

Simple models for piston-type micromirror behavior

M H Miller¹, J A Perrault², G G Parker¹, B P Bettig¹
and T G Bifano²

¹ Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931,
USA

² Boston University, 15 St Mary's Street, Brookline, MA 02446, USA
E-mail: mhmill@mtu.edu

Received 7 September 2005, in final form 9 December 2005

Published 9 January 2006

Online at stacks.iop.org/JMM/16/303

Abstract

Parallel-plate electrostatic actuators are a simple way to achieve piston motion for large numbers of mirrors in spatial light modulators. However, selection of design parameters is made difficult by their nonlinear behavior. This paper presents simple models for predicting static and dynamic behaviors of fixed-fixed parallel-plate electrostatic actuators. Static deflection equations are derived based on minimization of the total potential energy of the beam. Beam bending, residual stress, beam stretch and applied electrostatic force are included in the potential energy formulation. Computation time is reduced by working with assumed mode shapes. The problem of predicting midpoint beam deflection has been reduced to finding the roots of a third-order equation. Model results are compared to finite-element analysis results. In the dynamic analysis, Lagrange's method is used to derive the nonlinear equation of motion. An equation for predicting natural frequency, assuming small midpoint deflections about a dc setpoint, is presented. In addition, the effect of gas pressure on the damped natural frequency of a rigid actuator is analyzed. Experimental measurements of static deflection and frequency response are compared to model predictions. The actual micromirrors exhibit less strain stiffening than the model predicts.