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P4.2011 A helicon plasma source for wakefield accelerators

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The need for higher energies in particle colliders led to the development of several types of particle accelerators, like plasma-based accelerators as a promising concept. The achievable electric fields in a plasma in the order of GV/m [1] exceed by orders of magnitude the conventional electric field generation by RF cavities and scales with the plasma density E(n). Circular accelerators are able to provide high energetic protons which serve as drive to induce plasma wakefields in a linear proton driven wakefield accelerator [2]. A current experiment as design study is the AWAKE project [3] at CERN. To realize a plasma wakefield accelerator, homogeneous, high density plasma columns of n_e ≥ 7 ·10^20m-3 are needed with a sufficiently long discharge duration [4]. The plasma cell must be modular and scalable to the needed target length of up to several 100 m. Such a plasma can be maintained, in principle, by a helicon discharge. The temporal evolution of radial plasma parameter profiles, in particular for neutral and charged plasma species measured by laser-induced fluorescence and corresponding plasma densities measured by a laser interferometer are investigated at the argon plasma cell PROMETHEUS-A. By combining both techniques with a reaction rate model and line-ratio measurements the electron temperature is calculated and compared to the principle of helicon wave heating. Neutral depletion in the center of the discharge and the influence on plasma density evolution is analyzed by calculating the ground state for argon neutrals and ions. It is shown that the maximum plasma density of n_e = 6 ± 1 · 10^20 m-3 is centrally peaked with a maximum electron temperature of 1.4 eV. The plasma density peaking time and width are determined to be 270 µs and 50 µs, respectively. This shows that the requirements for a plasma wakefield accelerator cell can be established. The duration of the peak plasma density is sufficient for a relativistic particle to pass a 1 km long plasma cell. Time-resolved LIF profile measurements show a hollow profile with highest densities at the edges. The ionization mean-free paths indicate increased ionization of neutral argon while dissipating inwards. This results in a depletion of neutrals in the center of the discharge.

References
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