Contribution ID: **9** Type: **talk**

TADPOLE for longitudinal electron-bunch diagnostics based on electro-optic upconversion

Tuesday, June 4, 2013 4:00 PM (15 minutes)

Electron-bunch diagnostics are desired to utilize unambiguous, non-destructive, single-shot techniques. Various methods fulfill the latter two demands, but feature significant ambiguities and constraints in the reconstruction of time-domain electron-bunch profiles, as for example uncertainties due to the phase retrieval of coherent radiation using the Kramers-Kronig relation. We present a novel method of upconverting the THz-field spectrum of fs electron bunches at the free-electron laser FLASH into the near-infrared in an electro-optic crystal. This technique allows the single-shot detection of its longitudinal form factor in both, amplitude and phase. The spectral phase and amplitude information is measured and thus the temporal profile reconstructed using temporal analysis by dispersing a pair of light E-fields, also known as TADPOLE. This is a combination of frequency resolved optical gating (FROG) and spectral interferometry, enabling the temporal measurement of low-power laser pulses. In this experiment, a narrow-bandwidth laser pulse detecting the longitudinal electric field of an electron bunch is interfered with a broadband and FROG-characterized reference pulse. The longitudinal beam profile may therefore be unambiguously inferred from the generated interferogram and the detected spectral-phase-information of the reference pulse.

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Session Classification: WG5 - instrum - Plasma sources and instrumentation

Track Classification: WG5 instrum - Plasma sources and instrumentation