A high power, high density helicon discharge as plasma cell for future plasma wakefield accelerators

B. Buttenschön1, P. Kempkes1, O. Grulke1, T. Klinger1,2

1 Max Planck Institute for Plasma Physics, Greifswald, Germany
2 Institute for Physics, University of Greifswald, Greifswald, Germany

Plasma wakefield accelerators (PWA) are a very promising concept for future electron accelerators with output beam energies in the TeV range. Simulations suggest [1] that considerable acceleration is achieved for plasma densities around $10^{21} \text{m}^{-3}$.

In contrast to commonly used laser generated plasmas which are limited in length by available laser power and beam defocusing, a helicon wave heated plasma can be generated and sustained by injecting the heating power using a distributed set of antennas along the plasma column and thereby avoiding the necessity for a multi-stage accelerator approach. This type of discharge is generally scalable to arbitrary lengths, making it particularly interesting for large-scale PWA. Power balance calculations suggest that unparalleled heating powers around 50kW per meter are required to reach the envisaged plasma densities in a discharge tube of few centimeters diameter.

This contribution presents a prototype helicon discharge with up to 33kW of heating power injected by three antennas into a one meter long, 5 centimeter diameter discharge tube in an axial magnetic field up to 110mT. The plasma is characterized with respect to PWA key parameters: a CO$_2$ interferometer is used to assess the overall density dependency on rf power, neutral pressure and axial magnetic field strength. The results, including measurements for He, Ar and Xe as working gas, are compared to their respective power balance and the helicon wave dispersion relation. Effects of previously observed density limiting factors such as neutral gas depletion are addressed based on measurements using a laser-induced fluorescence system.

References