InAs/GaAs submonolayer (SML) quantum dot-based semiconductor saturable absorber mirrors (SESAMs)

S.J. Addamane,[1] **A. Laurain,**[2] **J.V. Moloney,**[2] **and G. Balakrishnan**[1]
[1] *Center for High Technology Materials, University of New Mexico, Albuquerque, NM*
[2] *College of Optical Sciences, The University of Arizona, Tucson, AZ*

Semiconductor saturable absorber mirrors (SESAMs) have been used in recent years, with considerable success, for passively modelocking both semiconductor and solid-state lasers. Most state-of-the-art SESAMs around the 1µm wavelength range employ a quantum well (QW)-based absorber which has enabled stable modelocking in the picosecond and femtosecond regime. Recently, there has been substantial interest in studying SESAMs using quantum dot (QD) absorbers in order to exploit their advantages over QWs: atom-like density of states, variation in dot sizes and control over areal density. Around the 1µm wavelength range, using traditional Stranski-Krastonov QDs would require using an AlGaAs matrix which reduces the optical confinement factor. An alternative active component is submonolayer (SML) QDs that combine high excitonic gain and fast gain recovery (characteristic features of QDs) with the high modal gain of QWs. This work focuses on exploring the use of InAs/GaAs submonolayer (SML) QDs as absorbers in SESAMs.

The samples analyzed in this study are grown using molecular beam epitaxy (MBE) on epi-ready GaAs (100) substrates. The 1030nm SESAM structure consists of a 29 quarter-wave GaAs/AlAs pairs distributed bragg reflector (DBR) and an absorber region (QW or QD) sandwiched between GaAs spacer and cap layers. The SML QD absorber is formed by stacking 0.5ML/2.3ML of InAs/GaAs. The DBRs and absorber regions are calibrated to ensure that the reflectivity stopband and photoluminescence spectra are respectively centered at 1030nm at operating temperature and incidence angle. As part of this work, both QW and SML QD-based SESAMs are grown, comprehensively characterized and their device performances are compared. These SESAMs are characterized for reflectivity, temperature-dependence, dispersion control and lifetimes (both carrier and device) and are tested in a Vertical Cavity Surface Emitting Laser for modelocking. Through this process, we were able to achieve pulse durations as short as 128fs with InGaAs QW-based SESAMs and ~185fs with InAs/GaAs SML QD-based SESAMs. Along with higher output power, it is found that SML QD-based SESAMs have substantially longer device lifetimes compared to QW-based SESAMs.

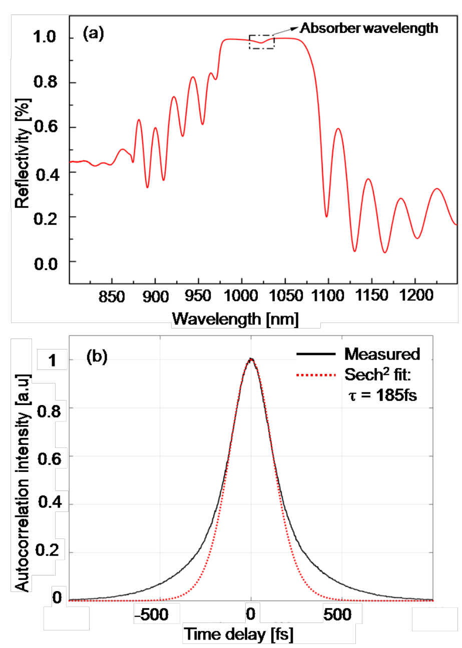
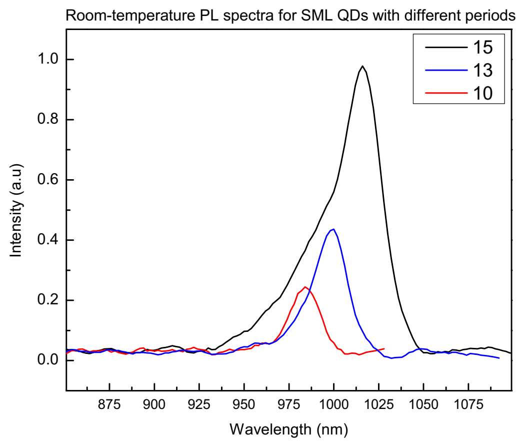


