Laser Ionized Rubidium Plasma Column Geometric Effects on Wakefields at AWAKE

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AWAKE is a proton driven plasma wakefield electron acceleration experiment at CERN [1]. In this experiment a proton bunch much longer than the plasma wavelength, i.e., $\sigma_{\mathrm{z}} >> \lambda_{\mathrm{pe}} = \mathrm{c}/\mathrm{f}_{\mathrm{pe}}$, undergoes seeded self-modulation through a plasma, resulting in a radially modulated proton bunch that effectively drives wakefields. The plasma column through which this process occurs is created by a laser field in the intermediate Keldysh/photoionization regime of rubidium vapor. The rubidium vapor's density is controlled within <0.5% over its 10 m length, resulting in a plasma column of uniform density at its transverse center and sharply falling radial edges ($\sigma_{\mathrm{edge}} << \lambda_{\mathrm{pe}}$) for the full length of the vapor. Resonances of two neutral rubidium valence electronic transitions fall within the bandwidth of the ionizing laser pulse. These resonances create a region of dynamically saturated anomalous dispersion near the radial edge of the plasma column where the ionizing laser field is strong but significant populations of unionized rubidium atoms exist. This dynamically dispersive region causes the ionizing laser pulse to propagate in an unusual way, changing the geometry of the radial plasma boundary. At AWAKE the operational density range allows plasmas where $\lambda_{\mathrm{pe}} \sim \mathrm{R}_{\mathrm{plasma}}$, resulting in wakefields that can react with the radial plasma boundary. This effect is more pronounced at the lower limit of the density range and particularly if there is inexact spatial overlap between the ionizing laser pulse and the proton bunch through the rubidium vapor. In this presentation, we explore the determination of the plasma column and the effects that the column wall may have on wakefields driven by a self modulated proton bunch with and without perfectly symmetric cylindrical overlap.

References

[1] A. Caldwell et al., Phys. Plasmas 18, 103101 (2011)