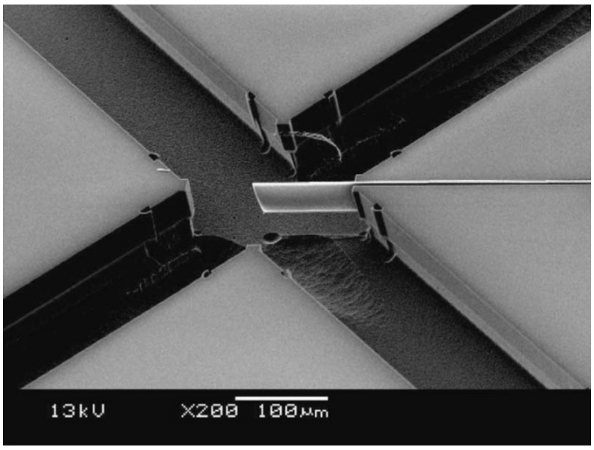
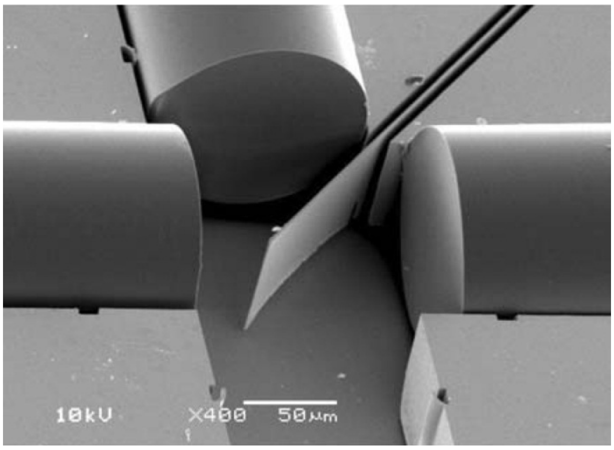
Task description

A. Objective:

To design a mechanically bi/multi-stable optical in-plane switch for routing telecommunication signals in an optical network





B. Application background:

A vertical, i.e. perpendicular to the wafer surface, micro-mirror has to be inserted or removed from a X-crossing of the optical path of optical fibers, for routing the optical signal either straight-through or in a 90° bend. Furthermore, the actuation mechanism has to be made so that it can be mechanically locked in both the full-in and full-out position, i.e. external energy is only required for the switch transition and not for keeping the mirror in either position. Furthermore, the device must also be able to operate in a tuneable-attenuator mode, which is achieved by partially inserting the mirror into the optical path into different positions.

C. Task description

All tasks must be solved using the SOI MEMS fabrication process with laterally (in-plane) moving microstructures.

Summary of most important geometrical limitations of this process: device layer thickness=30 µm, minimum feature size=4 µm, minimum gap=3 µm (check the fabrication lecture!), largest dimension of a single actuator should not exceed 1.5 mm.

In Tasks 1-3, you have to build the basic, main actuator. In Tasks 4-6, you will utilize the main actuator building blocks and design the basic micro-grippers. In Tasks 7-9, additional elements are added.

1. TASKS TO BE DONE FOR REVIEW MEETING 1:

Task 1.1. Design of basic actuator

Utilizing the SOI MEMS fabrication process presented in the lecture, design an in-plane moving (*x*-axis) electrostatic push-pull actuator which fulfils the following specifications:

- total displacement of 30 µm between its two end positions, i.e. a mirror of a length of 30 um can be completely moved in or out of an optical channel
- passive restoring force in each end position of $F_{rest,passive}$=30 µN

- the stiffness of the restoring mechanism in the unwanted in-plane direction (*y*-axis) should be at least 25 times higher than in the wanted (*x*-axis) direction.
- it must be possible to move and keep the moving mass of the actuator into any position along the line between the two end points, by controlling the external actuation voltage(s)
- for full control of this actuator, not more than two programmable voltage sources should be needed.
- the required actuation voltage for any of the voltage sources should not exceed V_{max}=65 V.
- the total area of the actuator should be minimized, and the largest dimension of the actuator should not exceed 1.5 mm

To be done for the first review meeting:

1. Decide which type of electrostatic actuator you want to utilized for these specifications. Motivate your decision!
2. Outline (drawing) a basic concept of the actuator, including actuation elements and restoring elements.
3. For the actuation elements you have chosen, simulate the actuation force over at least its whole displacement, by using COMSOL (2.5 D model; optional: full-3D model). Compare the simulation results to text book formulas.
4. Design a passive restoring force mechanism which fulfils the specifications of the actuator above. Think about how to arrange the restoring mechanism with the actuation elements.
5. Calculate the force over displacement of the passive restoring mechanism by using text-book formulas. Simulate the force by using COMSOL. Simulate the stiffness of the total restoring mechanism in the unwanted directions.

