Department of Electrical Engineering and Computer Science
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6.777 Design and Fabrication of Microelectromechanical Devices

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DESIGN PROBLEM: Thermomechanical Optical Attenuator

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Problem Statement

Optical communication systems require variable attenuators and shutters to control individual light beams. This project explores the use of thermomechanical actuation to create a MEMS variable optical attenuator (VOA) and its associated control circuitry. This device should incorporate a continuously adjustable element that can interrupt a light beam in a fiber optic network, thereby adjusting power level of the signal. The chip's design and packaging should therefore allow for connection with optical fibers.

Design Specifications

The concept proposed is a shutter, thermomechanically actuated, that interrupts a light beam. The travel required is 100 μm to be certain to intercept the beam from a standard multi-mode fiber. The actuation mechanism should have an open-loop switching time of 10 ms in either direction between minimum attentuation (no more than 3 dB) to maximum attenuation (at least 30 dB). Assume that the optical signals are in a 40 nm band of wavelengths centered at 1550 nm.

An important use of these attenuators is scaling of signal power to balance power at various points in the network. Therefore, your system should be designed to accept a set point and a transmitted power signal (measured after your attenuator) so that the desired transmitted power level is maintained by feedback to an accuracy of 0.2 dB.

Telecommunication standards require optical components to be guaranteed for a wide temperature range, i.e. 5 to 80 °C ; hence the VOA device and its actuation scheme needs to be insensitive to ambient temperature changes in this range (this is where feedback may help considerably).

An important feature of such attenuators is that the back-reflection should be low, less than 30 dB. The combination of attenuation and back-reflection specifications may require careful design of the thickness of the shutter in combination with various reflective films.

The VOA needs to operate with less than 5 V for full actuation. It is also desired to have less than 100 mW of power dissipation at maximum displacement.

Silicon micromachining is to be used in fabricating the device. This means, among other things, that no exposed metals may be present for high temperature steps (or DRIE, for that matter). Care must be taken in making sure that the designed process flow does not violate any fabrication constraints. The control/drive circuitry could be integrated onto the same chip if properly protected, or it could be fabricated separately.

Overview

The design process is described below in terms of several distinct tasks. However, it will be quickly recognized that all these tasks interact. The goal of the team is to delegate tasks and provide communication between tasks so that the final merged device design meets the requirements.

First-Order Device Design

Survey the thermomechanical literature to get ideas on a mechanism that could be used to create the shutter. Establish the size of the VOA device. Develop a lumped thermo-mechanical model for the actuator to support the design of the control circuit.

Circuit Design

Determine the power supply voltage you will need to drive this actuator. Design at the functional level (using, for example, op-amps, lumped passive elements, and switches), a control circuit that will drive the actuator to achieve the desired position. Develop a lumped model that supports the claim that the actuator plus circuit will meet the power and speed requirements.

Device Fabrication

Design a process flow and a mask set which produces the desired actuator. There is no need to design a process flow for the control circuitry, but an estimate of the chip real estate that would be used by the circuitry if fully integrated with the actuator should be given.

Packaging

You will need a packging concept. You can assume that your device must be placed in an enclosure that has fiber connections and lenses to focus the light exiting the input fiber and entering the exit fiber. You may be able to find an example from the optical-attenuator product literature to guide your proposed packaging scheme. Detailed package design is not required, but the method of bringing the light from the fiber to the optical pathway for your device must be clearly specified. You will also need to consider whether stray light can reach the output fiber.

Integrate the design

Iterate to ensure that the device geometry, process sequence, actuation characteristics, electrical characteristics, and packaging are compatible with each other and meet the system specifications.