InP Monolithically Integrated 1×8 Broadcast and Select Polarization Insensitive Switch for optical switching systems

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Abstract: For the first time we have designed and demonstrated polarization insensitive, high gain and broadband 1×8 broadcast and select switch suitable for optical packet switching system based on bulk SOAs integrated with passive elements.

1. Introduction

Fast gain dynamics, high on-off extinction ratio, high saturation power, and polarization independent semiconductor optical amplifiers (SOA) are key elements for all optical networks where they can be used as nanoseconds gates as well as amplifiers to compensate on-chip loss and pre-amplifiers at the receivers. SOAs are therefore a good candidate for the implementation of photonic integrated switches to realize low latency and high bandwidth optical telecom and datacom interconnect networks [1]. Among the several developed SOA based photonic switches, multi-stage broadcast and select switch (BSS) architecture requires multiple of SOAs functioning as gates combined with passive power splitter/couplers [2,3]. Therefore, the photonic integrated switch requires active-passive integration on InP wafer and polarization insensitive operation. Despite several active-passive photonic circuits including SOA amplifiers have been reported, no polarization independent operation has been demonstrated. In this paper for the first time we have designed, fabricated, and characterized a nanosecond broadband and polarization insensitive 1×8 monolithically integrated active-passive broadcast and select switch suitable for optical packet switching system based on bulk SOAs integrated with passive elements [4].

2. Broadcast and select switch design, fabrication and characterization

Compared to other works which use quantum well (QW) SOA as a switching element, bulk SOAs provide some advantages from a fabrication process point of view, like easier fabrication compared to QW active layer, and a wide range of polarization independent regimes (in wavelength and current) [5,6]. The developed monolithically integrated 1×8 polarization insensitive BSS on InP wafer includes the co-integration of bulk SOAs with passive multimode interferometers (MMI) and waveguides, fabricated with a total 4.6×1.0-mm footprint. The schematic and mask design of the developed BSS is shown in Fig. 1(a) and (b). The optical input is first amplified by the booster and then routed to the gates via MMIs which serve as splitter (and/or combiner) dividing the input optical power to 8-space channels. S-bend and MMIs connect the booster to 8th-gate SOAs. The radius of S-bend waveguide's is larger than 100µm to reduce bending loss to the minimum. The booster SOA length is 900µm, and the gate SOA length varies between 300µm and 900µm.

