Investigations on the seeded self-modulation in a long proton bunch using coherent transition radiation measurements

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AWAKE is a proof-of-principle experiment at CERN for testing proton-driven plasma wake-field acceleration over a 10 m laser-ionized plasma [1]. This novel acceleration method promises strong acceleration ($\sim$GeV/m) of electrons over long distances with a single drive bunch and a single, long plasma [2]. It is planned to accelerate a witness electron bunch in the plasma wake-field of a long proton bunch that is transformed into a train of microbunches by Seeded Self-Modulation (SSM) [3]. We present frequency measurements of the modulated proton bunch exiting the plasma, as well as investigations on the physics of SSM using these measurements. The self-modulated proton bunch is expected to be modulated at the plasma frequency, which can be varied in the range of 90-300 GHz, and the modulation is expected to have a duration of 300-700 ps. A waveguide-integrated heterodyne diagnostic for coherent transition radiation (CTR) was designed to precisely measure the modulation frequency of the modulated proton pulse through the frequency of its CTR-pulse [4]. In this contribution, we first describe the measurement principle and the experimental set-up of AWAKE, and of the diagnostic in particular. Moreover, we show how the frequency-measurement of this diagnostic can be used for investigating the nature of the SSM. We confirm that the modulation frequency indeed coincides with the expected plasma frequency, as predicted by theory, by measuring modulation frequency as a function of vapour density, that is ionized by a short laser pulse. In a second measurement, the modulation process in the presence of a linear density gradient is analysed. Using both the precise frequency-measurement of the heterodyne CTR-diagnostic and a streak-camera capturing the Optical Transition Radiation (OTR) emitted by the protons, the modulated bunch exiting the plasma can be studied in detail. From this, one can draw conclusions about the SSM-interaction inside the plasma, and inside the changing plasma density. Using these measurements, we will try to obtain a better understanding of important processes governing the SSM, which is important for optimizing and analysing the upcoming electron acceleration experiments.

References

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