Towards an RF Planar Waveguide Electron LINAC

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We present the first ever planar silicon-based charged particle electrostatic accelerator architecture to miniaturize electron beam systems. With volumes of 10-cc, producing 10-100keV energy electrons, the accelerators would enable small scanning electron microscopes, electron lithography systems, and x-ray generation. In this paper we describe design and initial experimental data from a LINAC that utilizes a co-planar waveguide(CPW) resonator to achieve accelerating voltages across the accelerating electrodes.

The device structure for the accelerator is shown in Figure 1. An LPKF laser machining tool is used to cut electrodes in three different silicon wafers as seen in Figure 2. These wafers are stacked and adhesively attached. The laser cutter is used again to break the tethers that were realized to ensure alignment between the three layers and the pc-board. This process is similar to the one we recently used to demonstrate a planar Einzel lens [1] [1].

The accelerator was designed for input electron energy of 2keV. Four different acceleration stages were used within a total length of 8cm. With the electron speed in the 0.8-0.9c range, where c is the speed of light, the transit time for the electrons is 3.0 nanoseconds requiring the RF frequency of the accelerator to be in the 1-GHz range. Hence, a CPW resonator of this frequency that can fit in the 8-cm length has to be folded. We designed and fabricated a folded CPW resonator (Figure 1). The resonances in the CPW were identified at 780MHz, 1.18GHz, 1.4GHz, 1.5 GHz, and 1.67GHz (Figure 3). The measured and designed S11 characteristics show matched response.

An energy analyzer located at the rear of the LINAC consists of electrodes that measure the incident current on separated wires with a DC deflector. With a fixed deflector voltage, incident electron flux is differentially measured on the collector electrodes. An energy resolution of 100-200eV is predicted for this energy analyzer.

The fabricated device is tested with a Kimball Physics electron gun with emitted 2-5keV electron beam. Electrons of 2keV energy is passed through the LINAC while being accelerated to the energies of 2.3-3.2keV. The frequencies at which high power is transmitted correspond to the resonance frequencies of the CPW. At these resonance frequencies, the power transmitted to the coplanar device ranged from as low as 1 Watt to 48 Watts, generating electrons with additional energies corresponding to the applied RF fields. (Figure 3).

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[1] Yue Shi, Serhan Ardanuç, and Amit Lal, "MICRO-EINZEL LENS FOR WAFER-INTEGRATED ELECTRON BEAM ACTUATION," Proceedings of the IEEE MEMS 2013.

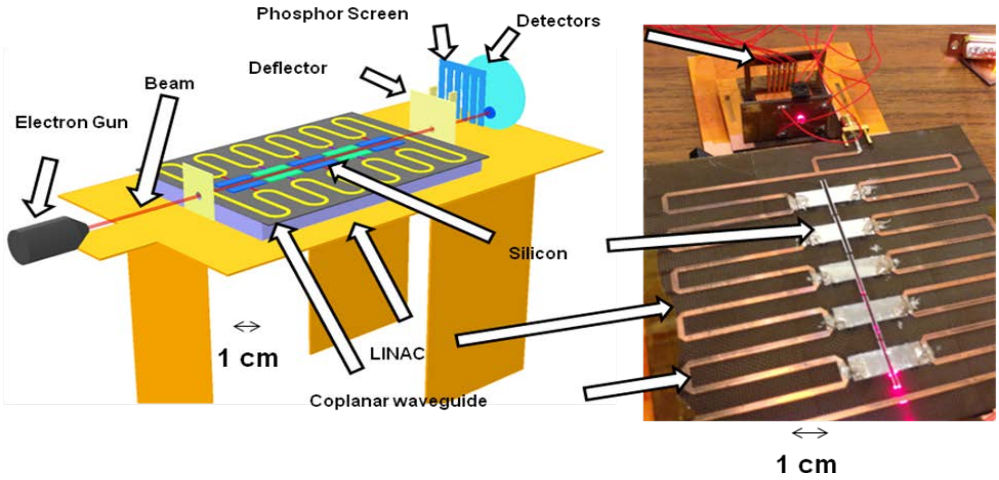

Figure 1: RF planar Waveguide LINAC: Electron gun emits electrons of 2keV that passes through the channel of the LINAC. The accelerated electrons are analyzed by the energy analyzer. The right figure shows the alignment process where a HeNe laser beam is passed through the LINAC system.

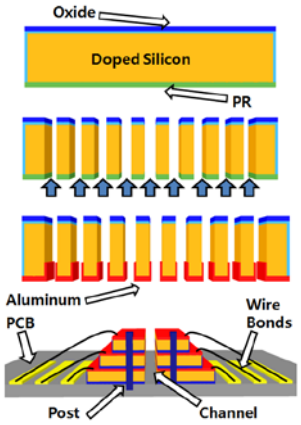

Figure 2: Fabrication Process: 4um of thermal oxide is deposited on the top and photo-resistive (PR) layer is deposited on the bottom. UV laser is used to etch and PR is stripped as shown in the second picture. For conductivity, Aluminum is sputtered. Finally the whole assembly is stacked on the PCB board using posts and the wires are connected to the silicon and copper.

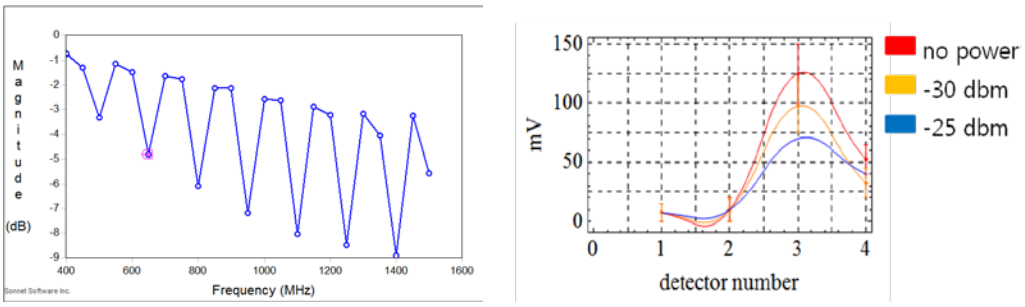

Figure 3: Planar waveguide simulation and experimental results: The resonant frequencies of the RF waveguide linac system are simulated with the Sonnet program. The Figure on the right shows the voltage on the 4 different detectors that was amplified by an op amp. The red graph is before applying an RF on the LINAC and the blue curve is after applying -25dbm power on the LINAC.