Ultrafast carrier dynamics of AlGaInP saturable absorbers

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We have investigated the ultrafast characteristics of novel quantum-well semiconductor saturable absorbers based on AlGaInP, which are proving instrumental for the development of cutting-edge ultrafast lasers operating in the visible spectral range. These structures have recently enabled the first demonstration of a red femtosecond vertical-external-cavity semiconductor laser [1]. With the support of the EPSRC Laser Loan Pool, the ultrafast absorption recovery dynamics of these novel saturable absorbers was investigated as a function of wavelength, fluence and number of quantum wells present in the structure.

A degenerate reflective pump-probe setup was used, with balanced lock-in detection. The polarization of the pump and probe beams were orthogonal to each other. Both pump and probe were chopped, and the sum frequency signal was detected, to increase the signal-to-noise ratio of the measurement. The pump beam waist at the sample was ~17.6µm, whereas the probe beam waist was approximately half of this. The pump, which was tuned between 655 – 668 nm, was obtained via second-harmonic generation of the APE synchronously-pumped optical parametric oscillator generating a signal tuneable around 1330nm, pumped by the Chameleon Ultra Ti:Sapphire laser. The pulse duration of these red pulses was estimated to be around 200 fs at the sample plane.
Two types of structures were characterized: one with two quantum wells and another sample with a single quantum well. A systematic investigation of their ultrafast absorption recovery dynamics was carried out, as a function of fluence, as well as wavelength. A representative trace is shown below, for the double quantum-well structure (Fig. 1), and for a pump wavelength of 665 nm. The observed decay can be well fit by a tri-exponential trend, comprising in this case a fast decay with a time constant of 277 fs, followed by a medium time constant of 3.5 ps and finally a slow decay with a time constant of 67.8 ps. The observation of a tri-exponential decay instead of the usually measured bi-exponential decay can be explained by the presence of two quantum wells in the saturable absorber structure, instead of only one. The initial fast absorption recovery is likely to be due to intraband thermalization of charge carriers. The intermediate decay could be ascribed to the surface recombination of charge carriers mainly from the first quantum-well (QW), which is located only ~2 nm below the semiconductor surface. For charge carriers in the second QW, which is separated by the first QW with a distance of ~4 nm, the probability of radiative decay is increased, resulting in a slow time constant. These results support the mode-locking performance obtained with VECSELs which incorporated this saturable absorber and have already resulted in a paper [2].

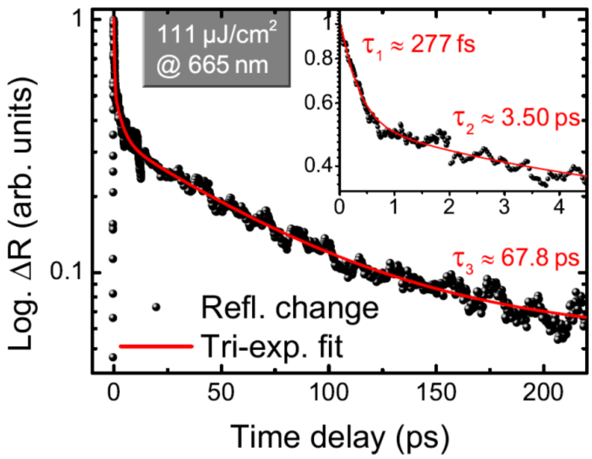

Fig. 1 - Absorption recovery dynamics for an AlGaInP semiconductor saturable absorber without the fused silica layer. A tri-exponential decay is observed with a dominant fast time constant of 277 fs. Reproduced from [2].

The investigation of the carrier dynamics with increasing fluence also revealed the influence of two-photon absorption effects, which becomes more prominent as the fluence increases. Another publication is anticipated for this work, stemming from these and other results obtained with the investigation of the influence of the pump wavelength and the number of quantum wells on the absorption dynamics of the various structures [3].

Acknowledgements

The authors would like to thank the EPSRC Laser Loan Pool for the loan of the UFL3 laser system.

References

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