Uniform and strongly magnetized plasma using a Halbach array

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For plasma confinement often magnetic fields are used, especially in fusion devices. Magnetic fields can either be produced by coils or by permanent magnets. Coils have the advantage of controlling the magnetic field strength by varying the current, but for high currents cooling systems have to be implemented. Permanent magnets can deliver magnetic flux into the airgap of a magnetic circuit without continuous consumption of energy and nowadays they are fully competitive with electromagnets for fields up to 2 T, and fields as high as 5 T can be produced in small volumes [1]. We present a way to produce magnetized plasma using a special magnet assembly, known as the Halbach array, which is able to produce a homogeneous magnetic flux density in a cylindrical volume. Electric probes were used to characterize this highly magnetized plasma.

1. Halbach array

An ideal Halbach array is a ring magnet where the polarization direction varies continuously along the circumference so that the magnetic flux increases inside and reduces or cancels outside. In practice, typical Halbach cylinders are built using discrete permanent magnets each with its own magnetization direction, approximating the Halbach distribution [2]. Choosing the orientation of each segment properly, the fields will add at the centre.

We have simulated the magnets' positions in order to obtain a uniform and homogenous magnetic field and the optimum cylinder bore diameter, using Quick Field v6.1 Student Edition software tool (Figure 1). The input parameters for the magnetic material were set according to the magnet’s technical datasheet.

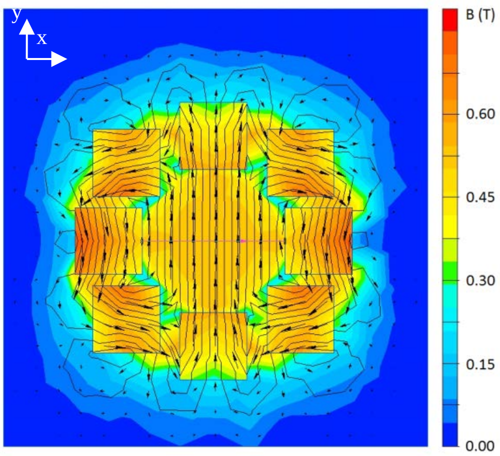

Figure 1: Magnetic flux simulation of experimental Halbach array.

2. Plasma device

To produce the magnetic field, we used 8 identical 50×15×15 mm $Nd_2Fe_{14}B$ cubic bar magnets. The perpendicular magnetic field strength ($\mathbf{B}_y$) was measured along the symmetry axis (Z) using a teslameter (Figure 2).

The plasma was created using two electrodes placed in such a way that the electrical field lines are parallel with the magnetic field (Figure 3). One electrode was grounded and the other was biased with negative voltages through a 2 KΩ resistor.

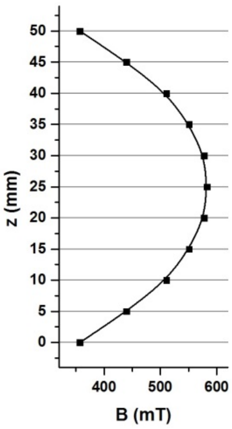

Figure 2: Magnetic flux distribution ($\mathbf{B}_y$) along the axis of the cylinder (Z axis).

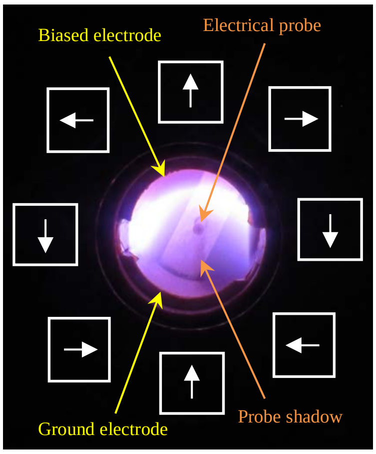

Figure 3: Plasma discharge inside Halbach array. White boxes with arrows represent the permanent magnets and their magnetic orientation.

3. Acknowledgement

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4. References

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