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Hosing of a long relativistic particle bunch induced by an electron bunch

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Hosing of particle bunches [1] (or laser pulses) driving or experiencing wakefields in plasma may impose limits on the quality and efficiency [2] of the acceleration process. Understanding and measuring hosing is therefore important and interesting. We present an experimental study of hosing of a long proton bunch in plasma. We induce hosing with the relative misalignment between the trajectory of a short electron bunch driving initial wakefields, and that of the proton bunch following it. The effect of the wakefields on the proton bunch is thus non-axi-symmetric. This asymmetry leads to transverse oscillation of the proton bunch centroid position in the plane of misalignment. Self-modulation (SM) takes place in the perpendicular plane. SM [3] and hosing are induced and are thus reproducible from event to event. They grow from similar amplitudes of the transverse wakefields, and with similar predicted growth rates[4]. They are thus coupled. While SM occurs as an instability without the electron bunch, hosing does not (except at much lower plasma densities). We observe hosing and SM on time-resolved images of the proton bunch density distribution, obtained at a screen 3.5m downstream from the exit of the 10m-long plasma. The amplitude of hosing increases along the bunch. It depends on the charge of the proton bunch, as well as on the extent of misalignment. The direction of hosing reverses with the direction of misalignment. The frequencies of hosing (oscillation of centroid position) and of SM (modulation of the bunch density, no detectable oscillation of centroid position) are close to plasma electron frequency and thus scale with plasma density. We will introduce the AWAKE experiment, describe the experimental setup and give an overview of the latest experimental results.
[1] D. Whittum et al., Phys. Rev. Lett. 67, 991 (1991)
[2] V. Lebedev et al., 20, Phys. Rev. AB 20, 121301 (2017)
[3] L. Verra et al. (AWAKE Collaboration), Phys. Rev. Lett. 129 024802 (2022)
[4] C. B. Schroeder et al., Phys. Rev. E 86, 026402 (2013)

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