# Plasmonic Solar Cells beyond the Shockley-Queisser Limit

**K. Kempa, F. Ye, M. J. Burns, and M. J. Naughton**
Boston College, USA

**Abstract**— We show that by combining two metamaterial effects, resonant light trapping and plasmonic protection of hot electron energy, solar cells with efficiencies well beyond the Shockley-Queisser limit can be produced. The first effect employs distributed subwavelength metallic nanopatterns embedded in the volume or on the surface of an ultrathin absorber. The metamaterial and plasmonic actions of the nanopatterns dramatically increase absorbance of light in ultrathin absorbers, over a broad frequency band. Preliminary results (simulations plus experiments) on near-field scattering-enhanced optical absorption using embedded metallic nanopatterns suggest the ability to increase the efficiency of ultrathin PV cells using CdTe by $\sim 80\%$, and CIGS, *a*-Si and *a*-SiGe cells by $\sim 60\%$. The second effect employs another similar metamaterial/plasmonic micropattern on the surface of an ultrathin solar cell, acting as a plasmonic reservoir, where plasmonic resonance can be tuned to match that of characteristic hot electron energies. Resonant energy transfer from those hot electrons into plasmons of the array can then occur, on time scales faster than irreversible phonon emission. Since plasmon-phonon and plasmon-photon scattering processes can be relatively slow in such structures, this could provide a "plasmonic protection" mechanism for the excess free energy of the excited hot electrons. Our simulations show that the protected energy could maintains available about 5 times longer in the collective, plasmonic electronic form, before dissipating into heat. This may be sufficient to collect significant numbers of hot carriers in ultrathin solar cells since, as we've recently shown, such cells already collect a small fraction of hot electrons even without plasmonic protection. By combining the two above schemes, solar cells with efficiencies well beyond the Shockley-Queisser limit could be developed.