Integrated All-Photonic Coherent Receiver

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An integrated all-photonic coherent receiver is presented for linear optical demodulation of phase modulated analog signals. The output of a balanced detector pair is directly connected to a tracking phase modulator to provide feedback phase tracking. The resulting measured link SFDR is 110dBHz$^{2/3}$.

High-performance analog optical links require high linearity in the optical transmitter and receiver. Phase modulation has emerged as a viable alternative to standard intensity modulation with the prevalence of lineal optical phase modulators (e.g. $LiNbO_3$). The main source of nonlinearity then resides in the receiver architecture due to the inherent non-linearity associated with any interferometer based phase detection process. By using a feedback loop in an optical interferometer receiver we have demonstrated that the net phase swing across the demodulator can be reduced without any penalty in SNR with a resulting improvement in receiver SFDR [1]. An integrated, optoelectronic version of the receiver, with a 3dB bandwidth of 1.45GHz, was demonstrated to have an SFDR of 125dB.Hz$^{2/3}$ at 300 MHz [2]. In this work we present link experiment results from an all-photonic version of the receiver. Figure 1 shows a schematic of the receiver architecture in which the output of a balanced receiver pair is directly interconnected to a balanced optical phase modulator with a 2x2 MMI coupler located between modulator and detector. Figure 2 shows a scanning electron micrograph (SEM) of the integrated device.

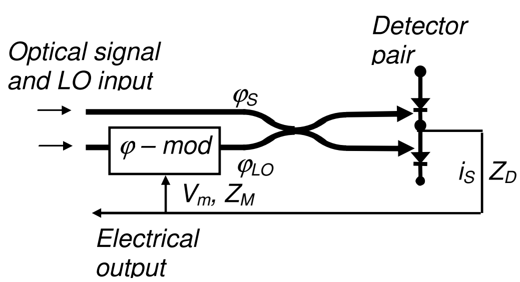

Fig. 1. Schematic of the receiver architecture.

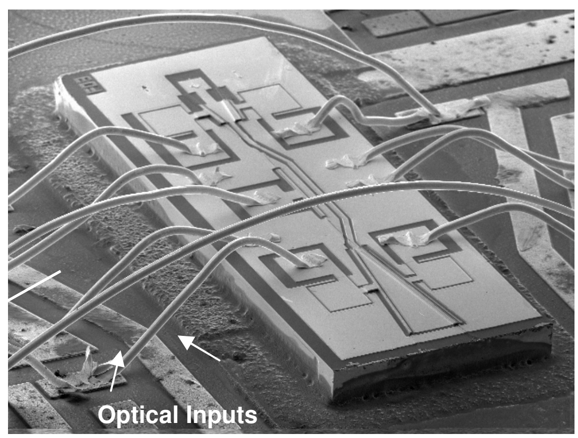

Fig. 2. SEM of Integrated All-photonic receiver

Unlike the optoelectronic receiver, the all photonic receiver has no electronic amplifiers in the feedback path. Instead, there is a direct interconnect between the detector and modulator. When the detected photocurrent is sufficiently high, it drives the sum of the photodiode and modulator capacitance, generating a voltage across the reference modulator that's proportional to the photocurrent. The modulator response is tailored to provide adequate filtering and stable phase feedback [3].

Figure 3a) shows the frequency response of the device with the modulators in this experiment is forward biased for greater efficiency. At lower frequencies and higher photocurrents, the link gain is determined by the ratio of the drive signals to the source and reference modulator. We can consequently observe that the response does not vary with received photocurrent. This suggests that the loop gain is sufficiently high for the reference modulator to closely track the incoming phase so. Figure 3b) shows the open-loop gain that is extracted from the response. It confirms that at higher photocurrent and low frequencies the link gain is proportionally higher. The increased loop gain at low frequency is attributed to higher phase modulation efficiency of the forward biased reference modulator. This is also mirrored in the reduction in loop gain at lower frequencies, as a lower drive voltage is required for phase tracking in the integrated receiver.

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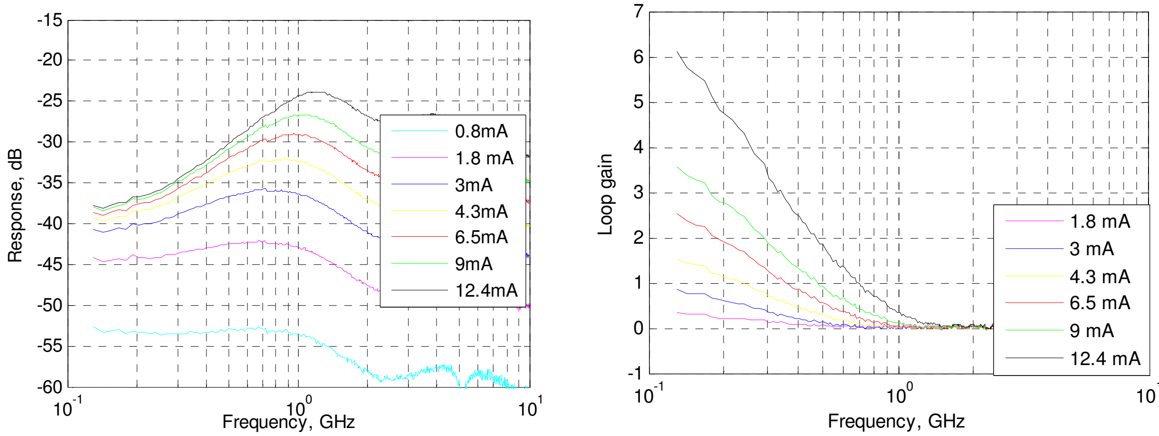

Fig. 3a). Frequency Response *b) Extracted loop gain*

Figure 4 shows SFDR data taken at 500 MHz with 15mA of photocurrent in the detectors. The experimental setup used for this measurement is discussed in [2]. The noise floor is calculated from receiver and shot noise contributions where the ASE noise contribution of the amplified optical source has been compensated for. Ideally, with detector balance, a low RIN source and higher photocurrent, shot noise limited receiver performance should be achievable. It was verified that receiver noise was well below the calculated shot noise level. An SFDR of 110dB.Hz$^{2/3}$ was measured. The detectors themselves have saturation current greater than 40 mA and OIP3 values of 43 dBm and 34 dBm at photocurrent levels of 20 mA and 40 mA respectively [4] and hence, can handle high optical powers. Efforts are being made to realize lower loss through the device so that the link gain can be increased. This is a fundamentally linear technique and with improved modulator efficiency, lower loss and shorter feedback delay the linearity performance of the receiver can be enhanced over a wide frequency range.

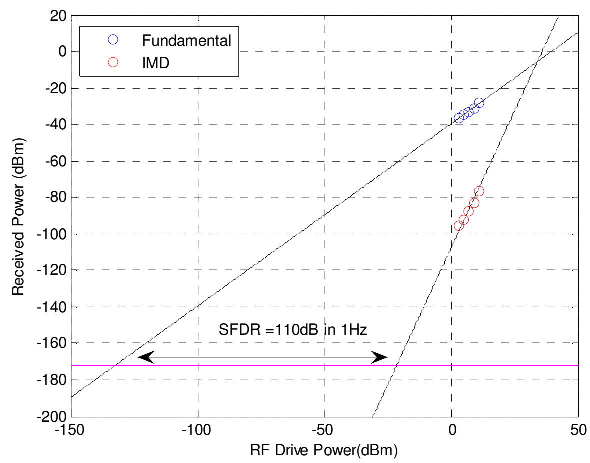

Fig. 4. SFDR at 500MHz with 15mA of detected photocurrent

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