Hint: investigate symmetrical designs; they are most promising for good stability.

<u>2. TASKS TO BE DONE FOR REVIEW MEETING 2</u>

<u>Task 2.1. Implementation of basic optical switch</u>

To be done for the second review meeting:

1. Investigate the lateral stability: up to which lateral displacement is the structure stable at full actuation voltage? (hint: as simplification, investigate for the rest position with applied actuation voltage; optional: investigate also for end position)
2. Investigate also the rotational stability. How can you improve your design in terms of rotational stability?
3. Develop an alternative passive-restoring force mechanism fulfilling the same specifications as in Task 1. Simulate the stiffness in the three axis and compare the stiffnesses of this new design to the design in Task 1.
4. Implement the design (actuator with actuation mechanism and restoring mechanism) of Task 1 and also the design with the alternative spring concept by using the LEdit layouting software. <u>Consider the design rules!</u> Finalize the LEdit design layout by considering the design rules shown in lecture 4. Implement the designs in a way that the optical mirror is completely inserted into the optical path in one extreme position of the actuator, and that the mirror is completely retracted from the optical path in the other extreme position. In rest position, the mirror should be in a middle position, i.e. attenuating the optical signal to 50%. When implementing the layout of this actuator, consider where to put structures for avoiding potential short-circuit between actuation elements, and how many of these structures must be used.

<u>Task 2.2. Implementation of basic optical switch, and concept for locking mechanisms</u>

To be done for the 2nd review meeting:

1. Develop (a concept drawing) of a locking mechanism for keeping the mirror locked in both of its end positions. Decide and reason on that type of actuator you want to use for this locking mechanism (basic specifications: max. 65 V operation voltage)

<u>3. TASKS TO BE DONE FOR REVIEW MEETING 3</u>

<u>Task 3.1. Implementation of switch with locking mechanism(s) and test actuator(s)</u>

To be done for the 3rd meeting:

1. Implement (=draw LEdit design) the design of Task 2.2, i.e. actuator for optical switch with locking mechanism(s)
2. Implement an embodiment of the basic actuator design (without locking mechanism), which also contains a test actuator for testing the lateral stability of the basic actuator.

D. Summary of LEdit designs to be delivered

Compulsory for passing the course:

A. Basic actuator design (actuation mechanism, restoring force mechanism) (Task 2), with extension to mirror
B. Basic actuator design with alternative spring mechanism (Task 2), with extension to mirror
C. Basic actuator with locking mechanism (Task 3)

Optional, i.e. recommended for trying to pass the course with a higher grade:

D. Basic actuator with test actuator (Task 3)
E. Variations of the basic actuator design, in order to try different arrangements and to investigate their different performance, for instance stability in unwanted directions of movement (instability both in y and z direction and also rotational instability)
F. Variations of the basic actuator design with the locking mechanism, in order to try different locking mechanism arrangements. One variation of the locking mechanism could be that the mirror can be locked in multiple positions between the end positions.

E. PhD course FEK3360

For the PhD course:

- all designs which are optional for the MSc course are compulsory for the PhD students.
- a proper analysis of the performance of the characterized devices as compared to the design expectations, must be more completely worked out.
- a proper analysis of stability in x, y, z dimensions and rotational stability must be carried out.
- after completion of the project, the PhD students have to elaborate on scientific papers related to the project work, and present an analysis of these publications to their peers.

E. Reports

The intermediate report should be a summary of the design phase, your achievements, description of your designs, simulation/calculation results, design considerations, etc., along the lines of the task description above. The intermediate report can directly be used as a part of the full final report.

The final report should contain all achievements, including the design phase, and in addition a section on the characterization phase with reflections on how the measurements match the design expectations, failure analysis, and in particular recommendations for design improvements of your devices for a (fictional) second development cycle. The final report should also contain the characterization results achieved during the fabrication phase.

The final presentation should summarize the project work, the results and the conclusions.