Widely Tunable Single-Chip Transceiver for 10 Gb/s Wavelength Conversion

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Wavelength conversion is an essential function in wavelength-division-multiplexing (WDM) optical networks, as it enables better utilization of bandwidth and reduces blocking probabilities. This work presents, for the first time, a fully integrated transceiver solution to wavelength conversion in which all microwave signals are confined on a single InP chip. This device architecture, referred to as a photocurrent-driven wavelength converter (PD-WC), is particularly attractive due to the potential for low power dissipation, high bandwidth, data regeneration, and no optical output filtering requirement unlike many all-optical implementations [1]. The PD-WC approach consists of an interconnected receiver and transmitter such that photocurrent from an optically pre-amplified receiver is used to drive a modulator, which functions to translate the signal onto any output wavelength within the range of a widely tunable laser. Previous widely-tunable PD-WC demonstrations have required high speed probes, bias-T's, and in some cases complex bias circuitry [1]. In this work, a termination resistor and DC-blocking capacitor are integrated with an electro-absorption modulator (EAM) based PD-WC such that only DC biases are necessary for device operation and no microwave signal must travel off the chip. This widely-tunable device demonstrates error free 10 Gb/s conversion and utilizes both a simple, single-regrowth fabrication and a simple bias configuration.

The PD-WC is essentially a monolithically integrated transceiver within a compact footprint of 3.1 by 0.5 mm. The transmitter ridge consists of a widely tunable sampled grating (SG) DBR laser followed by semiconductor optical amplifier (SOA) and a 400 µm long EAM. The receiver ridge consists of two SOAs followed by a p-i-n quantum well photodetector (QW-PD). The ridge width of the second SOA is flared (3 to 9 µm) to achieve a 3-dB saturation power greater than 15 dBm. The QW-PD is 20 µm long with a tapered ridge (9 to 7 µm) to prevent saturation at the front end while minimizing the total capacitance [2]. Benzo-cyclobutene (BCB), a low-k dielectric, is defined underneath the QW-PD and EAM electrodes for reduced parasitic capacitance and a 75 µm long microstrip line above the BCB connects the QW-PD to the EAM electrode in a traveling wave configuration. The EAM is terminated with a 35 Ω NiCr resistor followed by a large (~30 pF) on-chip parallel-plate capacitor in series, providing an RF path to ground. An additional chip capacitor is added in parallel on the submount to provide a low impedance ground path for frequencies less than 500 MHz.

The device was fabricated on a dual quantum well (DQW) base structure with a semi-insulating Fe-doped InP substrate. The DQW consists of a set of 7 offset quantum wells (λ_{PL}=1542 nm) above the waveguide layer, for gain in laser and amplifier regions, and 8 shallow quantum wells (λ_{PL}=1455 nm) centered in the waveguide for modulation efficiency. The offset wells were selectively etched from all passive and modulation regions before the p-type InP cladding was grown.

Wavelength conversion experiments at 10 Gb/s in the non-return to zero (NRZ) format demonstrated open eye diagrams with output extinction ratios ranging from 8.0 to 6.6 dB for output wavelengths from 1527-1553 nm. Bit error rate measurements achieved 10 Gb/s error free wavelength conversion over the same 25 nm output wavelength tuning range. In this tuning range, the power penalty of wavelength conversion ranged from 1.5 -2.5 dB compared to back to back transmission. The input power for these measurements was -4.5 dBm neglecting coupling losses. DC characterization experiments showed the receiver SOA gain to be greater than 18 dB and QW-PD output to be linear up to 25 mA of photocurrent. The EAM demonstrated peak DC extinction slope efficiencies from 10 to 20 dB/V for wavelengths from 1527 to 1553 nm.

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[1] J. Barton, et al., SPIE Photonics West, 5729, pp. 177-191, March 2005
[2] A. Tauke-Pedretti, et al., IEEE Photonics Tech. Lett. , Vol. 17, No. 10, October 2005

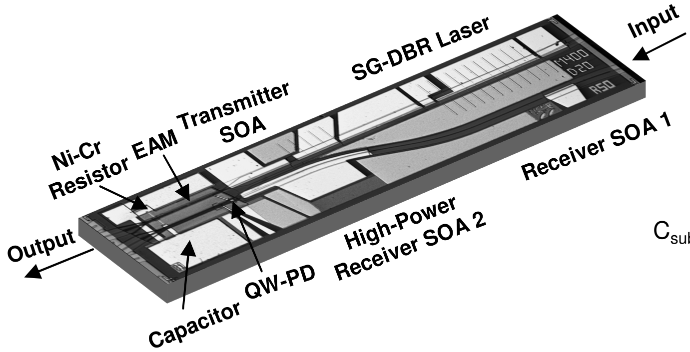

Figure 1: Photograph of widely tunable transceiver for wavelength conversion. Device dimensions are 3.1 mm by 0.5 mm.

