MEMS VOA WITH POLYMERIC THERMAL MICROACTUATORS

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Abstract *A MEMS VOA with polymeric microactuators using microoptics is presented.
Its insertion loss < 0.5 dB, dynamic range > 50 dB, power and time for 20 dB, < 40 mW and 40 ms resp.*

Introduction

In fiber-optic networks variable optical attenuators (VOA's) are required to remotely control the power in cross-connected nodes and the gain of optical amplifiers in wavelength division multiplexed (WDM) systems. VOA's can be realized with bulk opto-mechanical components, side polished fibers, planar waveguide components and microelectromechanical systems (MEMS)[1]. A MEMS approach with a variable reflectivity mirror using microoptics is described in [2]. We take the same approach in order to take advantage of the relatively large diameter of the collimated beam that facilitates the MEMS chip fabrication. In our approach the attenuation is induced by efficient polymeric thermal microactuators that tilt a mirror and that are fabricated by a low-cost stencilprinting technique.

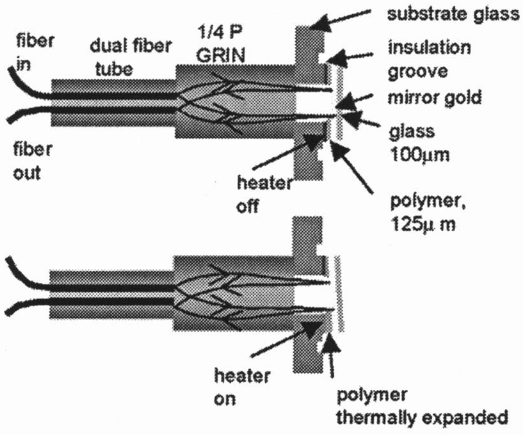

Fig.1. VOA principle of operation with mirror tilted by thermally expanding polymer bumps

VOA operation

The operation of the component is depicted in fig. 1, where its cross-section is shown with the ray paths in the activated and inactivated case. It is based on creating an offset from the minimum coupling loss point of the mode field of the input fiber with respect to the output fiber. The offset is realized by first collimating the modefield of the input fiber using a ¼ pitch GRIN rod lens. The beam is reflected and tilted by the tilted mirror and refocused by the lens onto the output fiber. The lens thus transforms the beamtilt into an offset of the modefield in proportion to its focal length. During assembly a fibertube is aligned in such a way that minimum insertion loss is obtained with an untilted mirror. The mirror tilting is realized by mounting it onto two silicone bumps en thermally expanding one of these bumps by activating a thin film heater onto which the bump is deposited. The combination of high (linear) thermal expansion (α=270 ppm/°C) with high thermal stability (-45 to+200°C) and good adhesive properties of the silicone bumps is ideal for this application.

The attenuation, Att (in dB's), in the Gaussian fiber modefield approximation, can be expressed as:

$$\mathrm{Att} = 4.343\left(\frac{2.f.c.\alpha.t.\Delta T}{\omega.w}\right)^2$$

where t is the bumpthickness, w is the bumpspacing, ω is the fiberspotsize radius, f is the lens focallength and c is an amplification factor (1<c<3) due to constrained in-plane expansion of the silicone bump. Because the temperature difference, ΔT between the bumps is proportional with the power dissipated in the heater, the attenuation will depend quadratic on the power dissipation. It can be calculated that for 20 dB attenuation, a temperature difference of 75 degrees is required in our VOA with t=125μm, w=2mm, f=3mm and ω=5.25 μm @ 1550 nm (Corning SMF 28 fiber).

VOA fabrication

The substrate with photolithographic defined NiCr heaters for 350 chips (5x5mm) is a 100x100mm borosilicate wafer. Square holes (2x2mm) to pass the lightbeam and thermal insulation grooves next and under the heaters are made by dicing the front and backside. Through that the heaters lie on airbridges (width and thickness: 500 μm). This will reduce the thermal crosstalk (power dissipation) and thermal mass (response time).

