
The Polychromator: A MEMS Correlation Spectrometer

Personnel

E. Deutsch, J. Bardhan, and S. Vengallatore (S. D. Senturia), in collaboration with Honeywell Technology Center and Sandia National Laboratory

Sponsorship

DARPA

There are a number of promising applications for MEMS devices in the field of optics. This project explores a particular application in infrared spectroscopy. The basic concept is to use a linear array of mirrors, each one of which can be vertically positioned throughout a gap of several microns. By adjusting the relative positions of the mirrors, it is possible to create a special kind of diffraction grating such that incident light is diffracted into a selected viewing angle at multiple wavelengths (hence the name, "Polychromator"). In particular, it is possible to create artificially the absorption or emission spectrum of a target molecule. Then, by modulating the lines in the target spectrum, one can build a new kind of correlation spectrometer -- one which uses artificially created spectral features to correlate with the presence or absence of specific absorption lines in the incoming light. The Polychromator has many advantages over conventional correlation spectroscopy: (1) the Polychromator replaces the reference gas cell with a synthetic spectral device that can be programmed for many different species; (2) it is easy to modulate compared to gas cells; (3) by using the emission spectrum instead of the gas-cell absorption for the correlation, the overall intensity is lowered, reducing detector shot noise; and (4) interferences between species can be omitted from the synthetic target spectrum by design.

Device fabrication occurs as a shared Honeywell-MIT activity, and optical testing is done at Sandia Labs. MIT's contribution to this three-organization collaboration is the modeling and design of the polychromator, and electromechanical testing and voltage-displacement calibration, including material property extraction from test structures. For this latter purpose, we have developed a number of automated optical inspection methods.

Electromechanical testing of Polychromator devices is now a highly automated activity, using Bardhan's robust adaptation of correlation analysis of digitally upsampled fringe-shift patterns. The system includes automatic repositioning of the stage so that an entire device can be tested automatically. An important detail is that the regular features of the polychromator provide self-alignment targets for the repositioning using the same type of correlation analysis that is used to extract voltage-deflection data.

Work in the past year has focused on the design and fabrication of polychromators with large vertical travel, greater than 4 microns, so that the 8-12 micron region of the infrared regions can be addressed. Deutsch has created a functional design which achieves this goal, and the Honeywell-MIT fabrication team has succeeded in building and testing these devices. The result is a 512-element polychromator with each grating element individually actuatable, robust against pull-in, and with optically flat mirror elements 20 microns wide and 1 cm long. A critical feature in the design is the tensile-stress management at the ends of beams and at the supports between beam segments. Fully packaged devices are now being incorporated into table-top spectrometer systems at Sandia Labs for evaluation by Department of Defense laboratories.

We are also studying the shock-survivability of the Polychromator in support of its eventual deployment. This is reported separately (see "Reliability of MEMS Devices in Shock Environments").

This program will end in May, 2002.
