Seminar announcement

Tuesday, May 16, 2023
1:30 pm
WSI, Seminar room S 101

"Towards hot-carrier photovoltaics using heterostructure nanowires"

When a solar cell absorbs a photon, the resulting electron-hole pair typically has excess kinetic energy that gets lost to heat. An exciting emerging concept in photovoltaics is to use the nonequilibrium energy of such so-called "hot" charge carriers to boost solar cell efficiency or to design ultra-fast photodetectors.

Semiconductor nanowires have several distinct advantages as a system to explore hot-carrier concepts: (i) in thin nanowires, slow carrier relaxation is observed, perhaps due to a phonon-bottleneck effect; (ii) photonic or plasmonic engineering allow to design the location of light absorption and (ii) strain relaxation enables great freedom for heterostructure band engineering for energy filtering.

I will report on a series of experiments exploring the possibility of hot-carrier photovoltaic energy conversion in nanowires. One key element is the ability to efficiently harvest electricity from heat stored in electrons. A near-ideal quantum-dot heat engine in single, InAs/InP heterostructure nanowires, can achieve power production with Curzon-Ahlborn efficiency (> 50% of Carnot efficiency) at maximum power settings, and reaching more than 70% of Carnot efficiency at maximum efficiency settings [2].

In experiments with light as the energy source, we demonstrated hot-carrier photothermoelectric energy conversion with an open-circuit voltage that exceeds the Shockley-Queisser limit, and we demonstrated avenues to increase quantum yield by use of plasmonic elements. [3]

Recently, we are interested in avenues allowing us to optimize the so-called fill factor (the shape of the IV-curve) in thermal-to-electric energy conversion and found that intentional symmetry-breaking can play a perhaps unexpectedly positive role that opens up for new approaches based on fundamental symmetry considerations. [4]

[1] Fast, J., Aeberhard, U., Bremner, S. P., & Linke, H. Hot-carrier optoelectronic devices based on semiconductor nanowires. Applied Physics Reviews, 8 (2), 021309 (2021). doi:10.1063/5.0038263

[2] Martin Josefsson, Artis Svilans, Adam M. Burke, Eric A. Hoffmann, Sofia Fahlvik, Claes Thelander, Martin Leijnse, Heiner Linke: A quantum-dot heat engine operated close to thermodynamic efficiency limits. Nature Nanotechnology (2018)

[3] S. Limpert, A. Burke, I-Ju Chen, N. Anttu, S. Lehmann, S. Fahlvik S. Bremner, G. Conibeer, C. Thelander, M.E, Pistol and H. Linke: Single-nanowire, low-bandgap hot carrier solar cells with tunable open-circuit voltage Nanotechnology **28**, 43 (2017)

[4] Chen, I. J., Limpert, S., Metaferia, W., Thelander, C., Samuelson, L., Capasso, F., … Linke, H. (2020). Hot-Carrier Extraction in Nanowire-Nanoantenna Photovoltaic Devices. Nano Letters, 20(6), 4064–4072. doi:10.1021/acs.nanolett.9b04873

[5] J. Fast, H. Lundström, S. Dorsch, A. Burke, P. Samuelsson, and H. Linke (2023). Geometric symmetry breaking and nonlinearity can increase thermoelectric power. arXiv:2304.01616

Prof. Heiner Linke
NanoLund and Solid State Physics
Lund University, Sweden