Joint DESY and University of Hamburg Accelerator Physics Seminar

Monday, 12.02.2018

(14:00 in Room 459/30b)

Transverse Space-Charge Field Induced Plasma Dynamics for High-Brightness Particle Beam Characterization at the Frontiers of Performance

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Abstract

Light induced dynamics in materials are widely studied at modern light sources and offer the potential to engineer new materials, or understand chemical reactions and biological processes. The photon beams used for such experiments are themselves routinely characterized by photo-ionization based methods combined with time resolved streaking techniques. Maximizing the photon beam brightness relies on optimizing the electron accelerator performance. A new concept for measuring the charge density of the particle beams will be presented that relies on tunnel ionization of a neutral gas by the electron beam's transverse space charge field. By measuring the plasma dynamics including the plasma density, kinetic energy distribution and arrival time distribution of the expanding ion cloud, the charge density of a micron-cubed electron beam can be inferred and optimized, including effectively the Pierce parameter. However, when using intense electron beams to ionize a gas, very different physics is manifested compared to photo-ionization. This is due to the large unipolar fields of the charged particle beam that impart a significant momentum to the plasma electrons. As they escape with high radial velocities, they leave the ions unshielded. This non-neutral plasma undergoes Coulomb explosion and the resulting dynamics offers new avenues for direct electron beam characterization. Using both analytic theory and highly sophisticated particle-in-cell simulations (using VSim and WARP), case studies were analyzed for electron beams in conventional and advanced accelerators, for different experimental conditions, such as initial neutral gas density, gas mixtures and electron beam properties. Due to the exponential dependency of the tunnel-ionization probability on the electric field strength, it is shown that the method has the potential to measure electron beams of sub-femtosecond in duration focused down to sub-micrometer sizes. As such it provides a powerful noninvasive, single-shot diagnostic for micron-cube electron beams, instrumental to operation of advanced particle accelerators. We also note that for ultra-short intense unipolar electron beams ionization quenching may be observed, providing access to fundamental quantum mechanical questions.

NOTE THE UNUSUAL DATE AND TIME

W.Hillert, (Univ. HH), I.Agapov (MPY) and M.Vogt (MFL).

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