Planar Electronic Picosecond Electron Pulser

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Generation of picosecond electron packets without using a high-speed laser is one technology approach towards realizing a compact and cost effective electron pulser for applications such as terahertz-wave generation and time-resolved microscopy.[1] In this paper, we present a design and initial experimental results on an electron pulser that uses a swept voltage and beam blanking pillars to generate short electron packets (Figure 1).

The device structure consists of laser-cut silicon and FR4 structures as shown in Figure 2. The silicon pillars, deflectors, and stage are manufactured by laser micromachining using LPKF laser cutter.

Electron pulses are generated by passing a continuous beam through a deflector region followed by an array of pillars. As the beam is exposed to electrostatic forces in the deflector region, it gains a transverse velocity and sweeps along the pillar region, generating electron packets by a knife-edge method. The duration among the electron packets is determined by the initial energy of the electrons, location of the pillars, and deflecting voltage.

The average time interval between the electron packets is given as:

$$\tau = \frac{\rho}{Velocity_x},$$

where τ is the time interval between the packets, ρ is the distance between the pillars, and $velocity_x$ is the initial speed of the electrons. Decreasing the pillar width and increasing the initial kinetic energy would potentially generate shorter electron packets. Analytical calculations show that 200 µm spaced pillars with initial electron energy of 147.9keV can generate approximately 700fs spaced pulses.

Figure 3 shows the simulation of the device in Opera. Here, the gap between the pillars is ρ=400µm and the width of the pillars, which are slightly tilted to allow a larger effective gap for the electron beam without increasing the device dimensions, is 200 µm.

The fabricated electron pulser is tested with a Kimball Physics electron gun at a pressure of 10^{-5} Torr. The initial 2 keV electron beam is passed through the front cover of the pulser as shown in Figure 2. After leaving the front detector, the electron beam is deflected by a voltage that is swept from 0 to 400V. The swept electron beam is cut by the knife-edge shaped gratings and generates short electron packets. Figure 3 plots the detector current as a function of the deflector DC bias, with insets showing the corresponding cases captured from simulation. Based on the correlation between the simulation and the data, the electrons pass through the pillars at 150V and 300V, but hit the pillars at other voltages, producing electron packets.

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1 C. T. Hebeisen, "Generation, characterization and applications of femtosecond electron pulses," Ph.D. dissertation, University of Toronto, 2009.

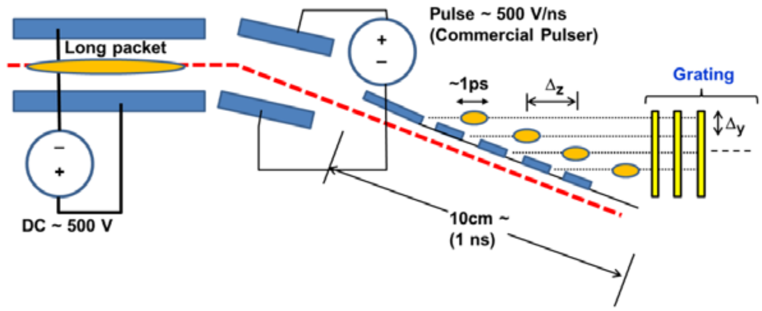

Figure 1: Schematic Drawing of the Electron Pulser: The long packets of electrons are allowed to pass through the series of biased electrodes to be deflected by the applied DC voltage. The swept electrons are cut by the knife-edged pillars to generate short electron packets. Smith-Purcell radiation generated by a grating is depicted as an application for the electron packets generated by the pulser.

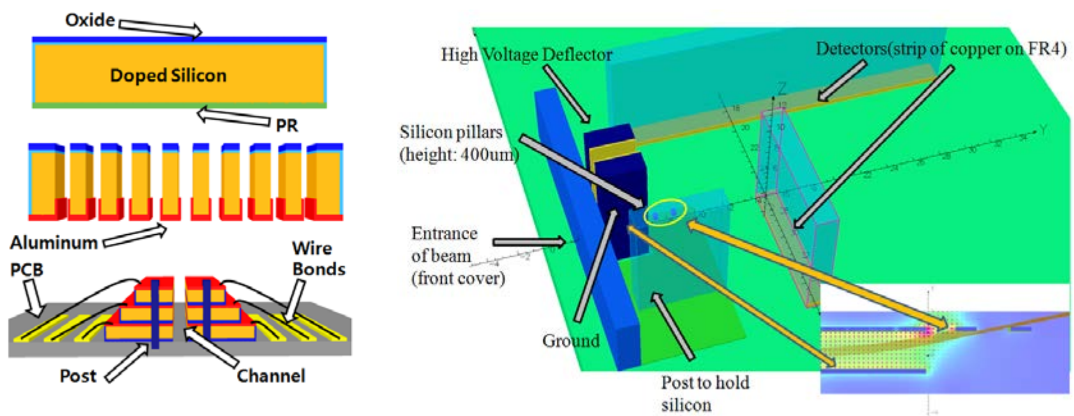

Figure 2: Fabrication Process and the Electron Pulser: The knife-edge pillars are fabricated by doping silicon with Oxide and Aluminum on each side. The initial electron pulser contains a deflector, two pillars, and detectors. The beam entering the front cover is deflected by the electrostatic voltage applied to the deflectors. After the deflection, the beam is cut by the pillars and detected by the detector.

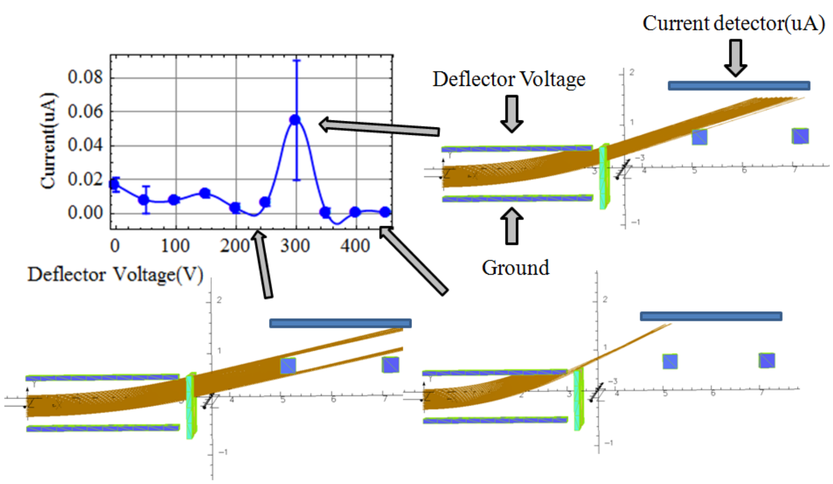

Figure 3: Experimental Results and Opera Simulation: The continuous electron beam is deflected at different voltages across the deflector. As the beam is swept across the different pillars, the current on the detector is measured and graphed.