Particle accelerator on a nanophotonic chip

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Particle accelerators are ubiquitous tools across scientific, industrial, and medical domains, pivotal not only in advancing particle physics but also in applications such as sterilization and radiotherapy in modern healthcare facilities. Traditionally, these accelerators harness microwave fields to impart momentum to swift electrons or other charged particles. Our research explores a paradigm shift, demonstrating the feasibility of employing laser light to achieve electron acceleration. Crucially, this approach necessitates structures capable of generating accelerating fields at the scale of the driving laser's wavelength – a scale substantially smaller than conventional accelerators, on the order of microns. Leveraging advancements in nanofabrication, we have developed the nanophotonic counterpart of an accelerator, enabling the acceleration of electrons through purely optical forces. A milestone achievement has been the realization of the electron "bucket," effectively confining and accelerating electrons within a 220nm narrow, 500 micron long accelerator channel. In our experiments, we have demonstrated electron acceleration from 28 keV to over 40 keV, marking significant progress towards compact and efficient light-driven electron devices. Furthermore, we explore intriguing phenomena arising from the natural bunching of electrons on attosecond timescales and the ability to shape individual electron wavepackets. These capabilities open new vistas for electron imaging, particularly in the realm of quantum mechanical phase imaging. In this presentation, we provide an overview of our experimental progress, offering insights into the potential of light-driven electron accelerator devices and electron wavepacket shaping and coupling.