New control over electrons: from photonics-based particle acceleration to a quantum electron microscope

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Transparent materials can withstand optical peak field strengths in excess of 1 GV/m. With the help of transparent nanostructures, this large field strength can be utilized to build new particle accelerators. Much like in their classical RF brethrens, the charged particles interact with the electromagnetic driving field, which is shaped such that efficient particle acceleration takes place. We show that this concept can be scaled down in size and scaled up in frequency by several orders of magnitude, to build laser-based particle accelerators with an acceleration gradient in excess of 1 GeV/m. This would allow shrinking down classical accelerators by around two orders of magnitude. In the second part of the talk, we will show that microfabricated Paul traps for electrons can be expanded to encompass beam splitter operation for electrons. Jointly with an electron resonator, this may enable building a quantum electron microscope, a device that may allow electron imaging of samples with a much smaller electron dose than required today. Based on quantum interrogation techniques, also known as interaction free measurements, the imaging of live biological samples might come into reach.