Tandem electro-absorption modulator for 40Gb/s RZ data transmission

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Electro-absorption modulated sources are key components for current and next generation 40Gb/s fiber transport systems. In this paper we describe the design, fabrication, and transmission performance of a 40Gb/s tandem EA modulator configured for short pulse RZ data transmission. The tandem EA modulators for pulse carver and data encoder functions were monolithically integrated with a semiconductor optical amplifier (SOA) and input / output spot-size converters (Figure 1). The device is fabricated using semi-insulating InP deep ridge buried heterostructure technology. There are significant advantages to using short pulse RZ transmission for long distance 40 Gbit/s communications systems[3]. For these systems a transmitter is required that can generate short optical pulses and encode them with data modulation. The use of a Tandem ElectroAbsorbtion Modulator (TEAM) offers a single compact device able to incorporate both stable short pulse generation and data modulation functions[1]. To reduce optical insertion loss, tandem modulators integrated with optical amplifiers have been reported. As a result Fiber-to-fiber insertion losses were reduced to 9 dB, and operation at 20 Gbit/s was demonstrated[2]. In this work, we report for the first time a tandem EA modulator with better than 0 dB insertion loss and greater than 40 GHz bandwidth.

The tandem modulator consists of a semiconductor optical amplifier sandwiched between two electro-absorption modulators Figure 1. Beam expanders (BX) are used on the input and output waveguide to improve the optical coupling efficiency. The modulators and the SOA have multi-quantum well active layers with a thin separate confinement heterostructure. The device is realized using a deep ridge buried heterostructure process. Modulators of varying widths from 2 to 3.5 μm, and lengths of 80, 100, and 120 μm were evaluated with SOA lengths of 400 and 600 μm.

The TEAM-SOA-BX structure shown in Figure 1 was fabricated by 4 LP-OMVPE growths. First the active region of the two modulators and the SOA based on strained multi-quantum wells was grown by selective area growth on a mask-patterned substrate. The composition and the thickness of the wells and barriers have been optimized to get high extinction ratio with low chirp in the modulator. The beam expander sections are coupled to the modulators using Reactive Ion Etching of the active region and butt joint assisted by selective area growth (SAG) of the passive waveguide. The SAG growth enables the beam expander waveguide to be tapered along its length. A reduced waveguide thickness is used at the input facet to provide good coupling to lensed optical fiber and at the butt joint the waveguide is thicker to provide good mode matching between the beam expander and the modulator. The third step consists of growing a thick p-InP cladding layer and InGaAs contact layer over the waveguides. The narrow mesa stripes are patterned using conventional photolithography and transferred to an SiO2 etch mask. The deep ridge mesa's fabricated in the [011] direction are etched in an inductive coupled plasma (ICP) etching system. ICP etching conditions were optimized to obtain a mesa with sharply defined vertical sidewalls and smooth morphology. Following this, Fe doped semi-insulating InP was selectively grown to embed the mesa. Growth conditions for this step were optimized to obtain planar regrowth around deep and narrow dry-etched mesa with no overhang growth on the mask. A thick spin on dielectric is used to reduce the parasitic capacitance of the p contact pads, which are designed to facilitate flip chip mounting of the device.

Extinction ratio and insertion loss were measured using lensed fibers to couple light from a tunable external cavity laser. For the devices with 600 μm long SOA's up to 8.5 dB fiber to fiber gain was achieved using an SOA current of 150 mA and an input power of 0 dBm. Device extinction curves are shown in Figure 2. A DC extinction ratio of 28 dB was measured for the 120 μm long devices at –3V bias with a 20 nm detuning between the band edge and the input wavelength. For 80 μm long devices the DC extinction ratio was 22 dB under the same conditions. The 3 dB bandwidth for the 80 μm long devices was 40.5 GHz measured using a network analyzer and a calibrated detector (Figure 3). Dynamic extinction ratios of 13 dB were achieved with 2.5 Vpp drive voltage at 40 Gbit/s using an SHF pattern generator. Short pulse generation experiments were conducted using a high power 40 GHz sine wave. Pulse widths of 7 ps, measured using a streak camera, duration and 20 dB extinction ratio were produced with a 5 Vpp drive signal. Pulse widths as short as 5.5 ps were achieved at higher drive voltages. RZ transmission experiments were conducted using a 10 Gbit/s BERT with an electronic multiplexer and an optical demultiplexer. The receiver sensitivity for back-to-back transmission was –29 dBm with a 0.5 dB penalty for transmission over a 100 km dispersion managed link.

These results clearly demonstrate that tandem EA modulators have the potential to provide high efficiency, low insertion loss, short pulse RZ transmitters for future 40Gb/s transmission systems.

References

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