High-Speed Switching of a 1.55-μm Symmetric SEED

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Abstract: We demonstrate high-speed switching of a symmetric self-electrooptic effect device (S-SEED) operating at 1550 nm. Transitions faster than 10 ps are observed, verifying the suitability of this technology for integrated logic operations beyond 40 GHz.

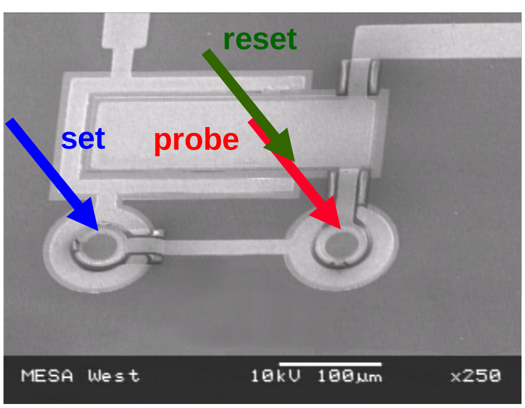
OCIS codes: (250.3750) Optical logic devices; (230.2090) Electro-optical devices; (200.6715) Switching

1. Introduction

The symmetric self-electrooptic device (S-SEED) is a bistable all-optical logic device that can implement both NAND and NOR gates, enabling the creation of complex logic circuitry [1,2]. Other device technologies are capable of all-optical switching at higher data rates [3,4], but their scalability has been limited to a handful of interconnected gates that perform highly dedicated functions. On the other hand, S-SEEDs have been demonstrated in computational systems that exceed 60,000 devices [5], and remain one of the most promising candidates for dense integrated all-optic logic systems due to their low switching energy and cascadability.

While many aspects of SEED technology have been studied extensively, high-speed operation is possibly the least investigated, with most published work performed at relatively modest speeds below 1 GHz. Previously, we demonstrated the fastest switching times for an (865 nm) S-SEED by combining extremely shallow quantum wells (ESQWs) and low series resistance [6]. Here we describe a telecom-compatible gate operating at 1550 nm that achieves similar performance in a new material system.

The S-SEED, shown in Fig. 1, is comprised of a pair of series-connected *p-i(MQW)-n* diodes designed for surface-normal illumination. The diode mesas are 25 μm in diameter, and the large rectangular mesa acts as a capacitor connected in parallel across the S-SEED to buffer the power supply during switching. The devices are fabricated from InAlGaAs-based epitaxy grown on InP by molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) – both techniques have produced similar results. The quantum well design employs precise control of strain to yield a superposition of light and heavy hole exciton wavelengths, significantly enhancing optical contrast. The shallow nature of the wells gives rise to two key device features: 1) the rapid carrier escape and sweepout needed for high-speed switching, and 2) complete ionization of the zero-bias exciton at low applied fields (i.e., this structure forgoes the quantum-confined Stark effect often used in SEED devices). The photocurrent measurements shown in Fig. 1 illustrate DC optical performance for a device with an intrinsic region thickness of 0.5 μm.



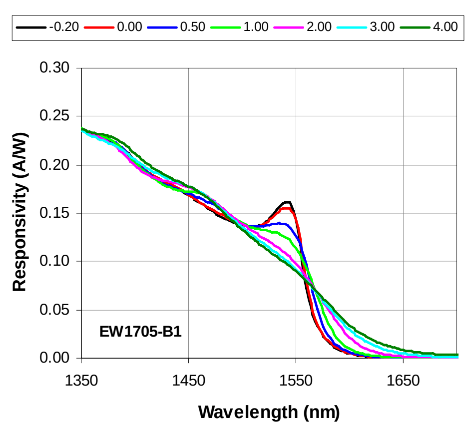


Fig. 1. Left: Scanning electron micrograph of an S-SEED device. The set/reset/probe arrows indicate the diodes illuminated by the pump-probe measurement described below. Right: Optical responsivity (photocurrent) measurements versus wavelength at different applied voltages. The strong absorption peak represents a superposition of light and heavy hole excitons.

2. Experimental measurements

An S-SEED was operated as a SET/RESET latch and its dynamic performance was characterized using an optical pump/probe high-speed measurement technique to avoid capacitive loading effects. The experimental setup is shown in Fig. 2. The ~1 ps optical pulses of a passively modelocked fiber laser were amplified and split between three different beam paths using adjustable polarization elements. The SET and RESET beams were used to repetitively toggle the SEED latch, providing sufficient energy to fully switch the device from rail to rail (i.e., a few picojoules per transition for the low-capacitance devices used here). A low-power probe beam was temporally scanned with a delay stage to characterize device response with sub-picosecond resolution. Optical switching at 1550 nm was measured with a 10%-90% transition time of 9 ps as shown below.

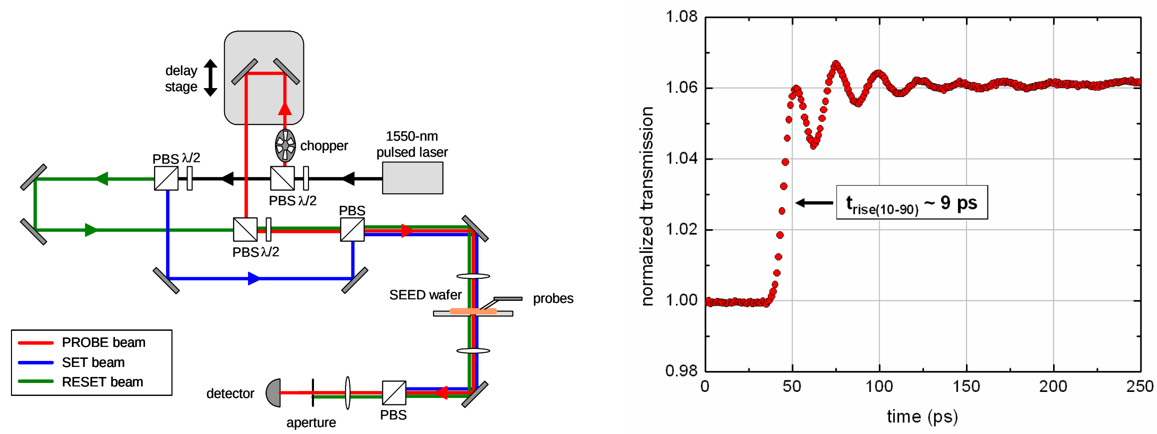


Fig. 2. Left: Optical pump-probe setup to measure switching of a 1550-nm S-SEED latch. The set and reset beams toggle the device state, while an optical delay stage enables device interrogation by a weak probe beam, mapping the transition with picosecond resolution. Right: Pump-probe measurement, demonstrating switching between logic states with a 10%-90% transition time of 9 ps. The transition is accompanied by ringing due to the diode capacitance and wiring inductance, which yield an LC frequency of approximately 40 GHz. Experimental parameters: 25-µm mesa diameter, 6-V applied bias, pump energy ~2.5 pJ.

3. Discussion

A high-speed 1550-nm S-SEED has been demonstrated for 40-GHz all-optical logic. To our knowledge, this is the first report of a fast SEED operating within the telecommunications window, and will enable future systems to interact with the network traffic and leverage existing equipment. Discussion at the talk will further describe device and epitaxial design, carrier dynamics, and scaling the technology to higher speeds and greater circuit complexity.

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