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Plasma Discharge Undulator: a novel concept for plasma-based radiation sources

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Plasma discharge devices have recently demonstrated their potential for compact particle beam manipulation. Building upon the Active Plasma Lens and its extension to curved geometries (Active Plasma Bending), new studies have revealed that chicane-like configurations can support sub-betatron oscillations of the beam. Motivated by this observation, the novel concept of the Plasma Discharge Undulator (PDU) is introduced. The PDU consists of a sequence of transversely displaced jointed plasma capillaries, carrying a high-current discharge. The resulting azimuthal magnetic field focuses the beam, while the periodic transverse displacement of the equilibrium axis acts as a geometric forcing term. This yields a well-defined oscillation at a wavelength $_{PDU}$, distinct from the natural betatron wavelength λ_β. By proper injection, collective betatron oscillations can be suppressed, leaving only the forced λ_{PDU} beam centroid oscillation. This approach eliminates the intrinsic K-spread limitation of plasma undulators, achieving a narrow undulator strength distribution while preserving strong plasma focusing for beam matching. The theoretical framework, single-particle and beam dynamics analyses, first estimates of radiation emission from the PDU and preliminary particle-in-cell studies of segmented capillaries are presented. The PDU thus offers a pathway toward miniaturized, tunable, full-plasma-based radiation beamlines, with enhanced control over beam quality and radiation properties.

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