10 Gb/s Monolithically Integrated, Photocurrent Driven Wavelength Converter with Widely Tunable SGDBR Laser and Optical Receiver

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Abstract: A monolithically integrated photocurrent driven wavelength converter is fabricated and characterized. Bit-Error-Rate measurements at 10Gb/s show 1dB power penalties over 32nm with extinction ratios between 8.5-9.5dB. Input power is -11dBm and conversion efficiency is +13dB.

OCIS codes: (250.5300) Photonic Integrated Circuits; (250.3140) Integrated Optoelectronic Circuits

1. Introduction

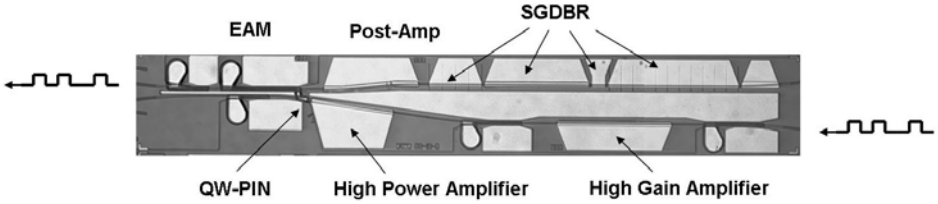
Photonic integrated circuits are key components in future all optical networks for increased functionality and lower packaging costs along with dynamic wavelength management. The development of a device that is capable of wavelength conversion and switching at high speeds without filtering to separate input and output signals, and without the cumbersome electronics associated with traditional OEO repeaters, has received significant attention [1]. To further reduce packaging costs and optical loss in such a device, a wavelength converter that is compatible with a monolithically integrated widely tunable laser source is a very attractive solution.

For very high speed filterless operation, wavelength converters based on photocurrent driven technology have been shown to support data rates up to 500 Gb/s [2]. In this device an input optical signal is detected in a photodetector and the generated photocurrent changes the voltage characteristics across a load resistor. This changes the transmission of a reverse biased Electroabsorption Modulator (EAM) and completes the wavelength conversion process. Several fully monolithic devices that utilize this technology have been demonstrated with a tunable laser source and optical amplifiers using the offset quantum well InGaAsP/InP integration platform, but bit rates were limited to 2.5 Gb/s and high input powers were required [3,4]. In this work, we demonstrate the first fully monolithically integrated widely tunable wavelength converter operating at 10 Gb/s with no filtering requirements and extremely low input average waveguide power requirements (-11 dBm).

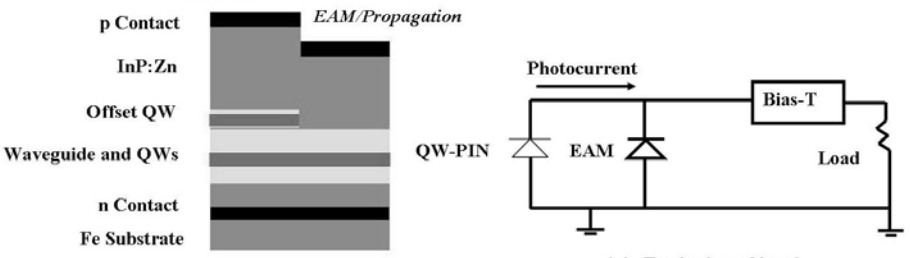
2. Device Layout and Epitaxial Structure

The architecture of the monolithically integrated wavelength converter consists of two parallel ridges interconnected by a very short (35 μm) single gold trace. The transmitter ridge contains a four section widely tunable sampled grating DBR laser, a 600-μm-long SOA, followed by a 400 μm EAM. A receiver ridge contains an optical pre-amplifier and photodetector similar to that used in [5]. The preamplifier is divided into a straight waveguide section that is designed for high efficiency and is 600 μm long, followed by a high power section that has an exponentially flared ridge width up to 12 μm and is 400 μm long. The photodetector contains laser offset quantum wells (OQW) that is reverse biased and is 50 μm long. The photodetector ridge waveguide is tapered from the final width of the amplifier (12 μm) down to 3 μm in order to accommodate high optical power levels in the receiver. The device uses a single applied bias for both photodetector and EAM with a single 50-Ω load applied after a bias-T. A device schematic from a Scanning Electron Micrograph (SEM) along with an equivalent circuit is shown in fig. 1. As a result of the physical separation between the input and output waveguides, the Input Signal Suppression Ratio (ISSR) is larger than 50 dB.

The epitaxial layer structure uses a Dual Quantum Well (Dual QW) integration platform similar to the offset quantum well (OQW) platform that has been used extensively for advanced PICs. The OQW stack provides gain in the laser and amplifiers (Photoluminescence (PL) = 1550 nm) and is located above the optical waveguiding layer. The second separate set of quantum wells (PL = 1480 nm), centered in the InGaAsP waveguide (PL = 1300 nm),



(a). *Device Schematic*



(b). *Base Structure*

(c). *Equivalent Circuit*

Fig 1. (a) SEM of wavelength converter. (b) Outline of Base structure for fabrication. (c) Wavelength converter equivalent circuit

provides broadband modulation efficiency when reverse biased in the EAM. The centered QW stack contains 7 x 90 A compressively strained wells and 6 x 50 A tensile strained barriers. The layer stack is shown in Fig. 1.

