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DESIGN OF A MEMS BASED WAVE DIVISON MULTIEXING (WDM)

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Abstract- MEMS optical switch have become important because of their application in the field of telecommunication optical networks. Here, design aspects of a MEMS based optical switch are presented for calculating the actuating voltage and displacement of 1×1 and 2×2 optical switches with electrostatic actuating. The analytical & FEM modeling results are presented.

Index terms - MEMS, Pull-in voltage, Optical Switch.

1. INTRODUCTION

Optical communication, in particular, wavelength-division-multiplexing (WDM) technique, has become a promising networking choice to meet ever-increasing demands on bandwidth from emerging bandwidth-intensive computing/ communication applications, such as data browsing in the World Wide Web, multimedia conferencing, e-commerce, and video-on-demand services. The unprecedented demand for optical network capacity has fueled the development of long-haul optical network systems which employ wavelength-division multiplexing (WDM) to achieve tremendous capacities. Such systems transport tens to hundreds of wavelengths per fiber, with each wavelength modulated at 10 Gb/s or more. Up to now, the switching burden in such systems has been laid almost entirely on electronics. In every switching node, optical signals are converted to electrical form (O/E conversion), buffered electronically, and subsequently forwarded to their next hop after being converted to optical form again (E/O conversion).

Electronic switching is a mature and sophisticated technology that has been studied extensively. However, as the network capacity increases, electronic switching nodes seem unable to keep up. Apart from that, electronic equipment is strongly dependent on the data rate and protocol, and thus, any system upgrade results in the addition and/or replacement of electronic switching equipment. If optical signals could be switched without conversion to electrical form, both of these drawbacks would be eliminated. This is the promise of optical switching. The main attraction of optical switching is that it enables routing of optical data signals without the need for conversion to electrical signals and, therefore, is independent of data rate and data protocol. The transfer of the switching function from electronics to optics will result in a reduction in the network equipment, an increase in the switching speed, and thus network Throughput, and a decrease in the operating power. In addition, the elimination of E/O and O/E conversions will result in a major decrease in the overall system cost, since the equipment associated with these conversions represents the lion's share of cost in today's networks.

One of the most promising concepts for high capacity communication systems is wavelength division multiplexing (WDM).

Wavelength Division Multiplexing (WDM) is the basic technology of optical networking. It is a technique for using a fiber (or optical device) to carry many separate and independent optical channels. The principle is identical to that used when we tune our television receiver to one of many TV channels. Each channel is transmitted at a different radio frequency and we select between them using a "tuner" which is just a resonant circuit within the TV set. Of course wavelength in the optical world is just the way we choose to refer to frequency and optical WDM is quite identical to radio FDM.

In fiber optic communication system, wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a

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single optical fiber by using different wavelength (i.e. colors) of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity.

A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer. This is often done by use of optical-to-electrical-to-optical (O/E/O) translation at the very edge of the transport network.

Erbium-doped fiber amplifiers (EDFAs) allow direct amplification of the optical signal of all wavelengths. This makes WDM a cost effective way to increase the capacity of fiber optical communication systems by adding wavelengths (channels) to the existing system. The number of channels one can add to the system in large part depends on the fiber performance.

Wavelength Division Multiplexing (WDM) is an important technique for increasing the overall capacity of optical networks. The evolutions of WDM (Fig.1) transmission from simple point-to-point Transmission to more complicated multi-user networks requires advanced functionality in the optical network nodes (ONN's) such as routing and add/drop functions.

Present day requirement is to transport tens to hundreds of wavelengths per fiber, with each wavelength modulated at 10 GB/s or more. Because of this, it becomes necessary to find new ways of provisioning and restoring network traffic in the wavelength level. WDM is similar to frequency-division multiplexing (FDM). But instead of taking place at radio frequencies (RF), WDM is done in the IR portion of the electromagnetic (EM) spectrum. Each IR channel carries several RF signals combined by means of FDM or time-division multiplexing (TDM). Each multiplexed IR channel is separated, or demultiplexed, into the original signals at the destination.

