Ionization-assisted self-compression of an ultra-intense, ultra-short microwave pulse in a gas-filled waveguide

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In this study, we present an experimental demonstration of ionization-assisted self-compression of high-power microwave pulses (~250 MW, ~0.5 ns, 9.6 GHz) that propagate "super-luminally" through a gas-filled waveguide. The ionization process occurring in the waveguide results in a substantial increase in plasma density within the pulse frame. This rise in plasma density, in turn, leads to the up-conversion of the local frequency, causing a corresponding increase in the wave group velocity along the pulse's length, from its leading edge to the tail.

As a consequence of these phenomena, we observe the self-compression of the microwave pulse, an enhancement in power, and an accelerated propagation velocity compared to an empty waveguide.

To substantiate our experimental observations, we have developed a one-dimensional theoretical model that accurately represents the underlying processes of ionization-assisted self-compression. Additionally, we have performed comprehensive three-dimensional particle-in-cell simulations that further validate our experimental results and elucidate the complex interactions between the microwave pulse and plasma in the gas-filled waveguide. This study offers valuable insights into the practical application of ionization-assisted self-compression for optimizing high-power microwave systems and devices.

References
[1] Y. Cao, Y. P. Bliokh, V. Maksimov, J. G. Leopold and Ya. E. Krasik, Frequency conversion, “super-luminal” propagation and compression of a powerful microwave pulse in propagating ionization front. Phys. Rev. E **107**, 045203 (2023).