Advanced characterization of hot carrier properties of InGaAs multi-quantum well structure using hyperspectral and time-resolved luminescence spectroscopy

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Hot carrier solar cells (HCSC) are one type of third generation photovoltaic devices, which have been proposed to increase the power conversion efficiency beyond the Shockley-Queisser limit (33%). In this type of solar cells, the excess kinetic energy of hot carriers (HC) is converted to useful electricity rather than being lost through thermalization mechanisms. Nanostructured materials, such as quantum well (QW) structures, have shown evidences of robust HC distributions at room temperature and relatively low excitation power [1]. One of the main characterization techniques to investigate HC potential of a solar cell is continuous wave photoluminescence spectroscopy (CWPL), which allows to estimate various parameters such has HC temperature, quasi Fermi level splitting and thermalization coefficient of the structure [2], [3]. In addition to CWPL, one can use time-resolved photoluminescence spectroscopy (TRPL) to see the carrier relaxation dynamics, as well as the carrier transport across the layers [4], [5].

We present our results of advanced CWPL and TRPL for the characterization of a multi-quantum well InGaAs solar cell, which consists of 20 $In_{0.2}Ga_{0.8}As/GaAs_{0.8}P_{0.2}$ QW in a p-i-n-GaAs structure, with electrical contacts on both sides and anti-reflection coating. Our hyperspectral CWPL setup allows us to study the PL spectrum with a 2D spatial resolution, which enables to probe diffusion properties of the sample. By studying the power- and temperature-dependent PL spectra on both CWPL and TRPL setups, we can consistently characterize the HC properties of the sample and build a precise understanding of the HC thermalization in the sample.

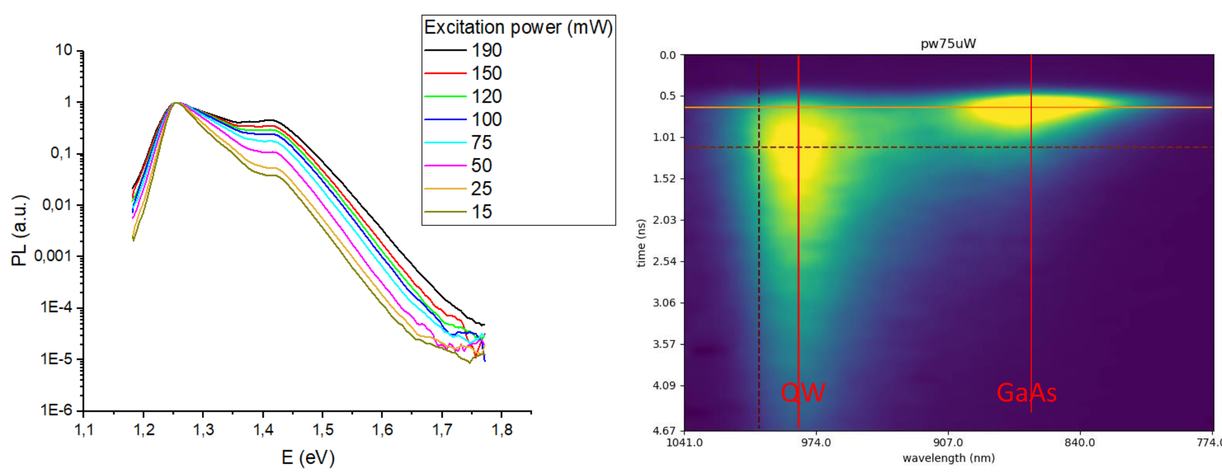

Figure 1: (a) power dependent CWPL spectra. The power dependence of the slope in the [1.28, 1.35] eV range denotes a HC effect. (b) streak acquisition of the same sample. The dynamics of the two main emitting layers (QW and GaAs) are different (lifetime, delay, …).

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