PIC Simulations of the Interaction between Self-Modulation in the Front and Rear of an ultra-relativistic Proton Bunch in Plasma

P. I. Morales Guzman[1], P. Muggli[1]

[1] *Max Planck Institute for Physics, Munich, Germany*

An ultra-relativistic long proton bunch propagating in plasma can undergo self-modulation (SM) [1], which transforms it into a train of microbunches that resonantly drive wakefields [2]. These wakefields can be used to accelerate particle bunches to high energies [3]. To produce accelerated bunches with reproducible properties, the SM must be seeded [4], so that its phase and amplitude can be repeated event by event. When there is more than one seed, two SM processes could develop simultaneously and interact. This is particularly interesting for the future of the Advanced Wakefield Acceleration Experiment (AWAKE) [5].

We present here a numerical study using particle-in-cell simulations with parameters similar to those in the experiment. To create two seeds at different positions, we first place a density cut at the bunch front. Second, we change the density of the bunch front, creating two sharp density steps along the bunch. We show that the phase of the wakefields at the bunch rear follows that of one seed or of the other, depending on the amplitude and growth rate of the wakefields driven by the bunch front, which depend on its density. We also show that at the transition between following one seed or the other, the phase of the wakefields from the front has a significant effect on the microbunches in the rear.

References

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