Linear Plate Equation Analysis for MEMS Deformable Mirror

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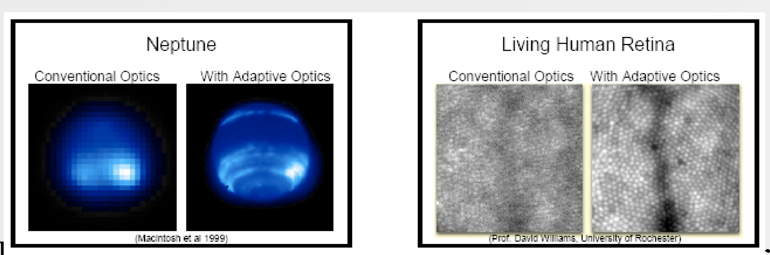
Abstract

Adaptive optics help improve the efficiency of ground based astronomical imaging systems by compensating for the unstable medium in the optical path. To accomplish this a wavefront sensor measures the distorted incoming wavefront from a reference object whose ideal wavefront is known. Based on the measured aberrations in the reference wavefront, a correction is applied to the deformable mirror which cleans up the image

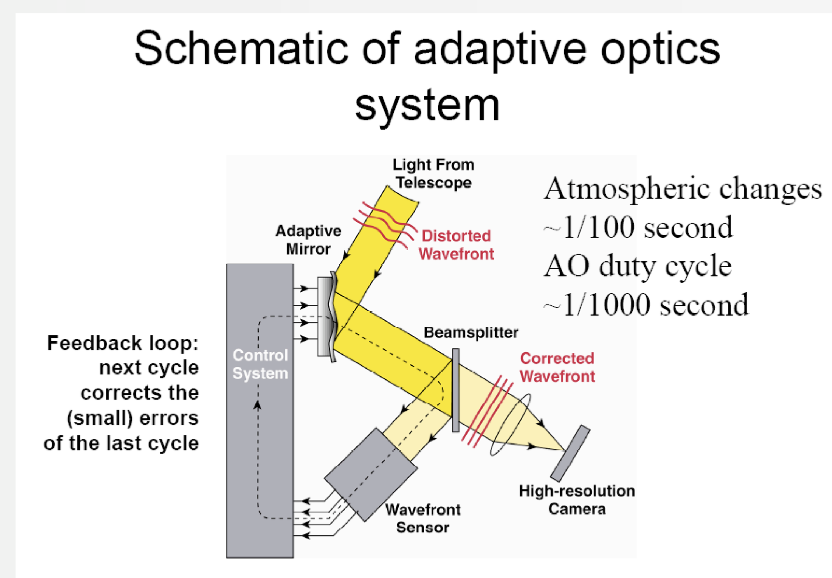


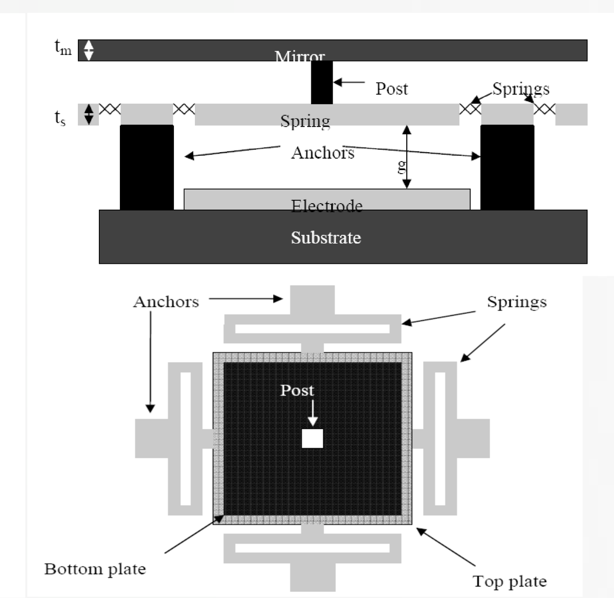
In order to properly correct the image, Micro-Electro-Mechanical System (MEMS) Deformable Mirrors need to be created with the correct design parameters. A MEMS DM can be modeled as a simply supported plate, and by using Navier's method, an expression can be found for the displacement of the plate. A simulation was created to analyze the displacement under various loads, as well as the displacement with different sized posts. From the results, the optimal value for MEMS springs could be determined.

