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Multiplexed magneto-optic probe of wakefield accelerators

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Ultrashort transverse Faraday-rotation probes of laser-driven wakefield accelerators (LWFAs) have measured kilo-T magnetic fields originating from accelerating electrons and bubble sheath currents in plasmas ranging in density from $>10^{19}$ [1] to 10^{17} cm⁻³ [2]. Such measurements have revealed e.g. wake size and shape [1,2], bunch duration [3], and longitudinal charge distribution within a bubble [2] at one location within the plasma. Here we describe a comprehensive obliquely-incident probe of all components a wake's magneto-optic tensor, including Faraday and Cotton-Mouton effects, using a three-channel Stokes polarimeter [4]. In addition, we have multiplexed the probe and detection system to record magneto-optic images at several locations along the wake's propagation path in one shot. Anticipated physics studies include dependence of B-field evolution on electron injection method, evolution of bubble size and intra-bubble charge distribution during multi-GeV beam-loaded LWFA [5], and B-field evolution during electron-beam-driven plasma wakefield acceleration.

[1] M. C. Kaluza et al., "Measurement of magnetic-field structures in a laser-wakefield accelerator," Phys. Rev. Lett. 105, 115002 (2010).

[2] Y. Y. Chang et al., "Faraday rotation study of plasma bubbles in GeV wakefield accelerators," Phys. Plasmas 28, 123105 (2021).

[3] A. Buck et al., "Real-time observation of laser-driven electron acceleration," Nat. Phys. 7, 543 (2011).

[4] P. F. Colleoni et al., "Space and time resolved measurement of surface magnetic field in high intensity short pulse laser matter interactions," Phys. Plasmas 26, 072701 (2019).

[5] C. Aniculaesei et al., "The acceleration of a high-charge electron bunch to 10 GeV in a nanoparticle-assisted wakefield accelerator," Matter Rad. Extremes 9, 014001 (2024).

Working group

WG1 : Laser-driven plasma wakefield acceleration

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