

CHARACTERIZATION OF SPM PROBES USING PHOTO-THERMO-ELASTIC PHASE LAG

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INTRODUCTION

- The heat absorbed by a bilayer cantilever in the optical beam deflection (OBD) method causes a temperature gradient over its length that results in thermal stresses and deformations.
- Dissipation requires times, resulting in a phase lag between actuation and response.
- The phase lag information can be used to accurately align the optical beam deflection method; to determine layer thicknesses; and characterize thermal properties.



THEORY

- Heat is supplied as a Gaussian function, centered at a distance b from the base of the cantilever.
- The absorbed heat results in a temperature distribution that yields thermal stresses and deformations.
- Temperature distribution assumed constant along thickness and in transverse direction.
- Predicted phase lag of rotations are depicted in Figure 1 for a bilayer cantilever as a function of the location of the laser spot and the driving frequency.

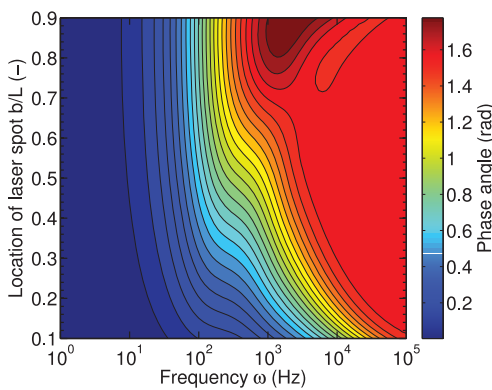


FIG. 1. Phase shift as a function of position and signal frequency. $L = 500 \mu\text{m}$, $D = 7 \times 10^{-5} \text{ m}^2 \text{ s}^{-1}$, full-width half minimum of spot of $30 \mu\text{m}$.

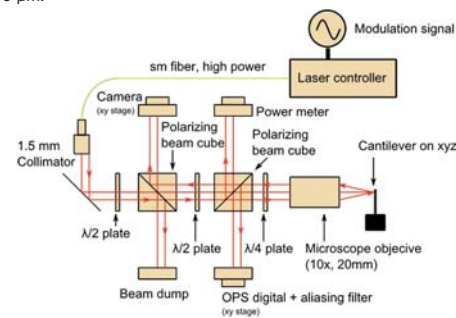


FIG. 2. Schematic illustration of the table-top OBD setup. Reproduced by permission from Herfst et al., Measurement **56**, 104–106 (2014). Copyright 2014 by Elsevier.

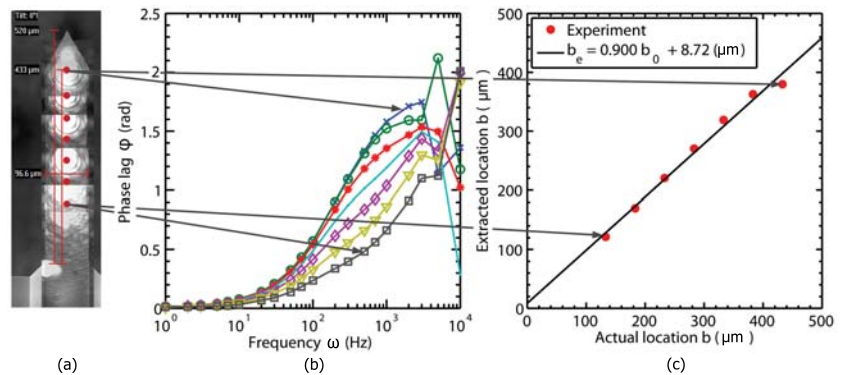


FIG. 3. (a) SEM of cantilever with CCD images superimposed. (b) Measured phase lag angles as function of actuation frequency. (c) Actual spot location as found in (a) versus extracted location based on phase lag ($R^2 = 0.986$).

EXPERIMENT

- Table-top OBD setup is illustrated in FIG. 2.
- Fiber laser of which the beam is focused on the cantilever. Amplitude is modulated harmonically at frequency ω .
- Reflected beam is imaged on an optical position sensor.
- CCD and microscope objective provide optical microscopy for manual alignment of focus.
- Spots are centered laterally and indicated in FIG. 3(a).

DISCUSSION

- Phase lag information can be used for automatic alignment of the OBD method.
- Thermal diffusivity can be derived and combined with the conductance to yield layer thicknesses.
- Convective heat exchange at the microscale is not well understood. To be further investigated.

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