60ps Recovery Time in an InGaAsP Quaternary Multiple Quantum Well Saturable Absorber employing Carrier Sweep-Out

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Abstract
We describe the first observations of fast recovery in an InGaAsP quaternary multiple quantum well saturable absorber using electric field induced carrier sweep-out. An 133kV/cm sweep-out field reduces the recovery time from 3.9ns to 60ps.
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Introduction. Carrier sweep-out as a fast recovery mechanism has previously been investigated in a range of multiple quantum well (MQW) saturable absorbers (SA), for example [1]. We describe a PIN SA incorporating InGaAsP quaternary wells and barriers, lattice matched to InP which can be used as a reflective saturable absorber at wavelengths in the erbium gain window and present the first measurements of carrier sweep-out in such a device. The MQW incorporates 60 wells to increase the contrast ratio under saturation and due to the quaternary structure presents low barriers to free carriers in both the conduction band and valence band wells to facilitate sweep-out. A distributed Bragg reflector (DBR) designed for operation at 1545nm is positioned below the MQW region allowing reflective operation. The DBR and MQW are grown on an n+ substrate in a single MOVPE step. Devices are fabricated as 100μm diameter mesa structures with anti-reflection coating to suppress Fabry-Perot effects (Figure 1).

Experiment. Time resolved characterisation of the SA was carried out using the pump-probe method. A figure 8 mode-locked fibre laser[2] was used to generate 2ps pulses at its fundamental repetition rate of 4MHz. This laser was tuned across the erbium gain window using an angle-tuned 3nm bandwidth interference filter in the passive loop. The output of the laser was passed through a variable attenuator before being split into pump and probe pulses, with the probe pulses subjected to a variable delay. The path lengths were such that the pump-probe delay was variable between +900ps and -100ps. The probe pulses were coupled to the SA through a fibre pigtailed optical circulator, allowing the reflected light to be observed using a slow photodetector and a lock-in amplifier. The pump pulses were launched independently such that they were coincident with the probe pulses at the saturable absorber. The power ratio of the pump and probe pulses at the SA was fixed at 50:1 and the maximum pump pulse energy at the device was 7.5pJ. Both the pump and probe pulses were focussed to 4μm diameter spots.

Results. The pump-probe trace illustrating recovery from saturation at the exciton wavelength with an applied reverse bias of 17V, and thus a sweep-out field of 133kV/cm, is shown in Figure 2. The transmission change recovers to half of its maximum value in 60ps. The corresponding recovery time with no applied bias is 3.9ns.

Discussion. We have reported the first measurements of carrier sweep-out saturation recovery in an InGaAsP quaternary MQW SA, demonstrating a substantial reduction in recovery time compared to the unbiased case. The use of carrier sweep-out makes the devices suitable for such applications as high repetition rate passive mode-locking of erbium fibre lasers [3] and soliton control [4] in 1550nm optical transmission systems. Further work will include optimising the well structure to enhance sweep-out, and to shift the exciton wavelength further into the erbium window at high reverse bias voltages.

References.