Design and Fabrication of a Liquid Crystal Diffractive Solar Sail Prototype for 2D Beam Steering and Enhanced Diffraction Efficiency (Year 3)

Tasneem, Tanzeela (School: Florida Atlantic University High School)

Diffractive sails are a novel aerospace propulsion concept that direct photon momentum through controlled diffraction. By electrically controlling how light is redirected as it passes through an optical surface, these sails enable lightweight, non-mechanical steering. Last year’s research used simulations of a liquid crystal (LC) diffractive sail and showed that voltage-driven molecular reorientation altered refractive index and diffraction angle; however, steering remained one-dimensional and efficiency declined at higher voltages. This year’s study advances that work by developing and testing a physical prototype to evaluate whether applying voltage using orthogonal electrode configurations can enhance diffraction efficiency and allow for 2D steering. A polymer-dispersed liquid crystal (PDLC) cell was fabricated using glass substrates patterned with copper tape arranged in either parallel or orthogonal geometries. A 40:60 mixture of 4CB liquid crystal and UV resin formed the cell, and an Arduino-based circuit supplied 0–9V. A 640 nm laser illuminated the cell, and a calibrated TSL2591 sensor recorded transmitted and diffracted intensities. Parallel electrodes produced x-axis modulation, with diffraction angles increasing from 0° to 32.75° and efficiency peaking at 84.0%. Orthogonal electrodes generated electric fields along both axes with max angles of 44.11 and 45.89° (x) and 41.18° (y). Diffraction efficiency peaked at 94.5% at 4 V before gradually declining. These findings support the hypothesis that orthogonal electrode fields improve diffraction efficiency and allow for 2D beam steering. Future work will prioritize independent voltage control for each axis to improve diffraction efficiency and achieve more precise multi-directional steering.

Awards Won:

Fourth Award of $600