5.3 Micro-Opto-Electromechanical Systems with Micromirrors

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Introduction

Micro-opto-electromechanical systems (MOEMS) consist of one or more optical elements, which are actuated electrostatically, magnetically, thermally or by other means. This actuation is applied to produce the desired operation, e.g., switching or filtering. MOEMS are one of the promising new enabling technologies for integratable complete optical systems. Assuming moderate production volumes, silicon micromechanics with integrated optics can provide better performance and quality with less space and lower expenses.

The aim of the MOEMS project at VTT is to develop the manufacturing technologies and the knowledge of Micro-opto-electromechanical systems and to apply them to telecommunications applications. The objective is to combine the knowledge the Microelectronics centre has on silicon processing with the knowledge the Photonics group has on integrated optics and telecommunications technology. At the moment two different points of emphasis have been chosen: Tunable Fabry-Perot filters and optical switches. Both technologies are based on moving micro mirrors. The actuating is done electrostatically and thermally.

SOI Micromechanical mirrors for optical switching

The continuously expanding traffic of telecommunication networks requires increasingly faster components, e.g., switches at the nodes of optical networks. In the switching units currently available, the optical signal is transformed to an electrical form for the switching operation, after which it is sent as an optical signal again. The problem arising from this type of switches is their limited capacity. A possibility to increase the capacity is to replace these electronic switches with all-optical ones. All-optical switches guide the incoming optical signal directly to the selected output port, keeping it optical all the time. The switching operation can be performed, e.g., by using moving micro mirrors.

The optical switches designed at VTT are based on movable micromechanical structures designed to the device layer of a SOI wafer [1]. A micro mirror that is integrated to a movable cantilever is used to guide an optical signal from an input waveguide to one of the several output waveguides, thus forming a 1xN switch. At the moment, two kinds of actuation mechanisms are under development: thermal and electrostatic actuation. Thermal actuation is based on a two-layer structure that consists of materials with different thermal expansion coefficients while electrostatic actuation is based on the electrical attraction between two structures with different potentials.

Figure 1. Microscope image of a thermally actuated micro mirror with an integrated temperature measurement circuit.

Figure 2. Vertical cross-section of the thermally actuated micro mirror. Note that the vertical dimension is exaggerated.
The design of the thermally actuated micro mirror (see Fig. 1) includes two-layer micromechanical cantilevers with integrated molybdenum heating wire for temperature control. Also demonstrated is an integrated temperature measurement circuit based on changes on the resistance induced by the temperature change. Structure designs with different number, width, length and placement of cantilevers have been fabricated to test mirror movement. The mirror is protected against distortion in the design. A microscope image of a fabricated test structure is shown in Fig. 2.

![Figure 3. Layout of the electrostatically actuated micro mirror. Capacitor area is enlarged by using comb structures.](image)

The design of the electrostatically actuated micro mirror (see Fig. 3) is based on cantilevers with comb structures to maximise the actuating force. The cantilevers have a heat-treated polysilicon layer with a residual stress, which rises the cantilevers and the mirror from the wafer layer. When a voltage difference between the cantilever and its surrounding electrode is applied, the cantilever bends back to the wafer level.

**Tunable Fabry-Perot devices for optical telecommunications**

Micromechanical tunable Fabry-Perot device is studied for optical telecommunications. The interferometer consists of two mirrors whose separation can be adjusted by applying a voltage between them. The change in mirror separation shifts the center wavelength of the transmission band. Possible applications include, e.g., channel selection, tunable attenuator and signal monitoring.

**References**