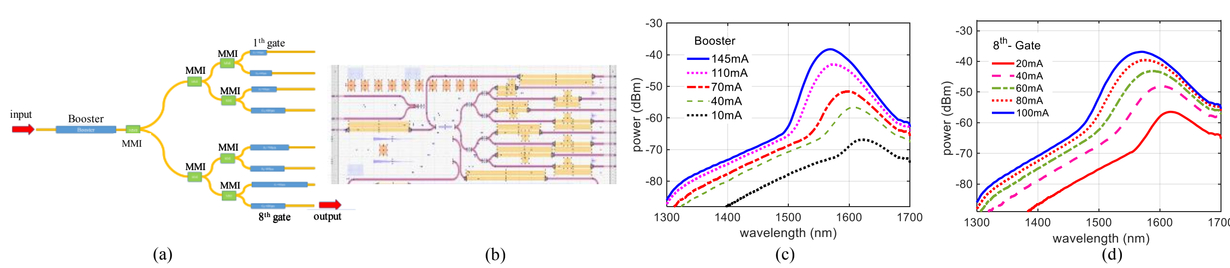


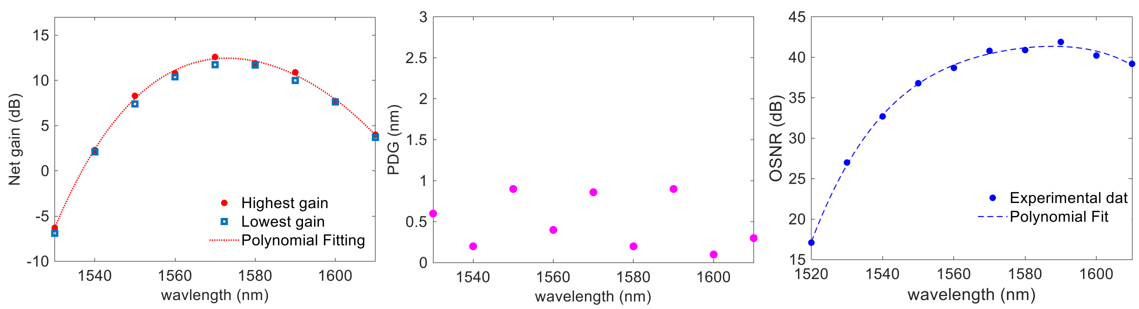
Fig. 1. (a) Schematic of 1×8 BSS, (b) Mask design of fabricated BSS. (c) ASE spectrum of booster. (d) ASE spectrum of 600 µm length SOA .

The distance between the gate SOAs is kept at 250µm because of fabrication reliability. Both facets are anti-reflection coated to minimize unwanted reflections. To fabricate low PDG SOA, a layer stack was grown consisting of an unstrained InGaAsP (λ=1610nm) surrounded by symmetric cladding layers of Q1.25. The thickness of the layers is optimized so that ratio of the confinement factor ratio for TE and TM mode (Γ_{TE}/ Γ_{TM}) is approximately unity allowing to achieve low PDG SOA. The passive waveguides connected to the SOAs and MMIs are deep-etched waveguides with 2µm width. More fabrication details are reported in [4].

3. Results and Discussion

The experimental setup to characterize the BSS consists of a continuous-wave tunable laser and a polarization controller (PC) is used to change the polarization of the injected beam and test the polarization independent operation of the circuit. At the device input and output facets, tapered (lensed) fibers are used for the fiber to waveguide chip coupling. The photonic chip is temperature controlled at 20°C and DC biased by injection of constant current. A power meter and optical spectrum analyzer (OSA) with 0.06 nm resolution bandwidth are used to collect data and further analysis. Fig. 1(c) and (d) shows the amplified spontaneous emission (ASE) spectra for the booster and one of gate SOAs, respectively, with typical blue shift of the peak wavelength when increasing the bias current because of band-filling effect.

Fig. 2 reports the performance and switching results for the path which includes the booster and the 8^{th}-gate.To demonstrate the switch performance and functionality, the booster and gates are biased with 90mA. By switching the gate SOA ON and OFF we achieved 58dB contrast ratio. By changing the polarization controller, the highest and lowest gain as a function of wavelength is reported in Fig. 2(a). Polarization insensitive operation is one of essential characteristics of the optical BSS. Fig. 2(b) shows that the polarization dependant gain (PDG) level ranges between 0.1dB and 1dB for the wavelength range from 1535 nm to 1610 nm. The net gain, considering the 12dB losses of the three cascated MMIs and waveguide losses, and 12dB fiber coupling loss (both facets), is 12.6dB at around 1570nm at 90 mA bias current. The net gain profile is around 70nm which shows the switch efficiently covers almost the C- and L-band and could be used in both communication bands.The measured high gain and broadband operation indicate that the 1×8 BSS can support further power splitter and thus it can be further scaled to larger port count and in principle able to amplify multiple WDM channels. Finally, the optical signal to noise ratio (OSNR) is also reported in Fig. 2(d) versus wavelength for BSS. Results shows an OSNR level around 40dB which is very suitable OSNR for high bitrate communincation.



(a) (b) (c)

Fig. 2. (a) Gain (b) PDG, and (c) average OSNR vs. wavelength for BSS switch. (input optical power is +5dBm).

We have demonstrated a 1×8 photonic integrated polarization insensitive broadband BSS based active-passive integration of bulk SOAs and passive MMIs. Results show that the BSS has a broadband fiber-to-fiber gain, low PDG (<1 dB) operation, and measured OSNR of 40dB in almost the C- and L-band (covering spectrum from 1535nm to 1620nm). The high gain and broadband operation indicate that the 1×8 BSS can be further scaled to larger number of ports and operate with multiple WDM channels.

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4. References

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