MEMS-based optical filters for spectrally adaptive remote sensing from visible, through infrared, to terahertz

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Improving current state-of-the-art infrared (IR) detector and imaging focal plane array (FPA) technologies includes adding so-called multi-colour capability, which allows real-time spectral information to be gathered from multiple wavelength bands. Multi-spectral imaging results in improved target recognition and is applicable to numerous remote sensing spectroscopy/imaging applications. In order to provide a reduced size, weight and power (SWaP) solution, a micro-electromechanical systems (MEMS) based electrically tuneable adaptive filter technology has been developed for important IR and emerging THz wavelength bands of the electromagnetic spectrum.

We present the development of MEMS-based optical filter technologies capable of adaptive low-voltage electrostatic tuning of spectral selectivity in wavelength bands spanning from visible, through infrared, to terahertz parts of the electromagnetic spectrum. Figure 1 schematically presents the adopted approach capable of delivering on-chip remote hyper/multi-spectral sensing by obtaining narrow-band spectral sensitivity utilising a tuneable MEMS optical filter fabricated directly on an infrared detector. The technology has been demonstrated to operate in the near infrared (NIR, 0.7 – 1.7 µm), the short-wave infrared (SWIR, 1.4 – 2.5 µm), mid-wave infrared (MWIR, 3 – 5 µm), long-wave infrared (LWIR, 8 – 12 µm), and terahertz ranges (~1 THz or ~300 µm). In LWIR, we report spatial peak wavelength selectivity variation of less than 1.2% across 200-µm × 200-µm optical imaging areas, exceeding the requirements for passive multispectral thermal imaging applications (spectral characteristics across the entire tuning range of 8.5–11.5 µm: peak transmission above 80%, full-width at half-maximum of spectral passband of ~500 nm, and out-of-band rejection greater than 40:1). Utilising the merger of the developed MEMS capabilities with metamaterial concepts as depicted in Fig. 1(c), shows suitability to extend the filtering capabilities towards the longer THz wavelength band by demonstration of wavelength absorption selectivity tuning across a 16 µm (60GHz) wide spectral band for 300µm wavelength (1 THz) radiation.

The presented MEMS-based optical filters are applicable for hybridisation into technologies capable of mechanically robust field-portable spectroscopic chem/bio sensing, as well as for UAV-based imaging and remote sensing applications.

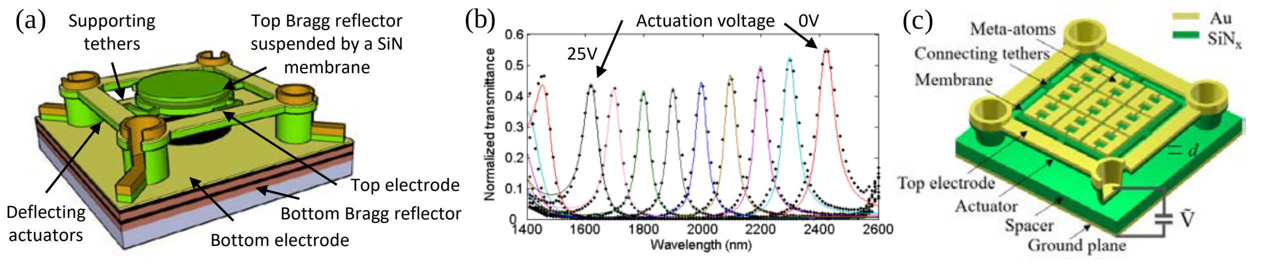

Figure 1. (a) Schematic illustrating micro-machined Fabry-Perot (FP) filter. The circular optical area has a diameter of 100 µm. An underlying IR detector (not shown) senses only IR photons that have been discriminated for a particular wavelength determined by a tuneable FP cavity formed between two Bragg reflectors. The top reflector is supported by a suspended membrane connected to four top electrostatic actuation electrodes used to vary the position of the top reflector, thus providing a means of controlling the cavity length and resulting in wavelength tuneability. (b) Experimentally measured tuning response of a filter shown in (a) with a spectral tuning range of 1.6µm to 2.5µm for a drive voltage of up to 25V, characterised by 50nm spectral resolution. (c) The merger of MEMS with metamaterials towards tuneable meta-MEMS using the suspended membrane to support an array of meta-atoms. Vertical actuation of the meta-atom array allows tuning the resonance of the effective structure to incident radiation.