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Simple In-Line Bi-Directional 1.5μm/1.3 μm Transceivers

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We propose some simple new single-waveguide in-line photonic integrated circuit (PIC) architectures for 1.3μm/1.5μm WDM bi-directional (duplex) transmission. Using a prototype in-line 1.5μm transmit/1.3μm receive PIC as one station in a 200 Mb/s - 155 Mb/s duplex link, we achieve 10^{-9} BER over 28 km of fiber using no electrical cancellation or isolation techniques, and only 50Ω 6dB noise figure amplifiers connected to the detectors. The design and fabrication simplicity of the new PIC's suggest their potential usefulness in low-cost local-loop applications.

The schematic design of both an exemplary in-line 1.5μmTx/1.3μmRx PIC and an exemplary in-line 1.3μmTx/1.5μmRx PIC are shown in Figure 1. Rather than relying on interferometric or grating-based wavelength filtering/routing for separate paths to the source and detector, these PIC's make simple use of the absorption/gain characteristics of different composition InGaAsP guide layers.

The 1.5μmTx/1.3μmRx PIC (upper figure) has a design similar to a simple conventional MQW-DBR laser[1], where a 4-well MQW stack for gain at 1.5μm is selectively etched from the upper surface of a 1.3μm λ_g InGaAsP-core guide to make the active/passive transition. This passive guide, which also contains the DBR grating, is low-loss at 1.5μm but strongly absorbing at 1.3μm. Thus, with a p-n junction at the 1.3μm input/1.5μm output end, the incoming 1.3μm signal is efficiently converted to photocurrent while the local high-power 1.5μm transmitted signal passes *directly through* the 1.3μm detector. It should be noted that this PIC will also function without the grating as a conventional Fabry-Perot 1.5μm laser. The upper SI-InP electrical isolation shown in Figure 1 can be achieved without additional growth steps using established processing techniques such as PPro-2[2]

The version shown of the complementary chip uses a DFB laser with a 1.3μm λ_g active layer and a 1.1μm λ_g grating layer above it. Directly to the right of this is an unpumped section of identical layer structure (no grating needed) which is strongly absorbing at 1.3μm and electrically terminated to act as a strong sink for 1.3μm light emitted to the right. Further to the right is an additional 1.5μm λ_g upper layer, which has been selectively removed in the first DFB/absorber sections. A 1.5μm signal incident from the left will then pass *directly through* the transmitting 1.3μm DFB laser and be absorbed at the far right end due to its mode overlap with the 1.5μm (possibly MQW) absorbing layer.

For initial experimental evaluation of these concepts, a 1.5μmTx/1.3μmRx PIC was fabricated. No semi-insulating InP was used for isolation, and the transmitter on the PIC was a 1.5μm DFB rather than the DBR version shown in Figure 1. The passive guide was itself composed of two layers, an upper 1.3μm λ_g and a lower 1.1μm λ_g InGaAsP layer, and the input/output side had an adiabatic mode expansion (AME) step taper[3] for easy-tolerance fiber alignment. Finally, a 1.5 μm amplifier, identical in structure to the DFB section but without a grating, was also fabricated between the 1.5μm DFB transmitter and the 1.3μm detector section.

To evaluate duplex transmission with this 1.5μmTx/1.3μmRx PIC, it was mated with a hybrid complementary 1.3μmTx/1.5μmRx station consisting of a simple fiber directional coupler with a conventional pin diode on one arm and a conventional 1.3μm DFB transmitter on the other arm. The 1.3μmTx/1.3μmRx PIC had a detection efficiency of 0.3 A/W of fiber power using a non-optimized lens-tip fiber. With a 6dB NF 50Ω amplifier connected directly to the un-biased detector, this PIC had a 10^{-9} BER at 155 Mb/s of -20dBm, within ~1dB of the thermal noise limit. In duplex operation, the 1.5μm transmitter on the PIC was operated at 200 Mb/s to insure no synchrounous pattern effects, and full duplex operation at 155 Mb/s - 200 Mb/s was obtained with 10^{-9} BER over 28 km of fiber using this

PIC. Even without SI-InP isolation, DC leakage of the laser drive current to the detector was down by a factor of 30,000. As shown in Figure 2, the reduction in the 1.3μm PIC receiver sensitivity due to the local 36 mA p-p transmitter current drive was only 3dB. This degradation is believed to result from mount and PIC electrical leakage and can be easily improved both with SI-InP isolation and several options of electrical local transmitter cancellation/isolation.

We will discuss in more detail the fabrication and operating characteristics of the in-line Tx/Rx concepts. Due to the low wafer real-estate and simple laser-like single-stripe fabrication, such techniques may be attractive for low-cost bi-directional link applications.

REFERENCES

[1] T. L. Koch, U. Koren, R. P. Gnall, C. A. Burrus, B. I. Miller, Electron. Lett. 24, 1431(1988).

[2] U. Koren, T. L. Koch, B. I. Miller, A. Shahar, paper MDD2, Tech. Dig. of the Topical Meeting on Integrated and Guided Wave Optics, Houston, 1989.

[3] T. L. Koch, U. Koren, G. Eisenstein, M. G. Young, M. Oron, C. R. Giles, B. I. Miller, IEEE Phot. Tech. Lett. 2, pp. 88-90 (1990).

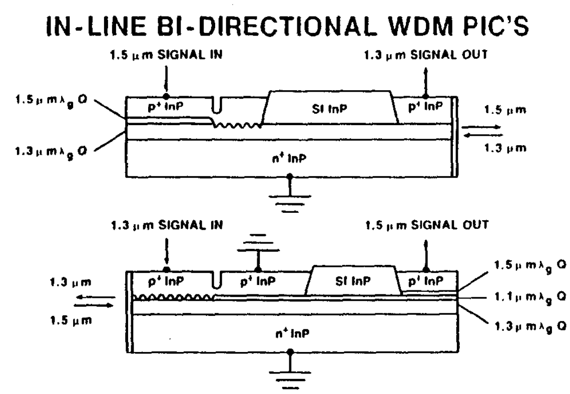

Figure 1. Architecture of exemplary in-line 1.5μmTx/1.3μmRx and 1.3μmTx/1.5μmRx duplex PICs.

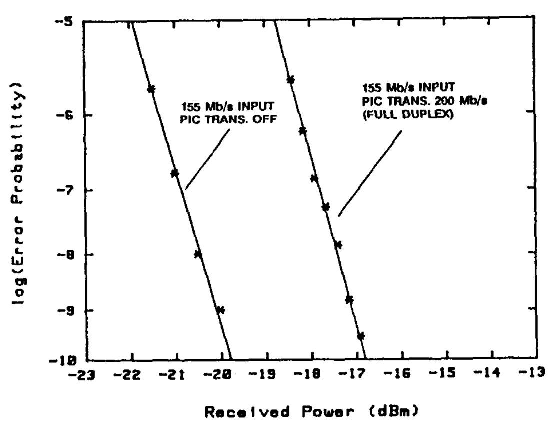

Figure 2. Receiver sensitivity for 155 Mb/s 1.3μm reception using 1.5μmTx/1.3μRx PIC with simple 50Ω amplifiers, both with and without simultaneous (full duplex) 1.5μm transmission at 200 Mb/s from PIC.