# Multiple Quantum Wells as Slowed Hot Carrier Cooling Absorbers in Hot Carrier Cells

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## 1 INTRODUCTION

The Hot Carrier solar cell has the potential to yield a very high efficiency, well over 50% under 1 sun. Multiple quantum wells have been shown to have significantly slower hot carrier cooling rates than bulk material [1,2] and are thus a promising candidate for hot carrier solar cell absorbers. However, the mechanism(s) by which hot carrier cooling is restricted is not clear. Presented is a systematic study of carrier cooling rates in GaAs/AlAs MQW with either varying barrier or well thickness. These allow a determination as to whether the mechanisms of either a reduction in hot carrier diffusion; a localisation of phonons emitted by hot carriers; or mini-gaps in the MQW phonon dispersion are responsible for reduced carrier cooling rates. Results will be placed in the context of use of MQW as absorbers in a real hot carrier cell.

MBE grown GaAs/AlAs MQWs samples are used to comprehensively investigate the mechanisms behind the reduction of carrier cooling within MQW structures. The following results are those for characterisation OF MQW samples thus far. Those for carrier cooling and effects of barrier and well thickness on these will be presented in the conference paper.

## 2 MQW WITH VARYING WELL OR BARRIER THICKNESS

MQW of GaAs/AlAs were grown by MBE on GaAs substrates. Series of samples were grown in which either the quantum well thickness ($L_W$) was varied or the barrier thickness ($L_B$) was varied, as denoted in Table 1.

| Sample | $D = L_W + L_B$ (nm) | | Difference (nm) | Rocking curve FWHM of 1st satellite peak (degree) | TCSPC $\tau_{thermal}$ (ps) |
|---|---|---|---|---|---|
| | Designed | XRD | | | |
| 1 | 6+40=46 | 45.5 | 0.5 | 0.0177 | 720 ± 4ps |
| 2 | 8+40=48 | 46.8 | 1.2 | 0.0132 | 1246 ± 16ps |
| 3 | 12+40=52 | 51.6 | 0.4 | 0.0383 | 855 ± 30ps |
| 4 | 30+40=70 | 69.7 | 0.3 | 0.0109 | 1021 ± 5ps |
| 5 | 30+5=35 | 34.4 | 0.6 | 0.0153 | 1086 ± 6ps |
| 6 | 30+2=32 | 31.3 | 0.7 | 0.0125 | 1500 ± 15ps |

**Table 1. The superlattice period (D) for the six MQWs samples, their rocking curve FWHM of first order satellite peak and TCSPC radiative recombination decay time constants.**

## 3 TIME CORRELATED SINGLE PHOTON COUNTING (TCSPC)

In Figure 1 the TCSPC results on samples 1 to 4 with increasing quantum well width are shown. They show a clear evolution of the spectral shape with time for all samples except for the narrowest 6nm well width. This could be evidence for state filling at higher intensities, cooling of hot carriers or some convolution of both.

The integrated PL data with time in Figure 2 are taken from the TCSPC data. Time constants describing an exponential decrease are indicated. The time constant clearly increases as the barrier width reduces. This is very consistent with the increasing overlap of wavefunction as barrier width decreases leading to increased mobility of carriers, particularly electrons, such that electronhole pairs become delocalized and reduce the probability of radiative recombination, hence increase the time constant.

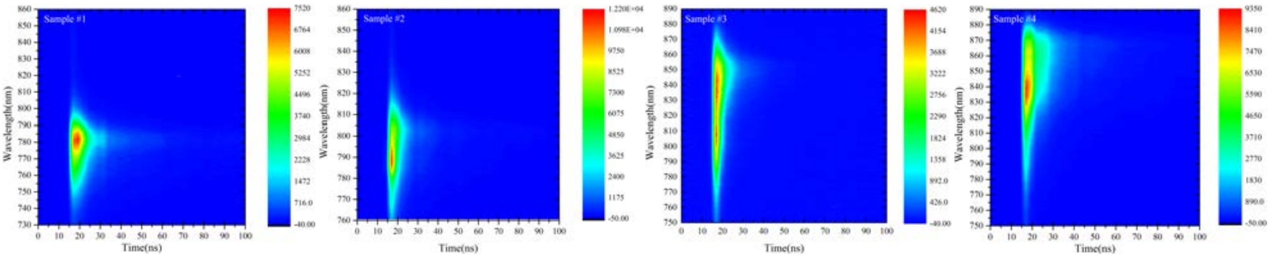
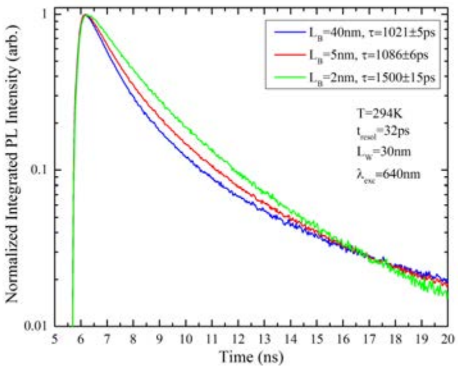



**Figure 1: TCSPC 2D plots for samples 1 to 4 with varying quantum well width. Excitation wavelength is 640nm and time resolution is 66ps. A clear evolution of the spectral shape with time is evident, especially for the wider wells.**

The integrated PL data in Figure 3 are taken from the TCSPC in Figure 1. They illustrate the change in time constant with change in quantum well width. Here there is a large increase in time constant in going from 6 to 8nm, followed by a large decrease again for 12 and 30nm wells. This suggests a resonant non-linear mechanism for the well width of 8nm. Qualitatively this is very consistent with the formation of mini-gaps in the phonon density of states for the MQW, with the energy of the mini-gap varying as the quantum well width changes. The resonance for the 8nm well is consistent with the mini-gap for this width occurring at just the energy of half the optical phonon energy. This would then very effectively block Klemens decay of optical phonons into acoustic phonons and lead to longer hot carrier and carrier lifetimes. Calculations of the phonon dispersion and more refined measurements are underway to confirm or deny this interpretation.



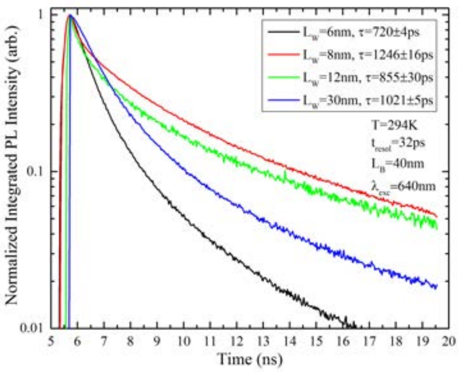




**Figure 2: Integrated PL intensity with time delay - samples with varying barrier width.**

**Figure 3: Integrated PL intensity with time delay for samples with varying well width.**

## 4 CONCLUSIONS

XRD and TEM results indicate that these MBE fabricated MQWs have relatively good crystal quality and layer thickness uniformity, and that each layer thickness is close to the designed values. High crystal quality of the material is vital for a hot carrier absorber. CWPL data are also consistent with good quality QW material and show a redshift in PL with well thickness quantitatively matching degree of quantum confinement.

## REFERENCES

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