MEMS are the recent technology used to implement such functions in compact and low-cost form.

The use of WDM can multiply the effective bandwidth of a fiber optic communications system by a large factor. There is a growing interest in deploying WDM (Wavelength Division Multiplexing) systems to meet the high bandwidth needs of Internet traffic, especially for networks of the scale envisioned for nationwide or global ISPs (Internet Service Providers).WDM is a mechanism to multiplex signals on different wavelengths using optical technology.

By adding reconfigurability to WDM multiplexers/demultiplexers, whereby light paths can be reconfigured as needed, the role of WDM technology has been extended from a simple point-to-point transmission technology to a networking technology. WDM is being used worldwide in both terrestrial and undersea installations.

A fiber optic repeater device called the erbium amplifier can make WDM a cost-effective long-term solution. The basic building block diagram of WDM is given here-

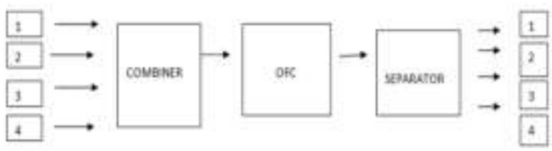

Fig. 1 Block diagram of WDM

II. THEORY

The two-dimensional (2D) MEMS optical switch is basically an optical crossbar switch with N^2 micro mirrors that can selectively reflect the optical beams to orthogonal output ports or pass them to the following mirrors. They are often referred to as "2D switches" because the optical beams are switched in a two-dimensional plane.

The core of the switch is an NxN array of micro mirrors for a switch with N input and N output fibers. The optical beams are collimated to reduce diffraction loss. The micro mirrors intersect the optical beams at 45^0 be switched in and out of the optical beam path.

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The micro mirrors are "digital", that is, they are either in the optical beam path (ON) or completely out of the beam path. When the mirror in the i-th row and j-th column (Mij) is ON, the i-th input beam is switched to the j-th output fiber. Generally, only one micro mirror in a column or a row is ON. Thus during operation of an NxN switch, only N micro mirrors are in the ON position while the rest of the micro mirrors are in the OFF position.

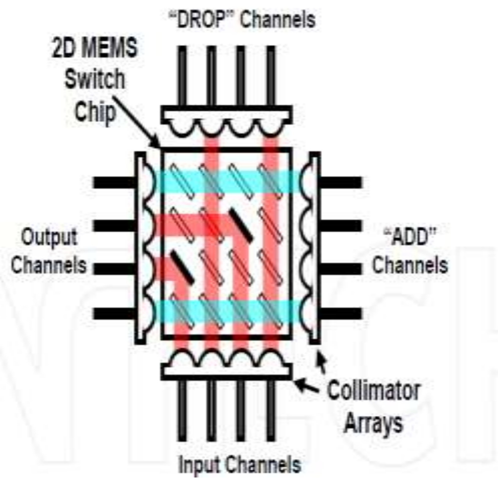


Fig.2 Schematic of 2D MEMS optical switches

The geometry of the switch (2X2) is shown in Fig 3. Here, this is cantilever beam structure with a loading mass, M at its free end and other end is fixed. Assume that the mass at the end is much larger than the mass of the beam so that the mass of the beam can be neglected. This structure can be considered as a spring-mass system.

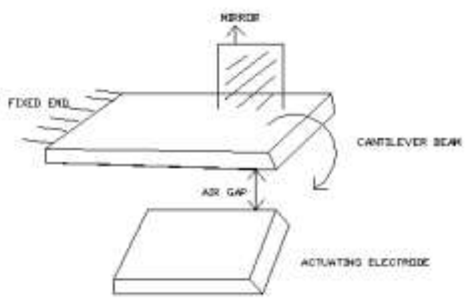


Fig.3

When voltage is applied, due to electrostatic force mirror plate comes down towards bottom electrode and thus, behaves as an ON/OFF switch.

