Semiconductor Q-switch Demonstrated in Solid-State Microlaser

by Jeff Cederberg, Daniel Bender, Michael Pack, Randy Schmitt

Motivation—Timing control is critical for solid-state microlasers. In a microlaser, the saturable absorber holds off laser oscillation until the field is high enough that the circulating photons can saturate the optical transition, rendering the absorber partially transparent. Existing lasers use doped insulators that either saturate at a low fluence or require high voltages. Semiconductor saturable absorbers (SESA) based on multiple-quantum-well (MQW) structures can be used as Q-switches and present the opportunity for improved pulse control. Developing such MQW structures, evaluating their optical characteristics, and demonstrating their suitability were necessary to evaluate if semiconductors saturable absorbers are suitable for this application.

Accomplishment—We developed epitaxial growth on InP substrates of MQW SESAs based on AlGaInAs quaternary materials. AlInAs serves as the barrier material with thickness corresponding the half the mode spacing in the material. The composition and thickness of the AlGaInAs well was set to produce a ground state transition at 1064 nm. We have optimized our epitaxy to achieve the growth of a SESA with 30 two-MQW periods, over 6 µm in total thickness.

We have optical characterization of the MQW saturable absorber focused on quantifing the absorbance bleaching lifetime, the modulation depth, and the unsaturable loss. Fig. 1b shows the transmission decay observed with a transient pump-probe measurement. A single exponential decay is observed with a lifetime exceeding 100 nsec. The modulation depth of the transmission was measured with a similar technique by monitoring the pump power incident on the sample. The transmission was increased by 8% for the sample shown in Figure 1a. The unsaturable loss was as high as 50% in the sample shown, but was reduced to 20% by using compensated substrates.

The SESA was tested as a passive Q-switch in a microlaser cavity (Fig.2). Pump light emitted from the fiber is imaged onto the gain medium, which is AR-coated at 808 nm and HR-coated at 1064 nm on one surface and AR-coated at 1064 nm on the second surface. The AR-coated MQW SESA, located approximately in the middle of the cavity, allows lasing modes to align with the QWs. Our SESA microlasers feature high efficiency (25%), single-mode operation, Gaussian beam profiles and repetition rates exceeding 1 MHz.

Significance—Through this demonstration, we have established that semiconductor heterostructures can withstand the high optical fluences produced in microlaser cavities. The use of semiconductors as saturable absorbers opens new possibilities for improving the timing control and jitter in Q-switched microlasers. The demonstration of long absorbance bleaching lifetimes suggests AlGaInAs heterostructures possess a high carrier lifetime, a critical requirement for optoelectronic devices.

Sponsors for various phases of this work include: Nuclear Weapons Program

Contact: Jeff Cederberg, Advanced Materials Sciences
Phone: (505) 284-5456, Fax: (505) 844-3211, E-mail: jgceder@sandia.gov

