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Guided propagation of extremely intense lasers in plasma via ion motion

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Theoretically, the upcoming 10-100 petawatt laser facilities may deliver laser pulses with unprecedented intensity of 10^{22}-10^{25} W cm^{-2}. As such, one will be entering the strong nonlinear QED regime in plasma for the first time, which is the key focus in a few research centers such as ELI-Beamlines in Prague, ELI-NP in Magurele, Apollon in Paris, and SULF in Shanghai, etc. On the other hand, technically it is still extremely challenging to manipulate such high power lasers with normal optical components for their limited damage thresholds. Plasma has been used as a nonlinear medium to control ultraintense lasers, such as guided laser propagation, laser pulse compression, high harmonics generation, etc. These are achieved based upon the linear and nonlinear plasma electron response to the laser fields.

For guided laser propagation in plasma, it is typically limited to the laser intensity less than 10^{20} W cm^{-2} since the electron cavitation formed by the strong laser ponderomotive force at higher intensity makes the linear and nonlinear electron response not effective anymore[1]. In particular, this cavitation formation results in invalidation of the criterion $P>P_c$ for self-focusing or self-guiding of the laser pulse in plasma. We found that this cavitation formation sets an upper power P_u of the laser for self-guiding[1]. Furthermore, we found that ion motion becomes significant even with the intensity around 10^{22} W/cm^2 when electron cavitation is formed by the strong laser ponderomotive force. Usually, ion motion is expected to be ignorable since the laser intensities below 10^{25} W/cm^2 are under-relativistic for ions. Due to the electron cavitation, guided laser propagation becomes impossible via usual plasma electron response to laser fields. However, our 3D KLAPS[2,3] PIC simulations[4] showed that ion response to the laser fields may effectively guide laser propagation at such high intensity levels when significant electron cavitation occurs. We derived criterions[4] for the guided propagation in a plasma channel and uniform plasma, respectively, based upon the ion response. These criterions were verified by our 3D simulations.

References

[1]Wei-Min Wang, Zheng-Ming Sheng, Ming Zeng, Yue Liu, Zhi-Dan Hu, Shigeo Kawata, Chun-Yang Zheng, Warren B. Mori, Yu-Tong Li, Li-Ming Chen, and Jie Zhang, Appl. Phys. Lett. 101, 184104 (2012).

[2]W.-M. Wang, P. Gibbon, Z.-M. Sheng, Y.-T. Li, and J. Zhang, Phys. Rev. E 96, 013201 (2017).

[3]W.-M. Wang, P. Gibbon, Z.-M. Sheng, Y.-T. Li, arXiv:1608.06356.

[4]Wei-Min Wang, Zheng-Ming Sheng, Thomas Wilson,Yu-Tong Li, and Jie Zhang, Phys. Rev. E 101, 011201(R) (2020).

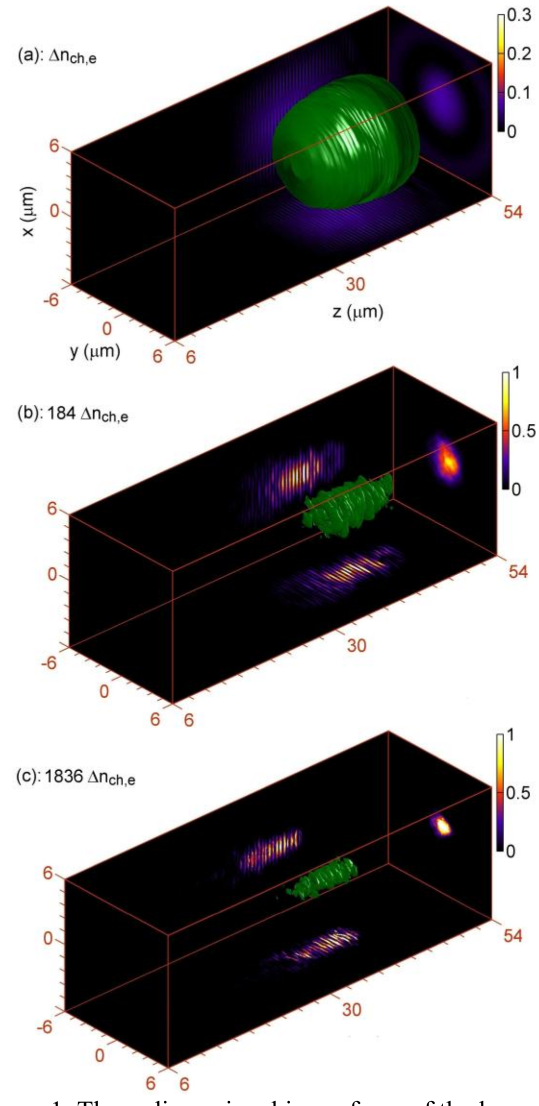

Figure 1: Three-dimensional isosurfaces of the laser intensity I/I_0 (I_0 is the initial intensity) as well as the slices at the planes with respective peak values at the time 50 τ_0 or 4 z_R/c. The plots (a), (b) and (c) correspond to different density depths of plasma channels, where $\Delta n_{ch,e}$ is the normal critical density depth due to the electron response.