Control of the self-modulation and long-bunch hosing instabilities with plasma frequency detuning

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When long particle beams propagate in plasma, they can be subject to two modes (symmetric and asymmetric) of the transverse two-stream instability called self-modulation (SM) and hosing (H), respectively. The interaction between relativistic charged particles and plasmas is at the heart of many astrophysical phenomena. The instabilities that develop between particle beams and plasma, such as the current filamentation (CFI) or Weibel instabilities, lead to the formation of collisionless shocks [1]. During the nonlinear stage of the CFI, an ion drift-kink mode with similarities to the H instability has been described [2]. In addition, when the effects of a finite beam are considered, the oblique two-stream instability, which is also relevant in astrophysical scenarios, exhibits spatiotemporal dynamics typical of the SM and H instabilities [3]. The physics of the latter instabilities may therefore be relevant for the understanding of astrophysical objects. The SM [4, 5] and H [6] instabilities modulate the beam radius and centroid, respectively. During their growth, both of these instabilities can be understood as driven harmonic oscillators. Here we show that it is possible to control their growth rates if the plasma oscillation responding to either the beam radius (SMI) or centroid (HI) perturbation is detuned early enough. The detuning can be achieved by varying the background plasma density, as we demonstrate with particle-in-cell simulations. Using plasma density steps, we apply this idea to slow down the growth of H and SM.

References

[1] F. Fiuza, et al., Phys. Rev. Lett. 108, 235004 (2012)
[2] C. Ruyer, and F. Fiuza, Phys. Rev. Lett. 120, 245002 (2018)
[3] P. San Miguel Claveria, et al., arXiv, https://doi.org/10.48550/arxiv.2106.11625
[4] N. Kumar, A. Pukhov, and K. V. Lotov, Phys. Rev. Lett. 104, 255003 (2010)
[5] C. B. Schroeder, et al., Phys. Rev. Lett. 107, 145002 (2011)
[6] C. B. Schroeder, et al., Phys. Rev. E 86, 026402 (2012)