Focused Ion Beam Fabrication of a Chiral Infrared Polarizer

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As fiber-optic communication becomes more integrated and all-optical circuits become more complex, the need for compact and inexpensive micro-optical components has increased rapidly. Many valuable new devices have been made from patterned structure-based metamaterials[1]. Components active in the relevant infrared (IR) wavelength regimes require nanometer-scale features in three dimensions. A specifically suited substrate material is required as well, making fabrication by conventional means challenging. Resistless, direct-write focused ion beam (FIB) patterning can fulfill these requirements and is widely used as a robust and versatile tool for prototyping metamaterials[2].

Here we present a novel, chiral metamaterial fabricated via FIB that transforms an unpolarized mid-infrared source into either right-handed circular (RCP) or left-handed circular (LCP) polarized light.

Each array element consists of opposing 90° stepped wedges. Each is comprised of three steps in Z, as illustrated in Fig. 1. The directionality of this "spiral staircase" provides chirality to the overall structure. For instance, if the direction of the descending steps is reversed from clockwise to counterclockwise, the transmitted light would be LCP instead of RCP. A simulation of the electromagnetic near-fields associated with this structure is provided in Fig. 2.

A substrate with high anisotropy is required to eliminate optical loss from reflection and interference. The substrate material chosen was hexagonal boron nitride (hBN). hBN has the advantage of exhibiting extreme birefringence throughout the IR and, in specific spectral ranges, is naturally hyperbolic[3,4]. Dose, dose rate, and etching gas selection are optimized to fabricate highly accurate devices by direct-write FIB. An SEM image of an initial prototype device fabricated in silicon is provided in Fig. 1.

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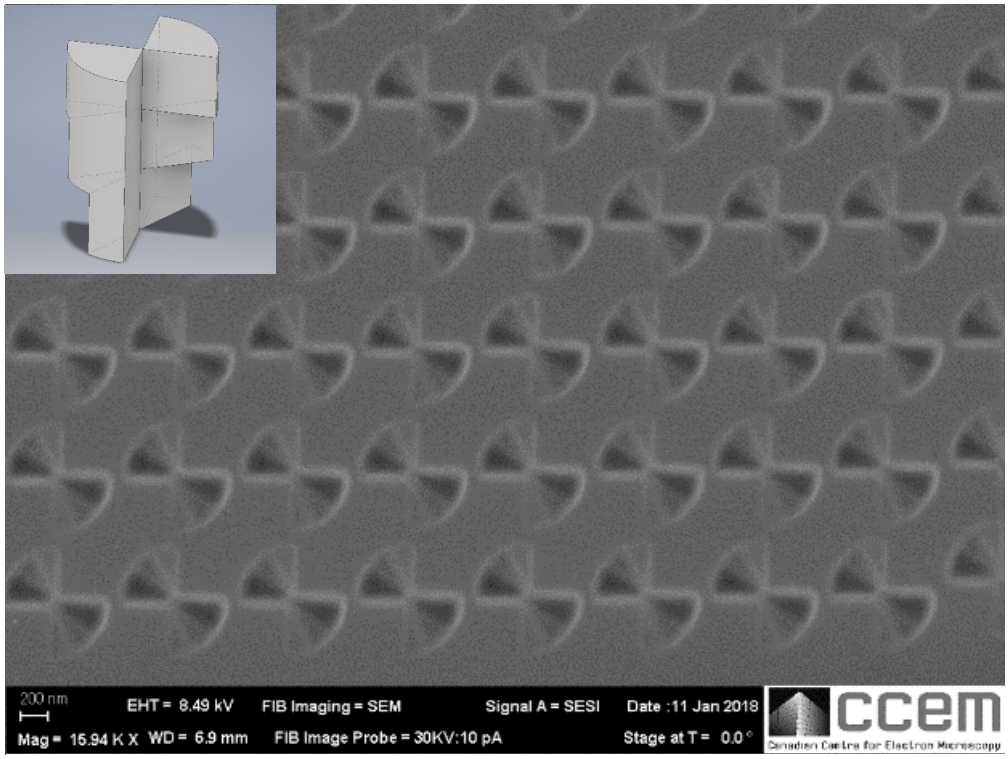

Figure 1: SEM micrograph of chiral metamaterial in silicon. Inset: Schematic of stepped wedge structure.

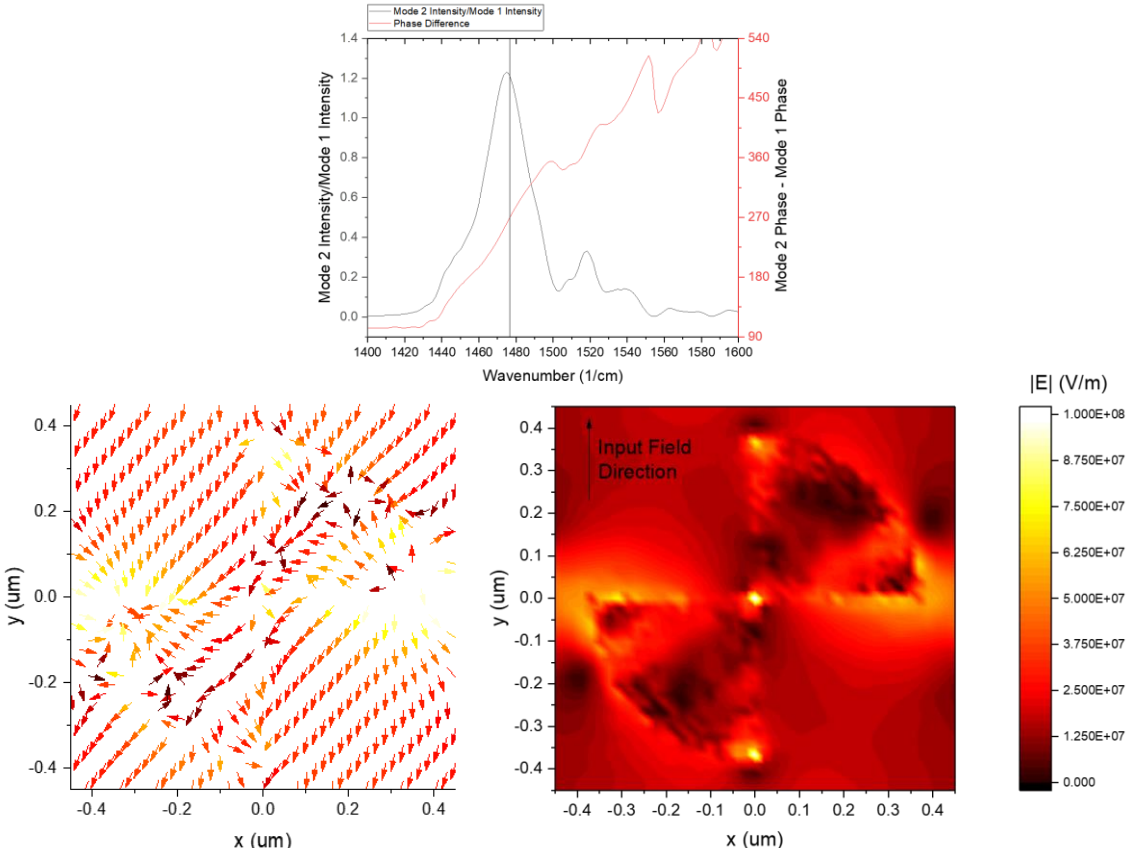

Figure 2: Top: Simulated spectrum of mid-IR transmission and phase difference. Bottom: Simulation of the electromagnetic near-field of the device.