Optical Determination of Thermoelectric Properties of a Hot Carrier Absorber

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Hot carrier solar cells (HCSC) have been proposed to increase the efficiency of photovoltaic devices beyond Shockley-Queisser (SQ) limit (~33%) [1]. In this type of solar cells, the excess kinetic energy of hot carriers is converted to useful electricity rather than being lost through thermalization mechanisms. From a device perspective, HCSC require two ingredients: an absorber where carriers exhibit a slow cooling rate and remain hotter than the lattice, and energy selective contacts for hot carriers extraction. While both ingredients have been successfully investigated separetly in III-V quantum wells (QW) [2], [3], there are very few realizations of full HCSC structures to date [3], [4], and none with efficiency exceeding the SQ limit. Achieving an efficient HCSC requires a better understanding of basic processes, in particular heat and carrier transport.

We argue here that transport in HCSC could be understood in terms of thermoelectricity. Indeed, heat and carrier fluxes are coupled by Seebeck coefficient (and other transport parameters), which need be determined in order to find an efficient way of extracting work out of such systems [5]. Unfortunately, usual electrical determination of Seebeck coefficient is challenging in QW because of electrical artifacts and difficulty to generate heat gradients over such thin structures [6], [7].

In the present study, we report a contact-less measurement of Seebeck coefficient through photoluminescence imaging. Using a hyperspectral imager and diffraction-limited punctual excitation, one can measure the carrier temperature gradient as we move away from the laser spot, along with the quasi-Fermi level gradient. Both those quantities can be used to solve Onsager's equations of transport, and hence measure the ambipolar photo-induced Seebeck coefficient [8]. We study both power and temperature dependency of this Seebeck coefficient, and explain it thanks to Boltzmann transport equation.

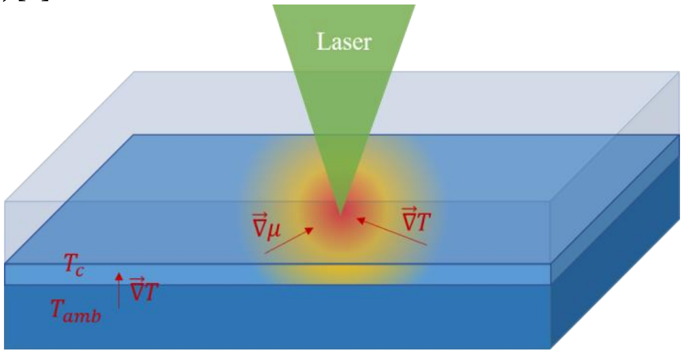

Figure 1: schematic of the characterization technique used. Shining an intense laser on a hot carrier absorber will generate a temperature gradient in the absorber, along with a carrier concentration gradient. Both gradients will affect carrier motion, allowing us to measure electrical conductivity and Seebeck coefficient.

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