plasma simulation require the knowledge of magnetic field in the central region of plasma chamber, (ii)for the placement of filament or RF antenna and electron filter magnet and proper design of extraction geometry, (iii) the field in the central region affects the cusp loss width, that helps in deciding the power supply requirement, and (iv) it is essential for analyzing the results of plasma diagnostics.

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