

Miniaturized standing wave transform spectrometer based on MEMS mirror and thin detector

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Recently semiconductor processing technology has been applied to the miniaturization of optical wavelength sensors. Compact sensors enable new applications such as integrated diode-laser wavelength monitors and frequency lockers, portable chemical and biological detection, and portable and adaptive hyperspectral imaging arrays. We have investigated existing and novel architectures for wavelength sensing. Many bulk wavelength sensors such as grating spectrometers, Michelson interferometers and Fabry-Perot tunable filters have already been miniaturized. These small sensing systems have trade-offs between resolution, operating range, throughput, multiplexing and complexity. We have developed a new spectrometer architecture that balances these parameters for applications involving hyperspectral imaging spectrometer arrays.

This new architecture is based on measuring the wavelength-dependent period of an optical standing wave. The standing-wave spectrometer creates and samples an optical standing wave as MEMS mirror scans along the beam axis. The Fourier transform of the resulting time-varying photocurrent yields the optical spectrum. Schematic of the spectrometer idea is shown in Fig 1. The spectrometer contains two components; a large displacement piston-motion MEMS mirror and a thin GaAs photodiode flip-chip bonded to a quartz substrate (shown in Fig 2). The spectrometer was demonstrated to have a resolution of 100 cm^{-1} (7.5 nm @ 866 nm) over an operating range of $633 \text{ nm} - 866 \text{ nm}$. The performance of this spectrometer is similar to that of a Michelson in resolution, operating range, throughput and multiplexing but with the added advantages of fewer components and one-dimensional architecture suitable for spectrometer arrays.

[1] H.L. Kung, et al., "Standing-wave transform spectrometer based on integrated MEMS mirror and thin-film photodetector", IEEE J. Selected Topics in Quantum Electronics, 8, 98-105 (2002).

[2] S. R. Bhalotra, et al., "Integrated standing-wave transform spectrometer for near infrared optical analysis," in IEEE Lasers and Electro-Optics Society 2002 Annual Meeting, Glasgow, Scotland (November 10-14, 2002). Paper ML5.

[3] S. R. Bhalotra, et al., "Standing-wave microsensors for adaptive analysis of spectral coherence," in CLEO 2003, Baltimore, MD (June 1-6, 2003). Paper CThA

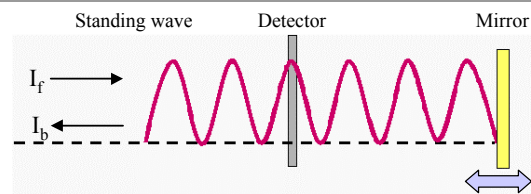


Fig 1: Schematic of a standing wave spectrometer. The forward and the backward wave interfere to generate standing wave. As the mirror scans a thin fixed detector samples the standing wave. This generates an interferogram that can be Fourier transformed to determine the optical spectrum of the incident light

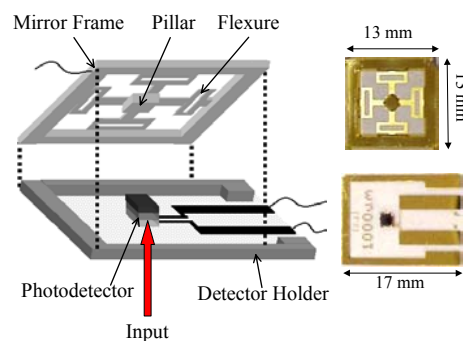


Fig 2. Schematic of the device. It consists of two components a MEMS mirror and a thin GaAs/AlGaAs detector. A voltage is applied between the mirror pillar and the photodetector causing the mirror to deflect toward the detector. On the right side are photos of the two components before integration.

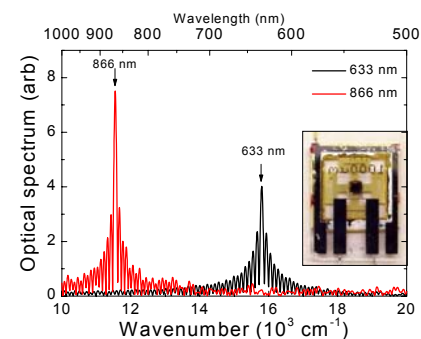


Fig 3: Fourier transform of the interferogram for 633 and 866 nm optical source. Insert shows the integrated device.