Diagnostics of plasma channel parameters by optical plasma radiation in laser-plasma electron acceleration experiment

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***Abstract*—A method for plasma channel characterization by optical plasma radiation was developed. The electron density of the unperturbed plasma was obtained from the backward stimulated Raman scattering spectrum, and the phase velocity of laser pulse inside the plasma channel was calculated from the second harmonic radiation angle.**

***Index Terms*—direct laser acceleration, high intensity laser interaction, plasma channel, plasma channel parameters**

Electrons can be efficiently accelerated by relativistic laser pulse due to various mechanisms. When laser radiation interacts with plasma, an extended plasma channel can be formed. In this case it is possible to accelerate electrons during their simultaneous movement in fields of laser wave and plasma channel. This acceleration mechanism is called direct laser acceleration (DLA) [1].

We have previously investigated an analytical model of direct laser acceleration of electrons [2] and have identified a range of parameters for effective injection of low energy electrons. These parameters are the electron density of the unperturbed plasma n_e and the phase velocity of laser pulse inside the channel – v_{ph}. We developed a method for plasma channel characterization from experiment by optical plasma radiation. It should be noted that the range of v_{ph} values is narrow, so for DLA electron acceleration it is very important to measure the phase velocity inside the channel directly from the experiment.

Stimulated Raman scattering (SRS) in plasma occurs when the laser pulse scatters on the plasma wave [3]. The spectrum of Backward SRS (BSRS) will characterize the unperturbed plasma and n_e will be obtained.

Second harmonic radiation from plasma channel sheath is another phenomenon observed in DLA experiments. The angle of the second harmonic radiation θ_c determine the phase velocity inside the channel: $\cos\theta_c = \frac{v_{ph\,2\omega}}{v_{ph\,\omega}}$.

Thus, it is possible to determine the electron density of the unperturbed plasma and the phase velocity inside the plasma channel from the BSRS spectrum and the angle of the second harmonic radiation.

The DLA experiment was carried out (1TW Ti:Sa, 800 nm, 10 Hz, 50 fs, 50 mJ). The target was a 12 μm lavsan film. Plasma was created by a Nd:YAG laser (1064 nm, 10 Hz, 200 mJ, 10 ns). By changing the delay, the plasma density could be varied from 0.01 to 0.06 n_{cr}. To register the second harmonic radiation, a CCD camera with a band-pass filter of 400 ± 20 nm was used. To record the BSRS spectrum, a fiber spectrometer of $200 - 1100$ nm was used. A > 850 nm filter and a 1064 nm narrow-band filter were installed in front of the fiber to protect against diffuse radiation. The radiation was collected into the fiber by a 50 mm focus lens. Fig. 1 shows the plasma channel parameters obtained from the experiment.

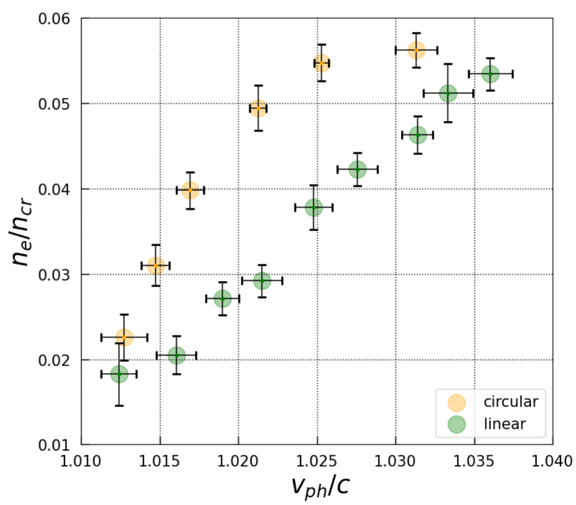

Fig. 1. The plasma channel parameters obtained from the experiment

The developed method of plasma channel characterisation allows to improve electron acceleration using analytical and numerical approaches.

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