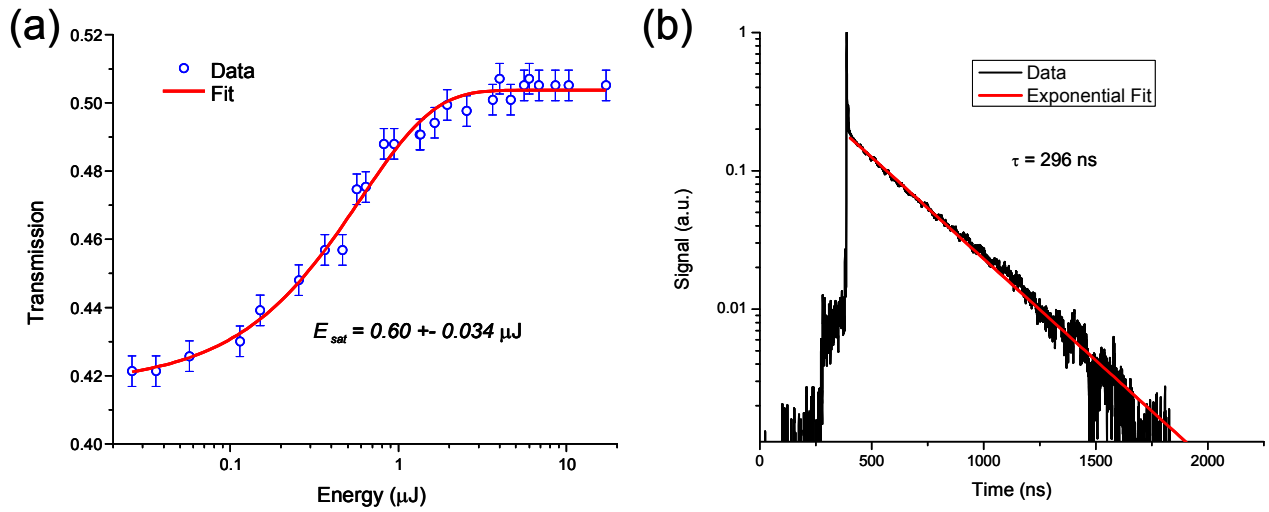

Figure 1. (a) Energy dependent transmission (blue dots) for a SESA containing 40 QWs. Exponential fit (red line) depicts a 600 nJ saturation energy (76 μJ/cm^2 saturation fluence). (b) Transmission decay after bleaching (black line) and exponential fit (red line) for a 60 QW sample. The fit gives bleaching lifetime of 296 ns.

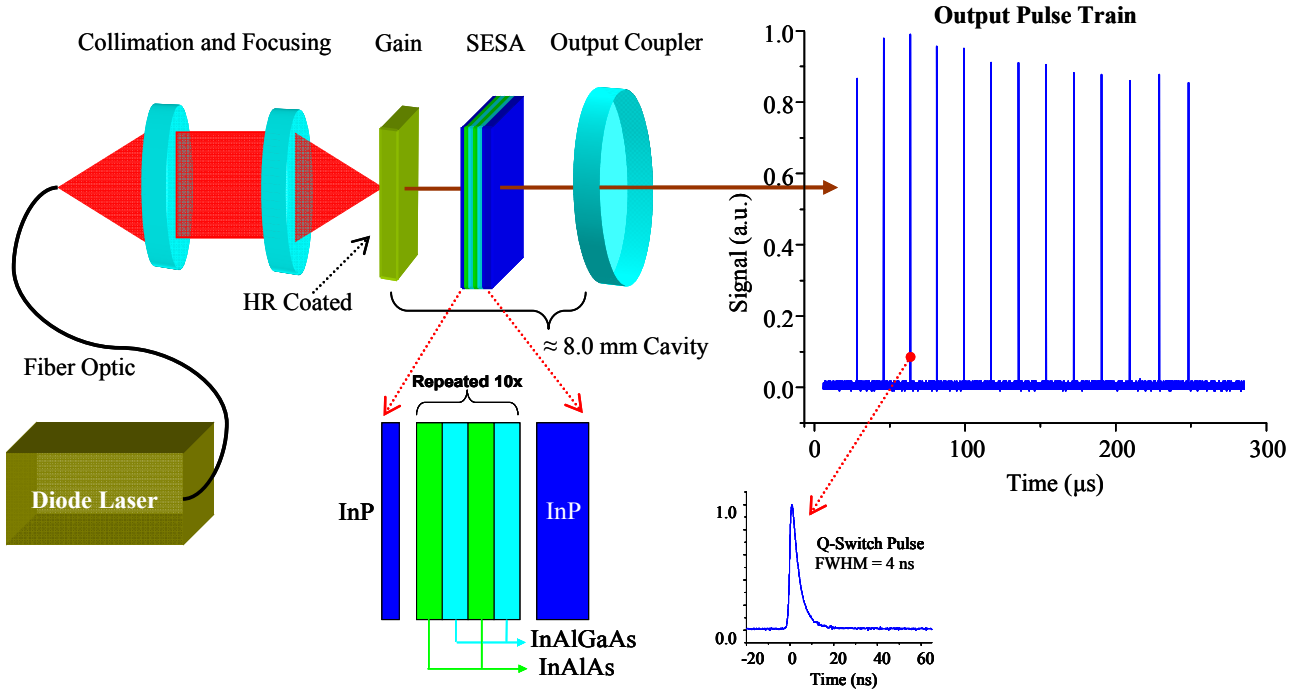

Figure 2. Complete SESA-based microlaser system with only three cavity elements. Expanded view of SESA shows QW structure. Depiction at right shows the output pulse train and a blow-up of a single pulse showing the pulse width.