A NEW TYPE OF HOT-CARRIER SOLAR CELL UTLISING THERMAL UP AND DOWN CONVERSION OF SUNLIGHT

Daniel J Farrell[1], Yasuhiko Takeda[2], Kazutaka Nishikawa[2], Tomonori Nagashima[3], Tomoyoshi Motohiro[2], Nicholas J Ekins-Daukes[4], Yoshitaka Okada[1]

[1]RCAST, The University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8904, Japan
[2]Toyota Central Research and Development Laboratories, Inc., 41-1 Yokomichi, Nagakute, Aichi, 480-1192, Japan.
[3]Future Project Division, Toyota Motor Corporation, 1200 Mishuku, Susono, 9 Shizuoka, 410-1193, Japan.
[4]Experimental Solid State Physics, Blackett Laboratory, Imperial College London, SW7 2AZ, UK.

The Hot-Carrier Solar Cell (HC-SC) is an ambitious approach to solar energy conversion which in principle can achieve high efficiency (84% under full concentration) from a single bandgap semiconductor. The HC-SC has three main material challenges which need to be overcome: (1) the rapid cooling of the carriers through irreversible scattering mechanisms, (2) hot-carrier transport through the device without incurring significant heat loss, and (3) the extraction of excess hot-carrier energy through monochromatic energy selective contacts at the device surfaces. These are stringent requirements because in general cooling is fast (sub-nanosecond), hot-carrier transport distances are short, and non-ideal energy selective contacts will pass a leakage current outside the selectivity window.

In this presentation we will discuss a new concept which has the potential to overcome these challenges: the 'optical' hot-carrier solar cell [1]. In this scheme energy is extracted from a hot-carrier distribution *optically* rather than through electrical conduction. This removes the difficulties of transporting hot charge carriers through a semiconductor because once energy is partitioned into photon modes cooling can no longer occur.

The energy selectivity of extraction can be achieved by enhancing the optical density of states over an narrowband of photon energies (see Figure 1). Introducing many new optical states will alter the emission properties of the material such that radiative recombination via these states will be strongly favoured: the material will absorb broadband sunlight but predominately emit narrowband hot-luminescence. Power conversion occurs by integrating a solar cell into the device structure which collects the narrowband hot-luminescence with high-efficiency.

By tuning the spectral position of the enhanced optical modes energy can be extracted from the hot-carrier absorber at a higher energy: thermal up-conversion, or at a lower energy: thermal down-conversion. In this device the properties of a hot electronic distribution are used to average the absorbed energy and extract it at convenient wavelengths for efficient solar energy conversion.

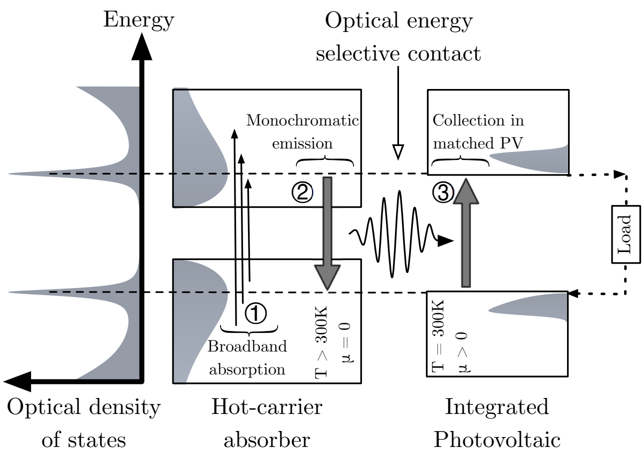

Figure 1: The optical hot-carrier solar cell: (1) broadband solar energy is absorbed and forms a hot-carrier distribution in the absorber (2) enhancement of optical modes favors the emission of mostly monochromatic hot-luminescence from the absorber, (3) the hot-luminescence is converted by an integrated photovoltaic cell.

[1] D J Farrell et al., Appl. Phys. Lett. 99, 111102 (2011); doi:10.1063/1.3636401