Photoluminescence analysis of hot carriers in ultrathin GaAs layers: identification of surface and volume thermalization mechanisms

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Hot-carrier solar cells offer the opportunity to harvest more energy than the limit set by the Shockley-Queisser model, by reducing the losses due to the thermalization of the photo-generated carriers. Previous reports have shown lower thermalization rates in thinner absorbers, but the origin of this phenomenon is not precisely understood. In this work, we investigate a series of ultrathin GaAs absorber layers sandwiched between AlGaAs barriers and transferred on host substrates with a gold back mirror. We perform power-dependent photoluminescence characterizations at different laser wavelengths in four absorber thicknesses between 20 and 200 nm. We determine precisely the carrier temperature by accounting for band filling, and observe a linear relationship between the absorbed power and the carrier temperature increase. By relating the absorbed and thermalized power, we extract a thermalization coefficient Q for all samples. It shows an affine dependence with the thickness, leading to the identification of distinct volume and surface contributions to thermalization (Figure 1). We confirm that volume thermalization q_V is linked to LO phonon decay. We discuss the origin of the interface-related thermalization Q_S, showing that the impact of LO phonon transport is negligible. This work, part of which has been submitted for publication, sheds new light on thermalization processes in ultrathin semiconductor layers and introduces a method to compare the performance of hot-carrier absorbers.

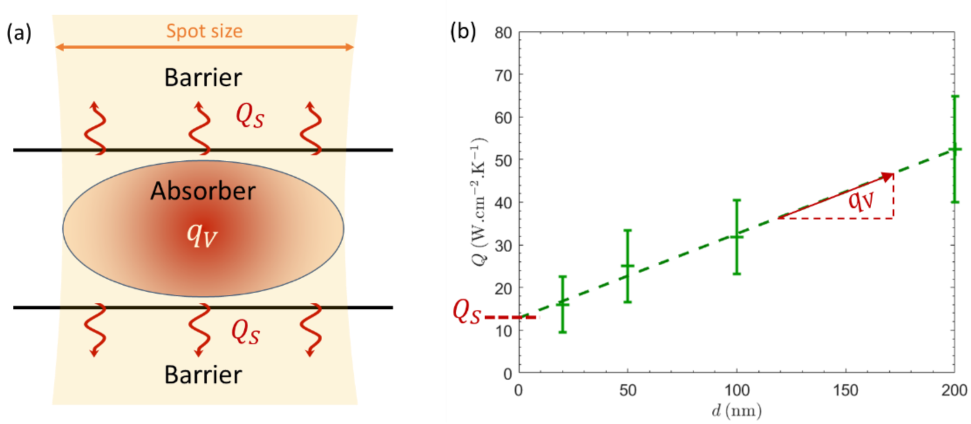

Figure 1: (a) Sketch illustrating the surface (Q_S) and volume (q_V) contributions to thermalization under illumination. (b) Thermalization coefficients measured as a function of the absorber thickness. The intercept corresponds to the surface contribution while the slope gives the volume contribution.