직렬형 Waveguide-MEMS를 이용한 고출력 가변광감쇄기

High Power Variable Optical Attenuator Based on Cascaded Waveguide-MEMS

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Introduction

A variable optical attenuator (VOA) has become one of the key components in optical communications based on dense wavelength division multiplexed (DWDM) systems, where optical signal and pump power level are simultaneously controlled. Various types of VOAs have been developed in microelectromechanical systems (MEMS), planar lightwave circuits (PLC), acousto-optics (A-O), or thermo-optics (T-O). Despite these prior technologies, high power tolerable in-line fiber VOA is still in need especially for pump power control in optical amplifiers such as Raman and erbium-doped fiber amplifiers (EDFAs). Fused biconical taper (FBT) technology has been adopted for VOA[1], where the refractive index of a polymer passivating a fused taper fiber is modified. Recently the authors reported a novel approach where mechanical stress was applied over the waist of FBT couplers[2].In this paper we present the waveguide-MEMS VOA where cascaded couplers provide a broad spectral range and a high dynamic range.

Elesto-optic Effects on FBT couplers

FBT couplers are fabricated by fusion and pulling processes to provide a low insertion loss and flexible control of spectral response. The FBT couplers are characterized by many factors, such the elongation length, heat-zone interval and heating temperature, which result in unique response in elesto-optic (E-O) effects. The proposed VOA is based on two-point bending provided by MEMS platforms that induces an axial stress along the waist of FBT. Due to the conically tapered geometry, E-O effects are amplified at the waist of FBT coupler[3] and requirements in the mechanical deformation for p phase shift could be minimized. However, the bent symmetric FBT couplers result in a wavelength-flattened response similar to asymmetric couplers[4] and the maximum splitting ratio (MSR) of the pristine FBT cannot be obtained after bending. Moreover, the polarization-dependent loss (PDL) could increase for high attenuation level because it is proportional to the axial tilt. We proposed a novel cascaded FBT-MEMS scheme that reduces requirement of bending and provide a high dynamic range.

Waveguide-MEMS VOA

As shown in Fig. 1(a), the proposed VOA is configured by cascading two FBT couplers whose taper waists are mounted on MEMS platforms that provides two-point bending. Here the spectral responses of the throughputs with respect to the mechanical perturbations are reciprocal as in Fig. 1(b). One of the output ports of the first stage coupler is connected to the input port of the second stage coupler to provide a broad bandwidth and a high dynamic range. The couplers are optimized for a high power VOA near 1450nm that could be directly applied to pump power control for both fiber Raman amplifier (FRA) and EDFA. The output transmission changes continuously by exerting axial stress over the coupling zone within the displacement range of 10mm. Note that this micro-actuation is analogous to that of MEMS so that conventional micro-actuators of MEMS could be readily applied in the

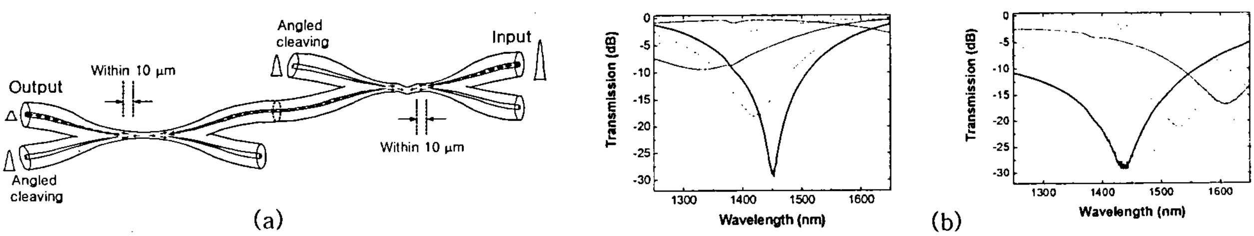

Fig.1 (a) Configuration of waveguide-MEMS VOA and (b) Spectral response of two FBT couplers for various axial displacement of two-point bending.

proposed device .

Experimental Results

The FBT couplers were fabricated with Corning SMF-28s. The fabrication parameters were; the elongation length of 17mm, the heat-zone interval of 6mm and the heating temperature of 610°C. To provide a uniform axial stress, the cross-section of the taper waist was maintained in a circular shape. The circular geometry results in a higher efficiency to modulate the coupling constant with two-point bending and a better PDL. The insertion losses of two couplers were 0.19dB and 0.21dB, respectively. Including the splicing loss of 0.1dB the total insertion loss of the proposed device was 0.5dB.Two ports of the couplers, whose spectral responses are reciprocal, were concatenated and the net spectral response provides thevery flat VOA characteristics as shown in Fig. 2. Within the range of 20dB attenuation the spectral flatness of < 1dB was achieved over the wide band of 100nm, from 1400 to 1500nm. As more axial stresses are applied to the couplers, the spectral flatness degrades but ultra-high attenuation is obtained. The dynamic range over 70dB was measured near 1450nm within the axial displacement of 10mm shown in Fig. 3. PDL was kept less than 0.1dB during the whole dynamic range. Note that this short axial displacement of 10mm strongly suggests that the proposed device could show fast response time. The current device showed response time of 20msec, which is only limited by MEMS platform speed.As In the previous work [2], the mechanical reliability and the performance reproduction were verified by an automated cycle test with axial displacement of 200mm. After 500,000 cycles of axial stress the device did not show any significant degradation.

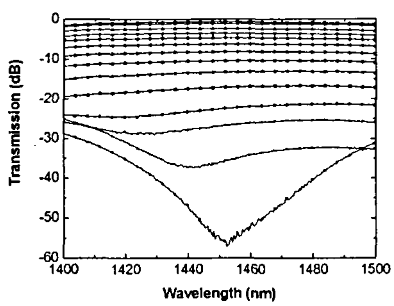

Fig . 2 Transmission spectra over wavelength showing spectral flatness of < 1dB within the range of 20dB attenuation

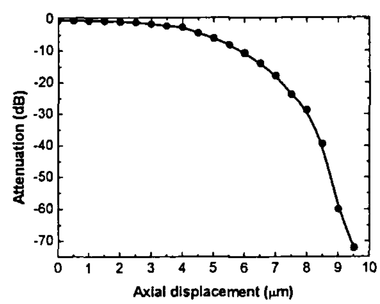

Fig. 3 Attenuation results versus axial displacements at 1450nm wavelength.

All fiber FBT couplers do have a high surface-to-volume ratio and a very low absorption to provide high optical power tolerance over level of few Watts. Maximum attenuation of 70dB was experimentally achieved at 1450nm at the input power level over 600mW without degradation, which confirms high power applicability of the device.

Conclusions

All fiber waveguide-MEMS VOA has been presented. The proposed device has low insertion loss of 0.5dB. With a proper coupler design we could achieve broad spectral flatness and the high-dynamic range of attenuation. The maximum dynamic range was over 70dB at 1450nm and the spectral flatness of less than 1dB for the 20dB attenuation was achieved over 100nm. The PDL was kept below 0.1dB. The proposed waveguide-MEMS VOA withstands high-opical power application and showed a good mechanical reliability.

Acknowledgement

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