FINAL PROJECT
Compliant Mechanism Design

Introduction

A flexure-based micro-mirror that can translate (i.e. piston) up and down can be used to modulate the phase of light reflected off of its surface for a variety of high-impact precision applications (e.g., adaptive optics). Such mirrors are often driven to operate at their resonant frequencies to minimize the system's required actuation energy and to simplify the mirror's control such that no sensors or closed-loop control circuitry is necessary to achieve the desired speed. Although it is important that the natural frequency associated with the mirror's translational degree of freedom (DOF) is as large as possible so that the mirror can resonate at the highest speed possible, it is even more important that all the other natural frequencies (rad/sec) are at least an order of magnitude (x10) larger than that first natural frequency so that the mirror does not move with other unwanted DOFs. It is also important that the desired translational DOF experience as little parasitic error as possible as the flexure elements deform over a large range so that the light is not redirected by unwanted tipping or tilting motions. For this project, you will design such a mirror and write a report about your design and its predicted performance. Note that this is not a group project and what you turn in should be your own original work.

Task 1: Background

Research all previous designs that utilize resonant frequencies to achieve a high-speed micro-mirror, particularly those with the single piston DOF desired. Learn how they work and reference them in the introduction of your report as you introduce the topic.

Task 2: Topology Synthesis

Use FACT to synthesize the topology of a micro-mirror with a reflective surface that covers 1 mm^2 of area. This mirror should be constrained by flexure elements of any kind that permit the mirror to achieve the single translational DOF desired. The translational DOF should point in a direction that is orthogonal to the mirror's reflective surface. The direction of this DOF should be maintained as much as possible as the flexure elements deform over a large range.

The resulting flexure system can be any configuration (i.e., parallel, serial, or hybrid), but the system should avoid parasitic error, over-constraint, and under-constraint wherever possible. Note that you may need to over-constrain your system to reduce parasitic error through symmetry or to enable a feasible fabrication approach, but over-constraint should be minimized to achieve as much precision as possible. Thermally stable systems are also desirable. As you synthesize the system, it is also important to consider fabrication feasibility. Your final design should be able to be made in a standard microfab like the one at UCLA (Note: you will, however, not be required to make your design for this project). You will need to determine what kind of actuator/s to use and where you'll put them to actuate (add energy to) the system so that it continues to vibrate with the resonant frequency of the desired translational DOF. It is recommended that the flexure elements used are derived from rectangular prism geometries so that they can be modeled using the twist-wrench stiffness matrix provided in the lectures. Be sure to provide a figure detailing all the features of your synthesized topology including where your actuator(s) are mounted.

Task 3: Design Characterization

You will generate a twist-wrench mass and stiffness matrix of your synthesized topology to calculate and optimize the first natural frequency of the desired translational DOF and the natural frequency of the second natural frequency. The final natural frequencies achieved should be verified by finite element analysis (FEA). The larger the first natural frequency is and the larger the difference between the second and first natural frequencies is, the better. Figures showing your deformed CAD model using modal analysis is required for these first two mode shapes.

Task 4: Fabrication Approach

In your report be sure to explain each step of your proposed fabrication approach detailing why you chose what you did. The fewer steps necessary to make your mirror, the lower your fabrication costs will be, and the more successful you would be at making a profitable startup company based on your design. You may also want to consider the time and cost necessary to perform each step of your proposed process.

Task 5: Report

You are required to write a 5-page report about your mirror design. Use the formatting in the template uploaded on the course's website. The report should be broken up into 7 main sections, which are organized as follows:

(1) Introduction explaining the purpose, importance, and impact of the project.
(2) Background information as detailed in Task 1.
(3) Explanation of your chosen topology and how it works as detailed in Task 2.
(4) Discussion about the first two optimized resonant frequencies and their corresponding mode shapes calculated using the mass and stiffness matrices taught in the course along with the supporting FEA verification as detailed in Task 3.
(5) Specific steps of your fabrication approach as detailed in Task 4.
(6) Conclusion
(7) References

You may also include copies of your Matlab files attached to the back of the report (these copies do not count toward the report's page limit). The final document should be submitted as a single pdf file titled using your last name (e.g., Hopkins.pdf). Read the syllabus very carefully to know how to turn in the project and what day and time the project is due. **Late projects will unfortunately not be accepted** (no exceptions for any reason). It is recommended that you turn the project in early so you do not have any last-minute issues.

Good luck!