WS101-3: Potential Near-Term Applications for a Laser-Driven Accelerator on a Chip

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Particle acceleration in dielectric microstructures powered by infrared lasers, termed *dielectric laser acceleration* (DLA), is a new and promising area of advanced accelerator research. The idea of using lasers to accelerate subatomic particles dates back even before the coinage of the word “laser.” However the technology to make such accelerators did not exist until more recently. With the advent of efficient solid state lasers and a rich variety of nanofabrication techniques developed by the semiconductor industry, scientific research in photonic devices, optical waveguides, and metamaterials for myriad uses (including particle acceleration) has garnered much interest in recent years. An active international community has developed working on photonic structure based particle acceleration, including government laboratories in both the United States and in Europe, as well as university groups in Israel, US, Germany, Japan, and Taiwan. In the last few years, the first demonstrations of particle acceleration have been conducted using such devices in experiments at both relativistic and subrelativistic energies [1-4], and compatible photonic systems for coupling of laser light and nanotip field emission sources have been developed [5]. Techniques using the laser field itself to provide transverse focusing and confinement of the particles have been proposed and are now being implemented into prototype experimental designs [6]. And waveguides based in silicon nitride have been found to provide a suitable architecture for delivery of ultrashort laser pulses to an on-chip accelerator [7]. An extensive international effort is underway to combine these approaches to make a working tabletop prototype accelerator [8].

Applications for a compact accelerator with target energies in the 1-20 MeV range (see conceptual illustration in Fig. 1), such as medical radiation oncology or ultrafast electron diffraction (UED) could provide compelling near term uses for a DLA based system. The operating principles are similar in some ways to conventional radio-frequency accelerators, but scaled down in operating wavelength and size by 5 orders of magnitude. This change of scale opens up a plethora of new areas of investigation and incorporates fields of study (material science, advanced photonics, laser science, nanofabrication) that are outside the usual framework for conventional accelerators as well as other advanced schemes such as plasma accelerators. The potential for sub-fs pulse structure and high repetition rates (1-50 MHz) for DLA also distinguishes it and may lead to very different operating regimes for light sources based on DLA. The evolving understanding of operation in this regime could lead to attosecond science developments for understanding atomic and molecular processes on short time scales. Links to other modern accelerator concepts may result: DLAs could tie in with conventional and plasma based schemes as ultra-high resolution monitoring devices. We will provide an update on new developments in this area of research and present results from a recent workshop held at SLAC to explore the variety of applications for this technology.

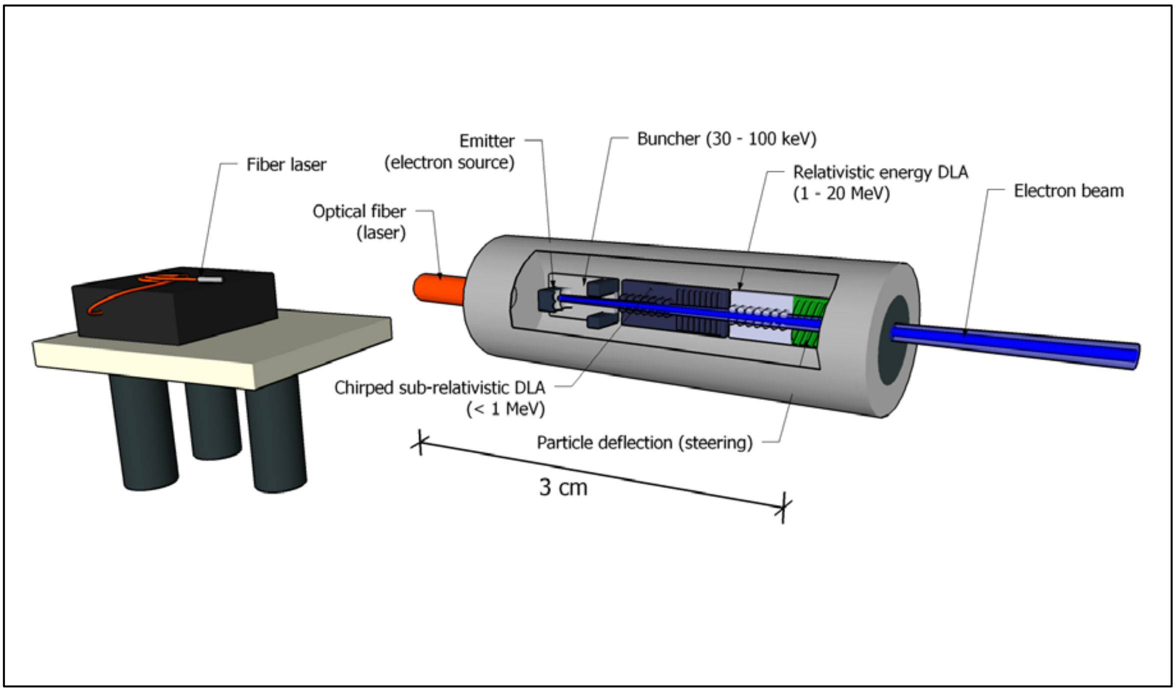

Figure 1: Conceptual illustration of a portable chip-based electron accelerator driven by a high repetition rate solid state fiber laser. Such a device could be used as a university-scale source of multi-MeV electrons or employed via robotic manipulation for radiation oncology treatment.

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