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Programmable Fiber Optic Splitters using

Distributed Optical MEMS

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Abstract

This paper proposes novel intelligent Value Added Modules (VAMs) which employ an intelligent spatial processing technique to realize variable optical power split ratios. To demonstrate the concept of the smart VAM, the Texas Instrument (TI) Digital Micro-mirror Device (DMD^{TM}) has been used. Different optical power split ratios have been experimentally verified.

Keywords: Fiber-optics, DMD^{TM}, VAM, Power Splitter

1. Introduction

In modern optical communication systems, there is a need to ensure that the communication signals are undisrupted during transmission as it results in service disruption to the customer. This signal disruption can be due to test and monitoring of the communication network. Test and monitoring sites in a fiber optic communication network such as the Wavelength Division Multiplexed WDM systems hold great importance to ensure a certain quality of service to the customers. Tap couplers are used to tap power from the main system for test and monitoring purposes. Various designs for fiber optic tap couplers (optical power splitters) have been proposed [1-3] including the use of thin film interference filters such as WDM couplers [4-6]. The main disadvantage of such fixed power splitter schemes is that power cannot be tapped out of the system as per dynamic network requirements. Therefore, when having a fixed tap coupler, some fixed percentage of the total optical power would always be drained out of the system regardless of the changing requirements of any fiber optic (FO) network.

The solution to this predicament is to employ variable optical power splitters or VAMs. Some designs have been proposed recently for variable optical power splitting employing various techniques such as Photonic Crystal Fibers (PCFs) [8], Opto-VLSI programmable chip[11], half wave plate rotation[10] and changing the refractive index of a Y-Junction [9]. These schemes have different drawbacks. Designs proposed in [8] and [10] are slow due to mechanical motion of different system components. The design proposed in [11] used a liquid crystal digital mode optical phase spatial light modulation that results in high pixilation leading to a low diffraction efficiency and hence high VAM static loss.

The novel design proposed in this paper uses two pixels to direct optical power to two ports. One of the pixels is in a fixed state. The other pixel has two states to direct power either to the main output port or the tap output port as shown in Fig.1 where a pixel is a mirror element.

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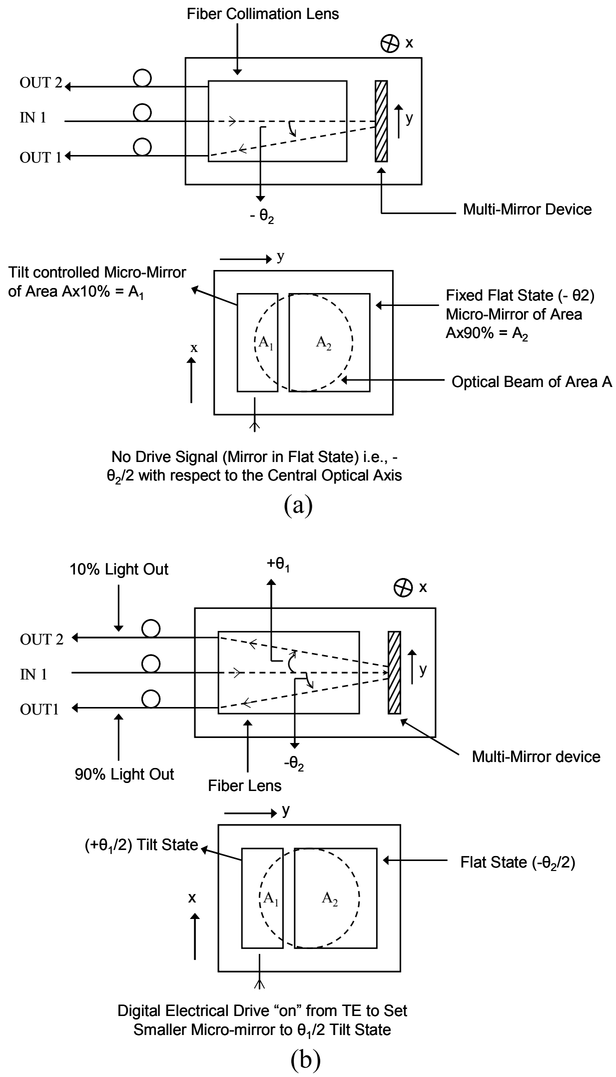

Fig.1. Proposed 90/10 smart splitter modules used to used to form the proposed smart VAMs. (a) Bypass-Mode and (b) Test-Mode of the smart splitter modules used to operate the smart VAM modes.

When this multi-state mirror is in state 1 (tilt angle of $\theta_2/2$), all power is directed to the main output port. When in state 2 (tilt angle of $\theta_1/2$), part of the optical power is tapped to the second output port that is dedicated for the tapped optical power. This is a smart VAM because it can operate both in the bypass mode and the test mode and optical power split ratios can be adjusted as per network requirements.

