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Author: Mr. Matthew Julian
National Institute of Aerospace (NIA), United States, mnj3db@virginia.edu

Dr. Calum Williams
University of Cambridge, United Kingdom, cw507@cam.ac.uk
Mr. Scott Bartram
National Aeronautics and Space Administration (NASA), United States, scott.m.bartram@nasa.gov
Dr. Hyun Jung Kim
National Institute of Aerospace (NIA), United States, hyunjung.kim@nasa.gov

TUNABLE MID-WAVE INFRARED SPECTRAL FILTERS BASED ON PHASE CHANGE MATERIALS FOR MULTISPECTRAL IMAGING

Abstract

The mid-wave infrared (MWIR) spectrum contains a wealth of invaluable information including the spectral 'fingerprint' of many chemical species, and has applications in remote sensing and astronomical imaging. Traditionally, filtering for the MWIR is achieved by means of passive multilayer interference (dichroic) filters, Fabry-Perot-based micro-electro-mechanical system (MEMS) filters, liquid crystal tunable filters, and focal plane array (FPA) filters. These approaches suffer from various limitations such as having moving parts, exhibiting slow response times, and having limited spectral bandwidth / resolution. Recently, there has been significant interest toward 'active' spectral imaging technologies, whereby the ability to provide electrically tunable narrowband filtering—spanning the entire MWIR—is highly desirable.

In this work we introduce a new spectral imaging technology, namely actively tunable optical absorption filters operating in the MWIR using the phase-change material (PCM) GexSbyTez (GST). The GST exhibits a large, reversible change in its refractive index across the MWIR upon a phase transition (from amorphous to crystalline). This refractive index modulation governs the filter's optical characteristics. Through an applied electric field – which changes the GST state from amorphous to crystalline – one can actively tune the filter to provide a continuum of narrow passbands. Tunability across a 2-μm bandwidth with the PCM-based MWIR is achieved with square Al nanostructures (40-nm thick and 310-nm wide), with a square unit cell (1.14-μm period) atop a GST layer (75-nm thick) design. The device exhibits a spectrally distinct plasmonic resonance which can be actively tuned using the GST with near perfect absorption beyond the 3-5μm wavelength range.

Using discriminated narrowband signals and multi-spectral/broad wavelength tunability, the PCM-MWIR filter will be able to extract the maximum amount of 'useful' information within the atmosphere for remote Earth sensing measurements. This technology exhibits operational speeds orders of magnitude faster than current airborne-based sensors, as the PCM is an established rewritable optical storage material with nanosecond switching speeds. Moreover, it enables affordable SmallSat-based MWIR instrumentation which is complimentary to other observation systems. The MISSE-13 (Materials International Space Station Experiment-Flight Facility) experiment has been proposed as a testbed for a PCM-based tunable MWIR filter module to allow exposure of the module to the low Earth orbit space environment. This will provide valuable data regarding the robustness of the filter to withstand the radiation and atomic oxygen environment and allow assessment of the technology for use in space applications.