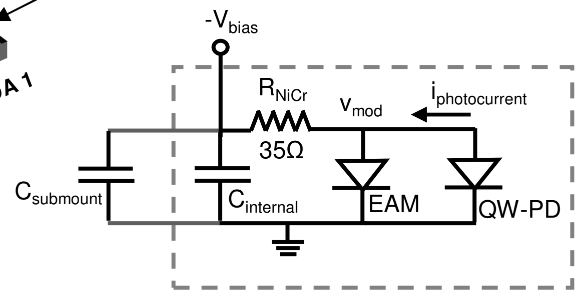

Figure 2: Circuit diagram of QW-PD and EAM with on-chip termination and single DC bias configuration with no bias-Ts.

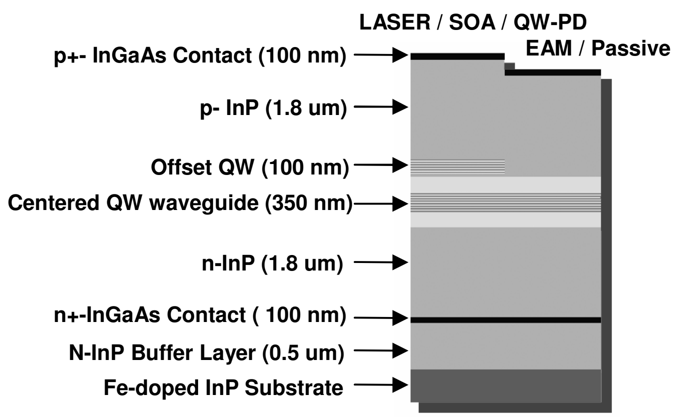

Figure 3: Diagram of epitaxial layer structure for dual quantum well integration platform.

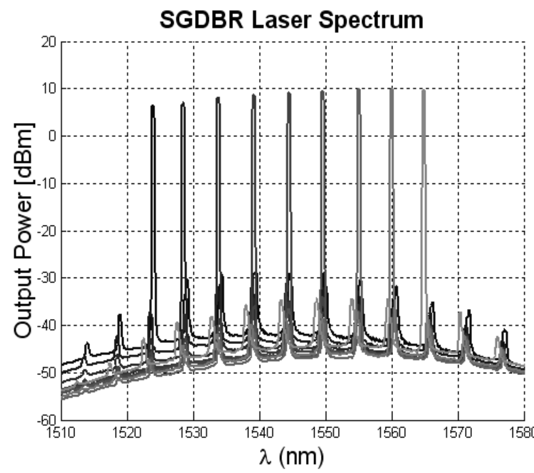

Figure 4: Tuning spectrum and fiber-coupled output power of SG-DBR laser with output SOA.

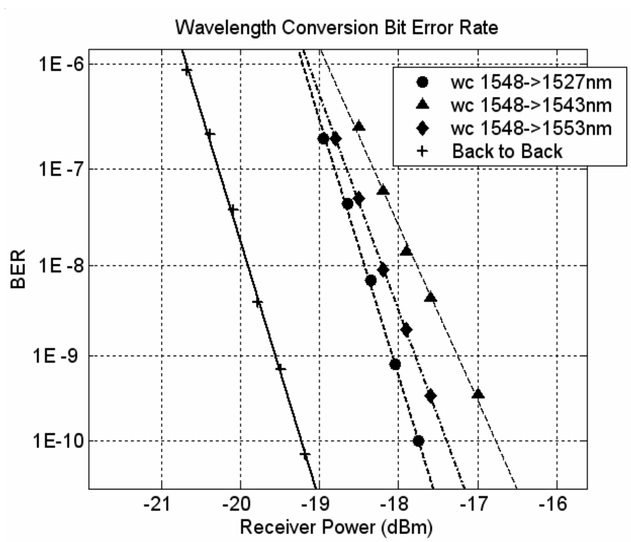

Figure 5: Wavelength converter bit error rate at 10 Gb/s demonstrating error free operation with less than 2.5 dB power penalty compared with back-to-back transmission over 25 nm output tuning range.

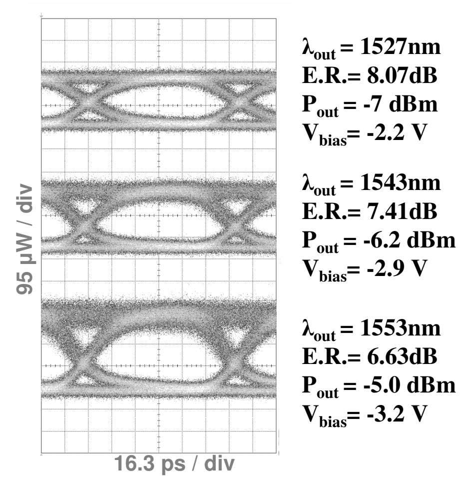

Figure 6: Wavelength converted output eye diagrams corresponding to BER measurements in Figure 5. Average output power (P_{out}), extinction ratio (E.R.) and EAM/ QW-PD operating bias (V_{bias}) are listed.