Objective

- Given initial parameters, find maximum actuator displacement under different loads
- Find the max displacement when using posts of varying length
- Analyze relationship between force and displacement, as well as post size and displacement
- Determine value for spring constant using Hook's law: F=-kx

Schematic of adaptive optics system





Procedure

A MEMS DM is modeled as a plate with simple supports using the plate equation:

$$D\nabla^2\nabla^2 w(x,y) = p_z(x,y)$$

Use Navier's method to transform the differential equation into an algebraic equation:

$$w(x,y) = \sum_{m=1}^{m=M}\sum_{n=1}^{n=N} W_{mn}\sin\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)$$

Determine parameters for length, width, and thickness of mirror, post location, and number of actuators

Create a simulation using Matlab to solve for the deflection given the inputs

Obtain optimal value for Spring constant k

Background

Micro -Microfabricated structures , 10-6 scale

Electro -Electrical signal/control (input/ output)

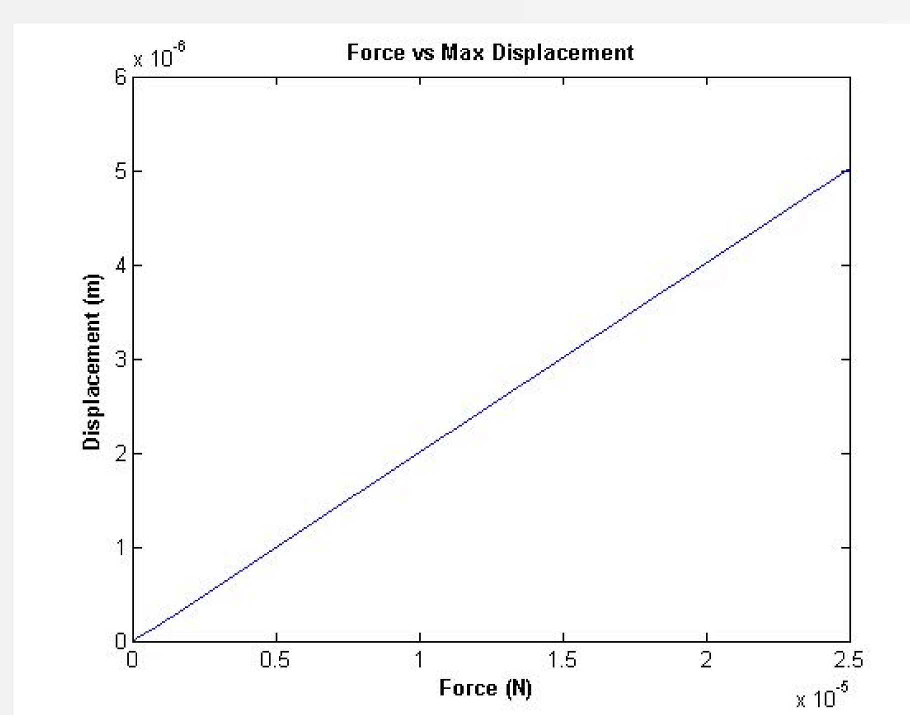
Mechanical -Mechanical functionality (input/output)

