Optical Remoting of Ultrafast Charge Packets Using Self-Linearized Modulation

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Abstract: Sensitive analog systems in mixed-signal VLSI circuits may be vulnerable to digital noise. We demonstrate a possible solution by optically remoting charge packets with a multiple-quantum-well self-electrooptic effect device in a novel self-linearized mode.

OCIS codes: (230.4110) Modulators; (200.4650) Optical interconnects

In such mixed-signal VLSI electronic circuits as analog-to-digital converters (ADCs), optical remoting of electronic charge measurements could increase the noise immunity of the analog circuit from digital noise. Such immunity would be particularly important in systems with large numbers of high speed ADC circuits yielding large aggregate data rates. For example, we might have sampled the instantaneous voltage of an electrical signal using a high speed photoconductive switch and a sampling capacitor, and wish to relay this sampled charge to a remote ADC. In such a case, a method for linear, high-speed electro-optic conversion is required. We propose to implement this conversion stage with a multiple quantum-well (MQW) self electro-optic effect device (SEED) in a novel self-linearized mode [1]. Such a device could also be integrated, allowing it to work with very small sampling capacitors.

Previous self-linearized operation of SEEDs showed that, if the device were driven with a DC input current, it would absorb a proportional amount of DC power from an incident CW optical beam [1]. For a sinusoidal drive, the SEED absorption amplitude would drop to 3dB at a characteristic frequency ω_{3dB} [2]. The measured ω_{3dB} was consistent with the predicted

$$\omega_{3dB} = \frac{1}{\tau_r} = \frac{e}{\hbar\omega}\frac{\gamma P_{in}}{C} \tag{1}$$

where τ_r is the response time, C is the total capacitance of the device, P_{in} is the incident CW optical power, and $\gamma = \partial A/\partial V$ is the absorption sensitivity with respect to voltage.

We here propose that the self-linearized SEED can perform linear electro-optic conversion even for signals that far exceed the ω_{3dB} bandwidth. If the electrical signal is represented as the amount of charge in discrete current pulses, the self-linearized SEED will take a time τ_r to convert this to an optical signal by absorbing a linearly proportional number of photons from an incident CW beam.

To demonstrate this, we used two GaAs/AlGaAs MQW SEEDs connected in series (Fig. 1). Device A is the modulator that performs the electro-optic conversion by modulating an incident CW 225 μW, 850 nm beam P_i. For this experiment, the current pulse $I_c(t)$ is provided by another diode (Device B) driven by 100 femtosecond pulses $P_c(t)$ from an 80 MHz mode-locked Ti:Sapphire laser; in actual applications, other charge sources such as sampling capacitors would likely be used.

Each time that Device B injects a charge packet onto Device A, the latter SEED's absorption increases, and the power of the modulated beam drops sharply. The modulated beam then recovers with a fitted time-constant of 2 ns (Fig. 1). With estimates of $C \approx 40$ fF and $\gamma \approx 0.1$, (Eq. 1) gives a response time τ_r of 2.4 ns, in good agreement with our measured result.

We determine whether self-linearization exists by varying the average power of the pulses driving the current source photodiode (Fig. 2). Since the unsaturated photodetector linearly converts the optical pulses into packets of electronic charge, which are then injected onto the self-linearized SEED, we see that the SEED modulator has linearly converted an electronic signal into an optical one.

In summary, we have measured the first-order time constant of a self-linearized MQW SEED. We have also successfully shown that, even under pulsed input conditions, the average reflected optical beam power

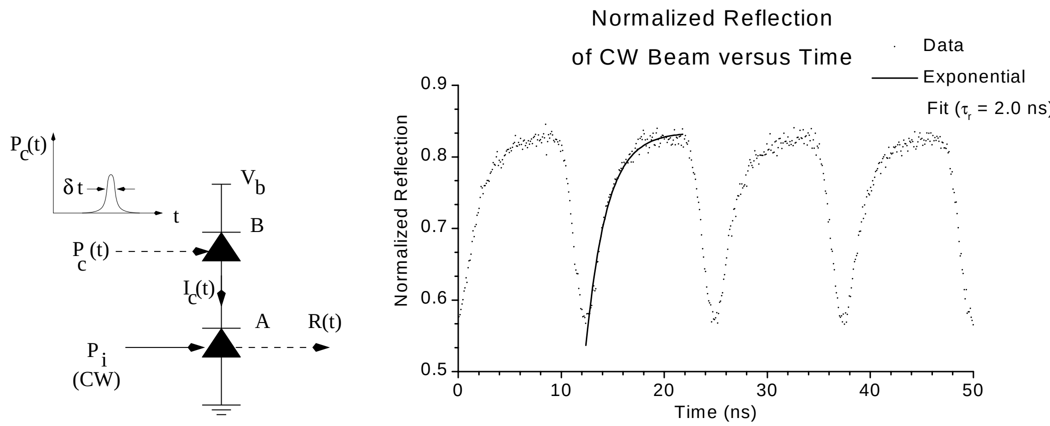

Fig. 1. (a) High-energy pulses from an 80 Mhz Ti:Sapphire laser illuminate the upper SEED (Device *B*), causing it to behave as a current source which injects pulses of current onto the lower SEED (Device *A*). Device *A* modulates a lower-energy CW optical beam in our newly proposed mode of operation. (b) Each current pulse that drives Device *A* momentarily decreases the power of the modulated optical beam. The SEED then recovers with a fitted time-constant of 2.0 ns. The periodicity of the reflected beam power is due to the repetition rate of the mode-locked laser driving Device *B*.

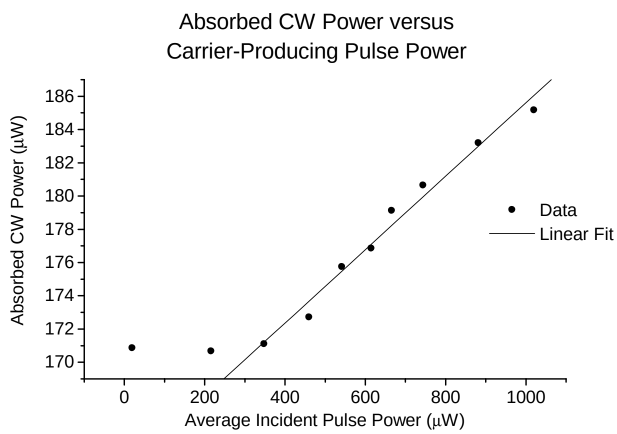

Fig. 2. Average absorbed optical power versus average power of the optical pulses that drive the photodiode current source. For a certain range of average pulse power, a linear relationship exists. This indicates that there is a regime where an electrical signal is linearly converted into an optical one.

remains linear with respect to the average input current. Such a device can perform linear electro-optic conversion, and holds great promise for high-sensitivity mixed-signal VLSI circuits.

This work was supported by DARPA/PACT contract no. DAAD17-99-C0048 and a Cadence Design Systems Stanford Graduate Fellowship.

References

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