- IFSA2025 –

Particle-in-cell study of the time evolving laser self-focusing characteristics in near-critical plasmas

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The field of plasma optics offers the ability to manipulate the properties of ultra-intense light without the concern of the damage threshold in conventional optical devices. As intensity limits the performance of many laser-plasma applications – such as ion acceleration, x-ray/gamma-ray production, pair-plasma production, etc. – the use of a plasma as a focusing optic through relativistic and ponderomotive self-focusing has particular appeal to the community. However, the near-critical density interaction regime capable of dramatically shaping light is also plagued by beam instabilities such as hosing and filamentation.

We perform a particle-in-cell study of semi-infinite laser pulses incident onto near-critical density plasmas to characterize the evolving focal spot characteristics before use of a more realistic short pulse. The use of longitudinal density gradients, varying laser rise times, and different ion compositions are explored as means of mitigating instabilities and controlling the time, location, and peak intensity of the focal spot. Such tunability is finally demonstrated with the use of sub-picosecond pulses.