2. Implementation of the Smart VAM

The experimental setup for the smart VAM is shown in Fig.2. The multi-pixel scheme proposed in the previous section is implemented through the TI DMD™. There are approximately 768,000 two-state micro-mirrors on the chip with a micro-mirror pitch of 13.65 μm. Each micro-mirror can be controlled individually with a switching time of 15μs. The large pixels can therefore be formed using the micromirrors on the DMD™. Light enters the system through the input port IN1. Light would either couple back to GRIN1 or GRIN2 depending on the position of the micromirrors on the DMD™. The micro-mirrors can be oriented in a way such that the right amount of optical power is tapped to the OUT1 and OUT2 output ports depending on the requirement. The OUT1 port is the main output port of the system and all the light is coupled back to this port when no light is tapped out from OUT2. The OUT1 output port is implemented in

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a retro-reflective configuration. When some of the micro-mirrors on the DMD™ are switched to the other state, part of the input light is directed to the port OUT2.

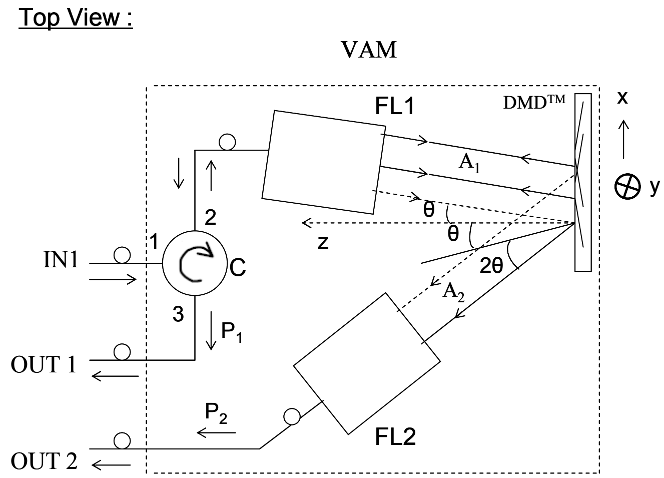
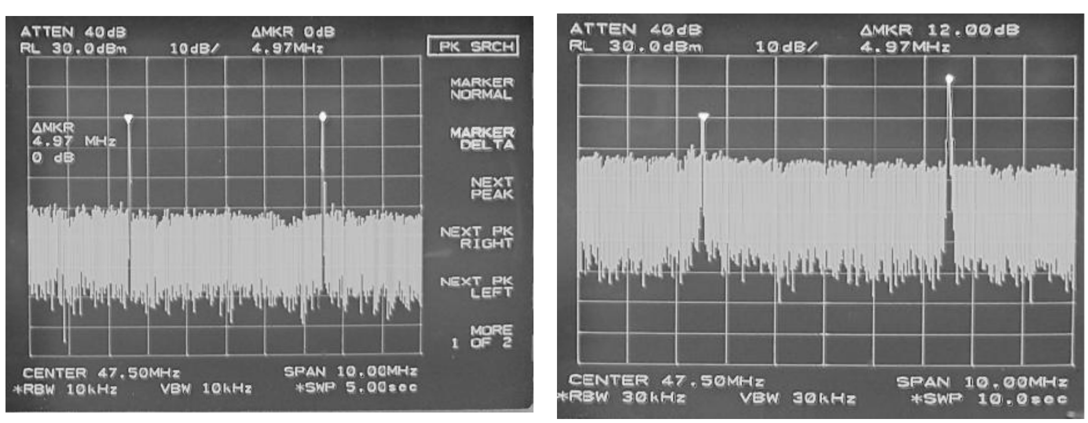


Fig 2. Demonstrated smart VAM design using a DMD™ Chip, C : Circulator, FL1/FL2 : fiber lens 1 /fiber lens 2

The advantage of using the DMD™ is that the spatial resolution of this device is very high. Therefore, power can be tapped out very accurately. Because of the fast switching time of the DMD™, the implemented VAM is very fast. The operating optical frequency of the tested VAM is in the C-Band (i.e., 1530 nm and 1560 nm).

3. Experimental Results

The experimental results have been verified by intensity modulating the light in each output port of the VAM by two different Radio Frequency (RF) frequencies at 45 MHz and 47.5 MHz. The RF signals have been detected using the RF spectrum analyzer. The difference in the two RF peaks indicates the percentage power in each of the two outputs of the VAM. The RF spectrum analyzer plots are shown in Fig.3.



(a) (b)

Fig.3. Measured RF1 (45MHz) and RF2 (50MHz) spectrum. Analyzer power traces for VAM optical power split ratios of (a) 50 : 50, (b) 20 : 80

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4. Conclusion

To the best of our knowledge, intelligent spatial processing employing fixed as well as electrically actuated pixels in a macro-pixel device has been proposed to realize a smart VAM or reconfigurable variable tap coupler [12]. The DMD^{TM} was used to generate the two pixels required to tap different amounts of optical power in an optical network scenario. Test measurements have been made in a dual-use RF infrared-band FO link. Multiple split ratios have been shown to have been achieved successfully. The advantage of the design proposed is its flexibility, repeatability and accuracy.

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