### CTuK95

## 1x8 Channel Power Splitter using Multimode Interference Couplers in InP/InGaAsP

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Numerous kinds of power splitters are proposed for optical communications, such as star couplers, cascaded Y-branch, and multimode interference (MMI) based splitters. Recently. multimode interference (MMI) devices get much attention for its use of photonic integrated circuits requiring low loss, compactness and ease of fabrication There are many research efforts regarding MMI itself as a power splitter or a coupler [1,2] and WDM devices integrated MMI.

The epitaxial waveguide structure was grown by MOCVD (metal organic chemical vapor deposition), which are composed of 1 µm-thick InGaAsP core and 0.3 µm-thick InP clad layers. The waveguide region and the MMI region are deeply etched to 1.5 µm employing $CH_4/H_2$ reactive ion etching with 100 nm SiNx masking The 1x8 MMI was designed to have the center wavelength of 1540 nm, and MMI width of 32 µm for 8 output ports The widths of both input and output waveguide need to be 2 µm for propagation with independent polarization for a given epitaxial structure.

We measured the wavelength dependence of the splitter for TE and TM modes as shown in Fig. 1(a) and (b). The output power distribution is within 2 dB for 1520 nm to 1555 nm for TE/TM modes TM mode is less disturbed for waveguide roughness, then the spectral response of TM mode shows better than TE mode. From the above results, the wavelength or mode dependency doesn't greatly affect on the splitting ratio or intensity over the measured range.

In summary, we have shown that the 1x8 MMI splitter shows good performance at power splitting in a wide wavelength range around centered wavelength. From the experimental results, the dominant factor that affects on the splitter performance is the MMI splitter width. The incident light mode or wavelength does not sensitively act on power splitting in MMI.

[1] David S Levy, Robery Scarmozzino, and Richard M. Osgood, Jr: "Length Reduction of Tapered NxN MMI Devices", IEEE Photon. Technol Lett , 10 (6) pp 830-832(1998).

[2] N S. Lagali, M R. Paiam and R. I MacDonald, "Theory of Variable-Ratio Power Splitters Using Multimode interference couplers," IEEE Photon. Technol. Lett., 11(6) pp 665-667(1999)

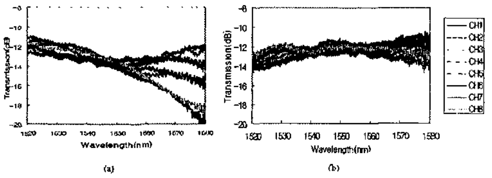

Fig 1 Transmission spectra of 1x8 MMI splitter; (a) for TE-mode (b) for TM-mode

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### CTuK96

## Balanced Electroabsorption Modulated RF Photonic Link

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Balanced RF photonic links are of great interest because they can suppress laser relative intensity noise (RIN) and amplified spontaneous emission noise (ASE) from optical amplifiers, achieving shot noise-limited performance [1]. To date, the highest performance RF photonic links have employed LiNbO3 Mach-Zehnder modulators (X-MZM). Due to their interferometric operation, X-MZM links cannot simultaneously achieve RIN cancellation and large linear dynamic range [2]

We propose a novel balanced RF photonic link using a balanced electroabsorption modulator (B-EAM). In contrast to X-MZM, the B-EAM enables the simultaneous cancellation of laser RIN, added ASE noise, all even-order distortions, and the 3rd order distortion The schematic of the B-EAM link is shown in fig 1 Differential modulation of the B-EAM is achieved by feeding the RF signals to the common electrode between the two EAMs, while the DC bias is equally split between EAMs. The 180° out-of-phase signals from the two EAMs have equal amplitudes for all bias voltages. Since the balanced receiver detects the difference photocurrent, the RF signals from the two photodiodes add in phase, while common-mode noises and even-order distortion terms are cancelled Therefore, the bias voltage on the EAM can be used to null the 3rd order derivative of the modulator transfer function Thus, the leading distortion term becomes the 5th order intermodulation.

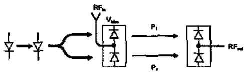

Fig 1 Schematic of the balanced-electroabsorption-modulated link

We have developed a theoretical model to simulate the performance of the proposed link. The model uses a Taylor series representation of the EAM transmission function to calculate the small signal gain, harmonic and intermodulation distortions. To determine the output noise floor, thermal, shot, and intensity noises from laser and SOA have been taken into account The equivalent Vπ of the EAMs is assumed to be 0 5V Total link loss per arm is 10 dB, amplifier gain and noise figure are 20 dB and 10 dB respectively Biasing the EAMs at 3rd order null results in a link gain of 3 25 dB, assuming 1mW laser power Figure 2 shows a comparison between single and balanced link in term of noise figure (NF) and spurious free dynamic range (SFDR) In the single-EAM link, for small laser power, the use of the SOA lead to shot noise-limited performance. As the laser power increases, RIN starts to dominate and optical amplification is no longer effective Thus, single EAM links with and without SOA have the same performance. In addition, the achievable NF and SFDR are limited by the additional noise from the SOA In contrast, in the B-EAM link the suppression of common-mode intensity noises allows shot-noise limited performance in a much wider range of laser power. NF as low as 5.8dB and a multi-octave SFDR of 130 dB-$Hz^{4/5}$ can be achieved with a laser power of 1 mW, in the presence of RIN as high as −140 dBc/Hz As optical power increases, NF asymptotically approaches 0 dB and SFDR saturates since the B-EAM link is ultimately limited by the thermal noise generated at the input and successively amplified by the link.

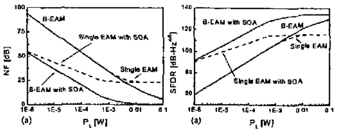

Fig 2 (a) Calculated NF vs $P_L$ and (b) SFDR vs $P_L$ for single (dashed) and balanced (solid) EAM's.

In summary, we have proposed a novel balanced-electroabsorption-modulated link that simultaneously cancels RIN, added ASE noise, all even-order distortions, and 3rd order distortions The B-EAM can be monolithically integrated with a DFB laser and SOA, allowing the possibility of all semiconductor RF lightwave transmitters to achieve ultra-wide spurious free dynamic range and low noise figure

[1] L T Nichols, *IEEE Microwave Theory and Techniques*, vol 45, p 1375, 1997

[2] E.I Ackerman, *MTT-Symposium*, 1993, p 723