LPAW 2023
Laser and Plasma Accelerators Workshop 2023
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Micro Plasmonic Wakefield Accelerators

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The use of a semi-conductor tube as a micro-structure for a high-gradient particle accelerator is analyzed analytically and numerically. This idea presented previously by A. Sahai has similarities to a hollow channel plasma accelerator in which the free electrons in the semi-conductor are analogous to free plasma electrons. It also has similarities to miniaturized structure accelerators, with a closer kinship to metallic conductors than to dielectrics.

Three regimes are identified for wakefields driven in a hollow tube by either a charged particle beam or a laser pulse: At low intensities of the driver pulse, the tube is dominated by collisions, the mean free path of an electron in the tube is too short compared to the quiver amplitude of a free electron to support a substantial wake. A threshold intensity is found above which the conduction electrons in the tube are driven to such high speeds that their Coulomb collision cross-section drops sharply, and the resulting wake resembles that in a hollow collisionless plasma of density equal to that of the conduction electrons in the semi-conductor tube. At yet higher intensities, the entire tube becomes ionized during the pulse rise, and electrons in the latter portion of the wake fill in the hollow region of the tube. This is the non-linear hollow plasma wakefield or "crunch-in" regime that can potentially produce TeV/m peak acceleration gradients. Prospects for near term experiments to demonstrate plasmonic wakes for the first time as well as the transitions between the regimes are discussed.