Up-converted photoluminescence in InAs QD-based structures with confined state

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Up-converted photoluminescence (UPL) in semiconductor quantum dots (QDs) and quantum wells (QWs) has attracted much attention in recent years [1]. Although numerous investigations have been performed on the mechanisms for UPL, where Auger recombination [2] and two-step absorption through intermediate state [3] are proposed, less information is available on the competing mechanisms between carrier extraction and relaxation processes, which imposes another great challenge for the observation of UPL. To overcome this challenge, introducing a confined state into the InAs QD-based structure is essential. In this paper, a new structure is proposed with self-assembled InAs QDs embedded in InAs/GaAs multi-quantum well (MQW) for elucidating the mechanisms.

Self-assembled InAs QD-based structures were grown on semi-insulating GaAs (001) substrates by MBE. The structure consisted of a 200nm GaAs buffer layer, three periods of InAs/GaAs MQW layer with 1ML InAs separated by 20nm GaAs, an InAs QDs layer of 1.5ML deposition, and InAs/GaAs single QW layer. PL measurements were carried out using a Ti:sapphire laser for excitation and a liquid nitrogen cooled InGaAs diode array detector.

Figure 1 shows laser power density dependent PL at 4K with λ_{ex}=780nm, in which emission from GaAs, MQW, InAs WL and QDs can be observed clearly. When the sample was excited at 910nm, a clear UPL peak from MQW is observed as displayed in Figure 2. Remarkably, the efficient observation of UPL is a consequence of more efficient carrier trapping in structures with MQW than pure InAs/GaAs QDs. The result shows that the electrons are initially excited into an intermediate state, then eject into GaAs barrier layer, and hence, it is crucial for the carriers to be captured by the MQWs rather than relaxing back to the ground state of the QDs. Our present results suggest that by introducing a confined state, up-converted carriers could be captured by MQW easily and give rise to efficient UPL.

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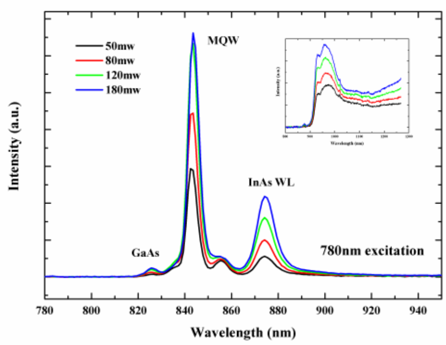

Figure 1. Excitation power dependent PL at 4K with λ_{ex} = 780nm. The inset shows emission from QDs ranging from 900nm to 1200nm.

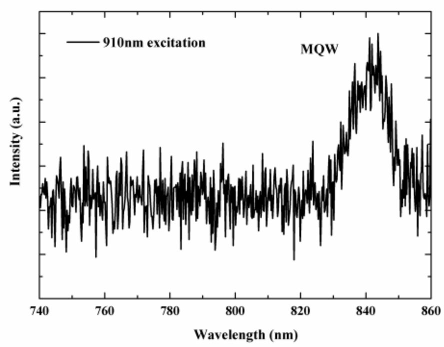

Figure 2. UPL spectra at 4K with λ_{ex} = 910nm and excitation power of 120mw.