3. Results

Device optical to optical S_{21} bandwidth measurements, EAM DC extinction characteristics, optical receiver characteristics, and Bit Error Rate (BER) measurements have been performed for a device that uses an external 50 Ω load. DC extinction characteristics are shown in fig.2. Measurements for the 400 μm long EAM show greater than 20 dB extinction over 30 nm with less than –4V bias. Receivers were characterized by fiber coupling DC light into pre-amplifiers. The input on-chip power levels were measured by reverse biasing the high gain receiver SOA. Both receiver SOAs were then forward biased and the output power levels measured in the QW-PIN. Results are presented in fig. 2 where devices show a 3-dB compression of +16 dBm. SOA bias current density was 6 kA/cm^2.

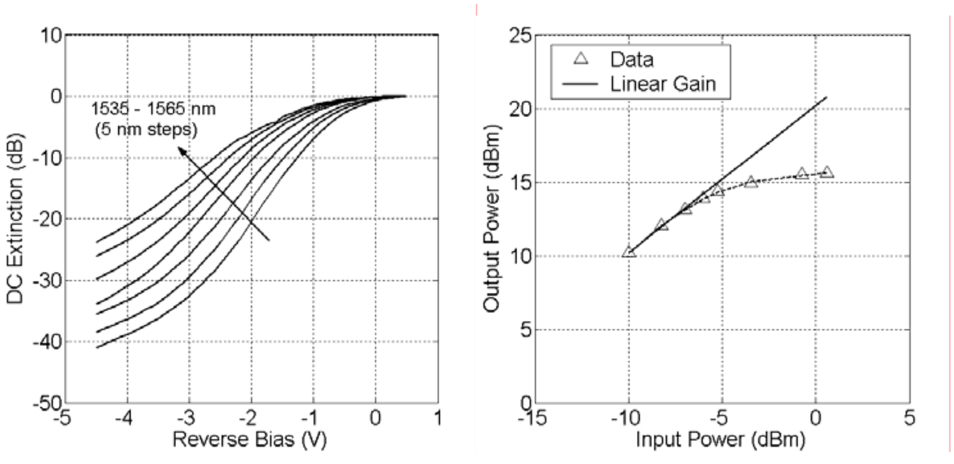


Fig. 2. DC extinction characteristics for Dual QW EAM (left) and SOA PIN receiver characteristics (right). Receiver input wavelength is 1548.1 nm. Input power levels are quoted as on-chip power levels and bias current is 6 kA/cm^2 for both receiver amplifiers. The reverse bias on the detector is -2.5 V.

BER measurements at a wavelength of 1548.1 nm using a non-return-to-zero (NRZ) $2^{31} - 1$ pseudorandom bit stream were performed at 10 Gb/s with an Agilent 83433A transmitter and bit error rate tester. The transmitter had an extinction ratio of 14 dB. The optical test signal was routed to an EDFA followed by an optical filter, then through a polarization controller and was coupled to the device using a lensed fiber. In this experiment, -5.5 dBm of optical fiber power corresponding to -11 dBm of waveguide power was required. After wavelength conversion, the output signal from the device was routed to a variable attenuator, then to a photodetector and back to the Bit-Error Rate tester. Error-free operation at a BER of 10^{-9} has been demonstrated with a power penalty of less than 1-dB over a bandwidth of 32 nm. Eye diagrams are shown in fig. 3 for transmitter (bottom left) and wavelength converted data (top right). Results for Extinction Ratio, output power, and BER curves for a variety of output wavelengths are shown in fig 3.

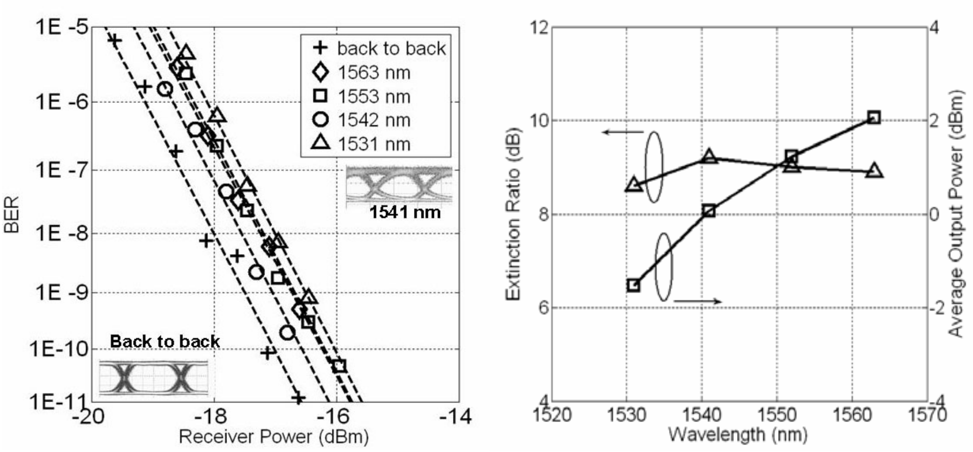


Fig. 3. Extinction Ratio and average output power accounting for 4.5 dB coupling loss (left) and 10 Gb/s BER curves for 50 Ω terminated EAM based wavelength converter (right). Input wavelength is 1548.1 nm with waveguide power of -11 dBm.

4. Conclusions

We have demonstrated the first filterless wavelength converter with an integrated tunable laser source operating at 10 Gb/s with compatibility over a wide tuning range (32 nm) with large extinction ratios (> 8.5 dB). The device showed less than 1-dB power penalty for wavelength conversion and required less than -5.5 dBm of input fiber power and -11 dBm of waveguide power. Overall facet to facet conversion efficiency ranged from +9 to +13 dB neglecting fiber coupling loss.

5. References

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