PLASMA WAVEGUIDES FOR LASER WAKEFIELD ACCELERATION

M.R. Akdim
FOM-Institute for Plasma Physics Rijnhuizen, Nieuwegein
The Netherlands, www.rijnh.nl

When a high-power (TW) intense laser pulse is guided through a plasma channel, a wakefield in the plasma is created, which accelerates injected electron bunches to energies of several hundreds MeV.
For easier synchronization of the injection of an electron bunch and the wakefield created by a high power laser pulse, a low density plasma channel is rather attractive. However at lower pressures the matched spot size is relatively large. The matched spot size is that particular laser spot size, which can be guided through the plasma channel without diverging. A large matched spot size means that only large focused laser spot sizes can be guided properly. This results in a lower energy density in the spot and therefore a weaker wakefield is created, which in turn results in a smaller energy gain for the accelerated electrons[1].
Plasmas with densities in the range 10^{23} – 10^{24} m^{-3} have been created by using low-current (300-800 A) capillary discharges[2] in hydrogen filled alumina capillaries of 0.15-0.25 mm radius.
The plasma produced in such a discharge has a lifetime of about a microsecond. During the discharge a hollow electron density profile appears for a few hundred nanoseconds, after which a bulbed electron density profile appears. In the case that the minimum electron density is situated on the axis of the capillary, the plasma is suitable as a waveguide for laser light.
The matched spot size is determined by interferometry measurements. From the curvature of the fringes in the interference pattern, the radial electron density distribution is determined and thus the matched spot size. This is done at different times during and after the current pulse. The results show that the matched spot size is only slightly dependent on the pressure. However at higher pressures a suitable matched spot size is maintained for a longer time. A larger discharge current (voltage) or a smaller capillary radius appears to be of much more significance for getting a smaller matched spot size than a larger pressure.

1. E. Esaray, P. Sprangle, J. Krall and A. Ting, “Self_focusing and guiding of short laser pulses in ionizing gases and plasmas”, IEEE journal of Quantum Electronics, Vol 33, No. 11, November, 1997, pp. 1879-1914.

2. D. J. Spence, A. Butler and S. M. Hooker, “Gas-filled capillary discharge waveguides”, J. Opt. Soc. Am. B., January, 2003,Vol 20, No. 1, pp. 138-151.