Abstract for an Invited Paper
for the APR09 Meeting of
The American Physical Society

Optical Diagnostics for Plasma-based Particle Accelerators[1]

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One of the challenges for plasma-based particle accelerators is to measure the spatio-temporal characteristics of the accelerated particle bunch. "Optical" diagnostics are particularly interesting and useful because of the large number of techniques that exits to determine the properties of photon pulses. The accelerated bunch can produce photons pulses that carry information about its characteristics for example through synchrotron radiation in a magnet, Cherenkov radiation in a gas, and transition radiation (TR) at the boundary between two media with different dielectric constants. Depending on the wavelength of the emission when compared to the particle bunch length, the radiation can be incoherent or coherent. Incoherent TR in the optical range (or OTR) is useful to measure the transverse spatial characteristics of the beam, such as charge distribution and size. Coherent TR (or CTR) carries information about the bunch length that can in principle be retrieved by standard auto-correlation or interferometric techniques, as well as by spectral measurements. A measurement of the total CTR energy emitted by bunches with constant charge can also be used as a shot-to-shot measurement for the relative bunch length as the CTR energy is proportional to the square of the bunch population and inversely proportional to its length (for a fixed distribution). Spectral interferometry can also yield the spacing between bunches in the case where multiple bunches are trapped in subsequent buckets of the plasma wave. Cherenkov radiation can be used as an energy threshold diagnostic for low energy particles. Cherenkov, synchrotron and transition radiation can be used in a dispersive section of the beam line to measure the bunch energy spectrum. The application of these diagnostics to plasma-based particle accelerators, with emphasis on the beam-driven, plasma wakefield accelerator (PWFA) at the SLAC National Accelerator Laboratory will be discussed.

[1]This work is supported by the US Department of Energy.