The parameters for this structure is given in the following table-

Table1 Parameters for optical switch

1.	Material used	Poly-silicon
2.	Young's modulus	169Gpa
3.	Density of material	2.32 g/cm³
4.	Length of the cantilever beam (μm)	1000
5.	Width of the cantilever beam (μm)	500
6.	Thickness of the cantilever beam (μm)	100
7.	Length of the mirror (μm)	100
8.	Width of the mirror (μm)	100
9.	Thickness of the mirror (μm)	10

The elastic constant of the beam is

$$K = \frac{EB1H1^3}{4L1^3}$$

Where K = elastic constant of cantilever beam E=Young's modulus of poly silicon material
L1= length of cantilever beam
B1= width of cantilever beam
H1=thickness of cantilever beam
For calculating the mass of the beam and mirror we use formula

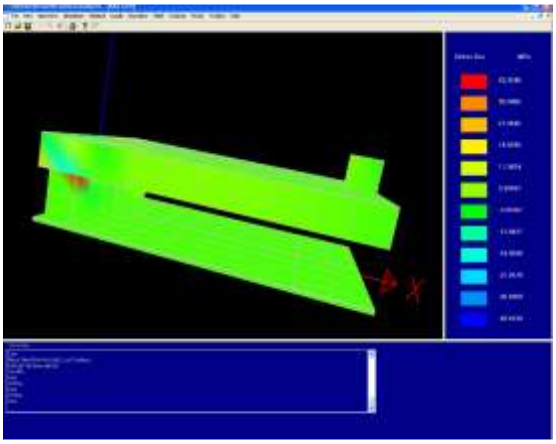
Mass= volume*density

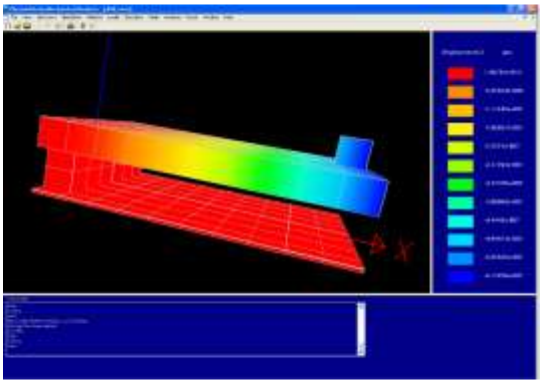
Cantilever beam's mass (M1) = L1xB1xH1xd
Mirror's mass (M2) = L2xB2xH2xd
Where L2=length of mirror
B2= width of mirror
H2= thickness of mirror
d= density of poly silicon material
Here M2> M1, so we neglect the mass of the beam. So we take M = M2 (mirror's mass)
By substituting the k, the radial frequency of the beam-mass structure is

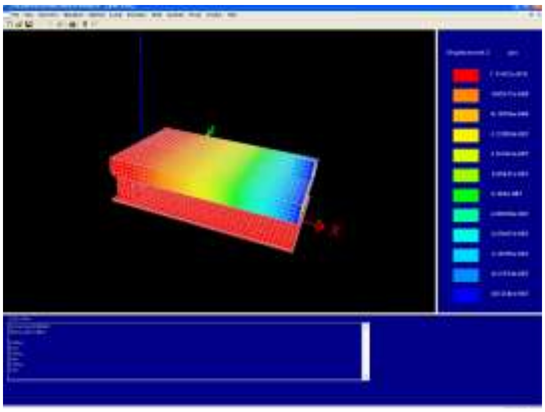
$$F = \frac{1}{4\pi}\sqrt{\frac{EB1H1^3}{L1^3 M}}$$

III. FEM ANALYSIS

The FEM analysis is done using the software intellisuite. With the help of this, we are able to view the 3D structure of the device and calculate the various parameters like resonant frequency, displacement and stress. The snapshot of the structure is given as:







IV.RESULT & DISCUSION

Analytical result and FEM simulated result are near to each other. WDM Design is for micro-second and below for MHz frequency multiplexing.

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