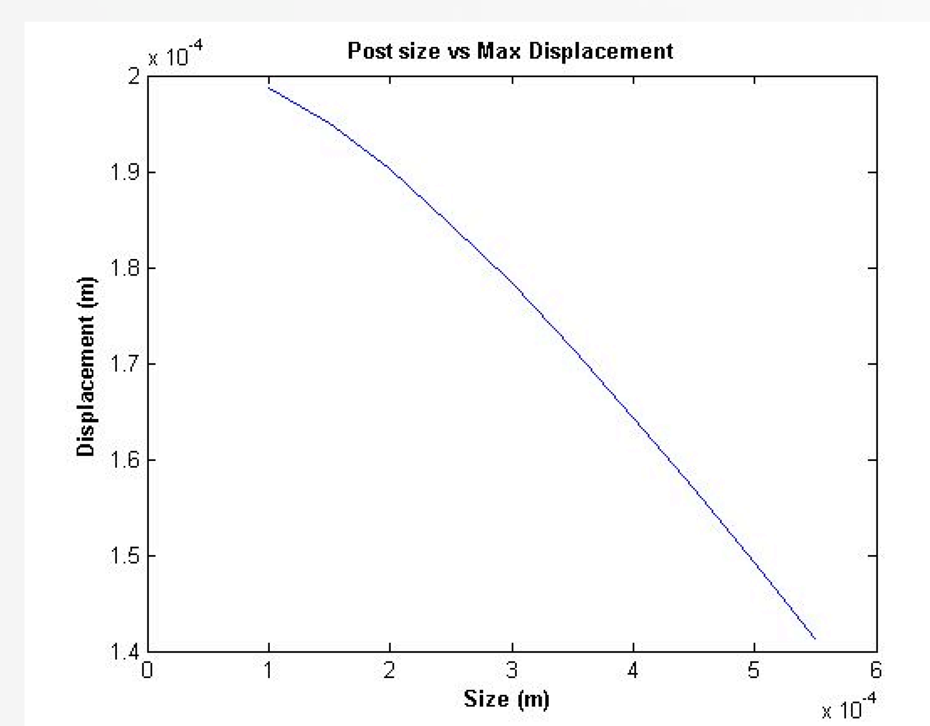
Systems -Devices, control, structures

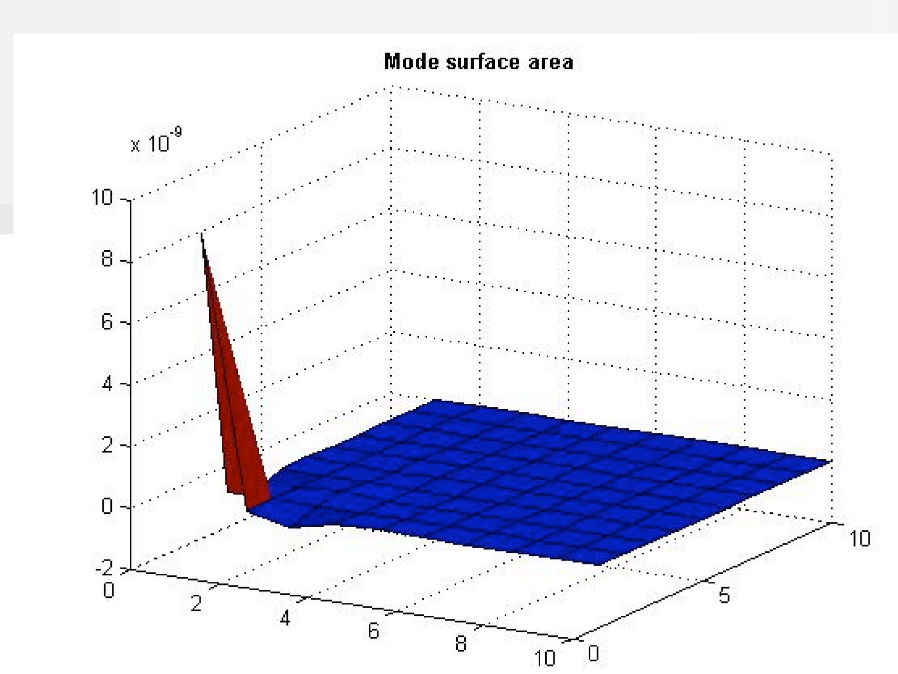
Common Applications

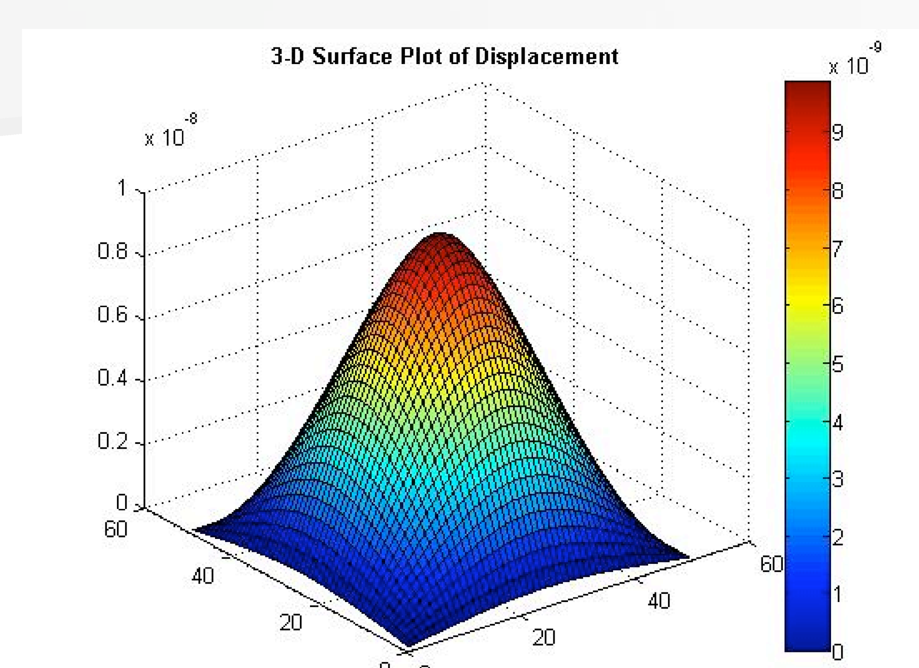
- Sensors
  - -Automotive
  - -Wii, Iphone
- Display
  - -Texas Instruments DLP
  - -Ink Jet Printing
- Adaptive Optics
  - -Vision Science
  - -Imaging Systems

Simulation Results









Conclusion

Square Force simulation

- A linear displacement was found when varying the force
- A non-linear, decreasing displacement given when the size of the post is increased

Point Force simulation

- A linear displacement was observed under a force approximated to a single point

Design Parameters

- A spring constant of 4.973 is required to design a DM with a deflection of 6µm when under forces on the micro scale

Acknowledgments

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References

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