The silicone bumps are stencilprinted onto the heaters and a thin (low thermal crosstalk), borosilicate substrate(100µm) with Au mirrors is adhered to these bumps. After thermal curing, the individual chips are diced out of the wafer assembly and GRIN rod lenses (NSG SLW3) are adhered to their backsides of the chips. Dual fiber tubes are aligned and attached to the back of the rod lenses. The chip (length with lens is 8 mm, width is 5 mm) fits in a TO-5-type package.

Results

The insertion loss of the VOA's @ 1550 nm is typically< 0.5 dB. Fig. 2 shows the expected quadratic dependence of the VOA attenuation on dissipation. Less than 40 mW is required for 20 dB attenuation. The dynamic range is over 50 dB.

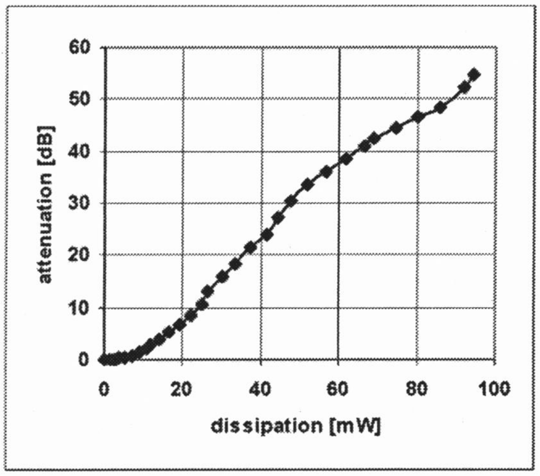

Fig2. VOA attenuation vs. heaterdissipation

Fig. 3 Shows the VOA time response after application of a voltage to a heater. The voltage has an initial overshoot to reduce the response time to 40 ms for about 20 dB attenuation. Calculations show that this can be reduced further to 4 ms (200 ms without application of an overshoot) by optimising the design. Fig. 4 shows the wavelength dependence of the VOA attenuation.

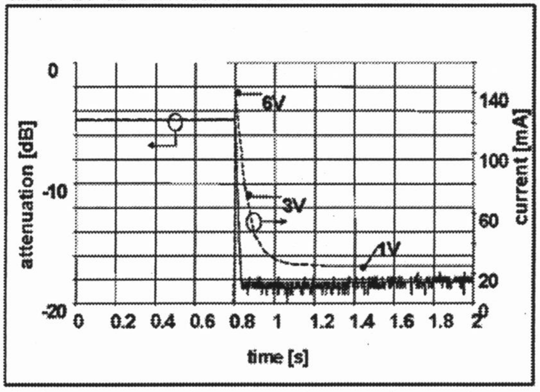

Fig3. VOA voltage/current and attenuation vs. time

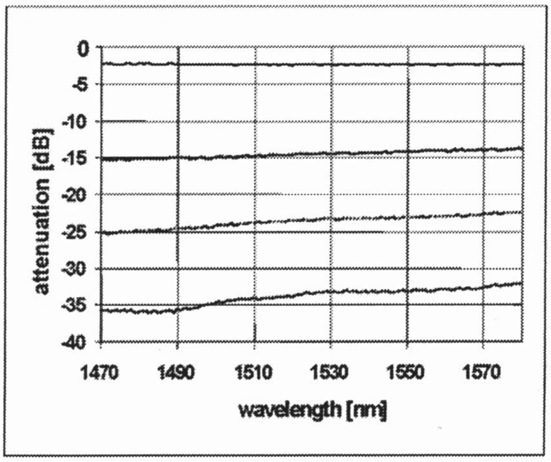

Fig4. VOA attenuation vs. wavelength

The tilt at higher attenuations can be fully attributed to the fiber spotsizeradius dependence on wavelength. It is < 0.001 dB/nm per dB attenuation. The PDL as measured is <0.01 dB per dB attenuation. The insertion loss in the off-state is stable within 0.25 dB for ambient temperature between –20 and 120 °C.

Conclusions

We describe a MEMS VOA based polymeric thermal microactuators using microoptics. This approach yields excellent devices: < 0.5 dB insertion loss, > 50 dB dynamic range, < 40 mW power consumption and 40 ms response time for 20 dB attenuation with low PDL and with low sensitivity for wavelength and ambient temperature. The fabrication process is simple with high yield and based on low-cost techniques.

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