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Coherent light from plasma waves in density gradients

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Recently, plasma wakes driven by photon bursts via Compton scattering were purposed as mechanisms for generating radio waves in astrophysical settings[1].

In such interactions, a photon burst that propagates into plasma scatters the electrons in front (ions remain stationary), leaving a space-charge electric field that pulls the electrons back to the propagation axis, thereby forming a relativistic plasma wave.

As the energy density of the photon burst increases, the interaction becomes highly non-linear. We show that plasma waves in this situation can radiate themselves, and that emitted radiation will be temporally coherent when the plasma density has a positive gradient in the direction of the photon burst propagation. This configuration gives rise to an accordion effect that progressively compresses the plasma wave. While the front of the plasma wave travels at the driver speed (close to the speed of light), such a compression effect causes the back of each node of the plasma wave to move superluminally. We show that this collective superluminal motion can create an optical shock at the Cherenkov angle. As a first step, we explore this behaviour by considering more conventional laser and particle beams as drivers for the plasma waves in conditions found in current laboratory conditions.

We explore the physics with theory and simulations, using the PIC code OSIRIS[2] and the newly developed RaDiO[3] (Radiation Diagnostic for Osiris) module to illustrate our findings.

References

[1] F. Del Gaudio *et al.*, Physical Review Letters **125** (2020)

[2] R. Fonseca *et al.*, Lecture Notes in Computer Science **2331** 342-51 (2002)

[3] M. Pardal *et al.*, submitted (2022)