Fig 1(a) Typical reflectivity spectrum (b) SHG correlation trace of output from a QD-based SESAM

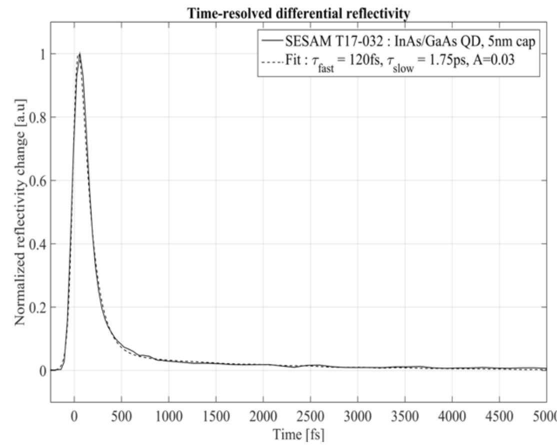
[1] A.-R. Bellancourt, et al., Optics Express 17, no.12 (2009)

+ Author for correspondence: addamane@unm.edu

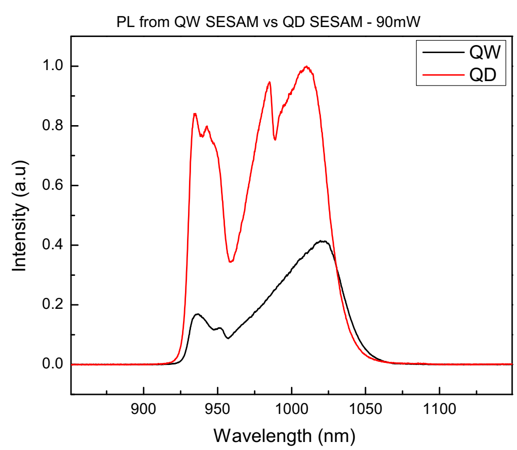
Supplementary information



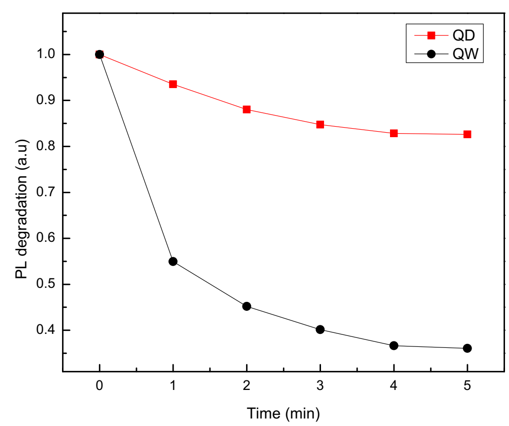
(a)



(b)



(c)



(d)

Figure (a) shows room-temperature photoluminescence (PL) measurements for InAs/GaAs submonolayer (SML) QDs with varying number of stacks (10,13 and 15). To align the absorber wavelength close to ~1025nm, the number of stacks for the SESAM samples is chosen to be 15. Figure (b) shows time-resolved differential reflectivity measurements for SML QD-based SESAMs measured using a pump-probe setup. As is standard for most SESAMs, the measurement shows two distinguishable recovery processes – a fast component (fitted to 120fs) which causes a sudden drop in reflectivity followed by a slow component (1.75ps). In order to quantify device lifetime of SESAMs, we have used a pulsed PL experiment (results shown in figure c) using femtosecond pulses (100fs@780nm) from a mode-locked laser setup. For these measurements, we define SESAM "damage" or degradation as an irreversible decrease in the PL intensity over time. The degradation in PL intensity is compared between a QW-based SESAM and a QD-based SESAM in figure (d).