Quantum Cascade Coolers

Chloe Salhani[1,2], Marc Bescond[1,2], Kazuhiko Hirakawa[1,2]

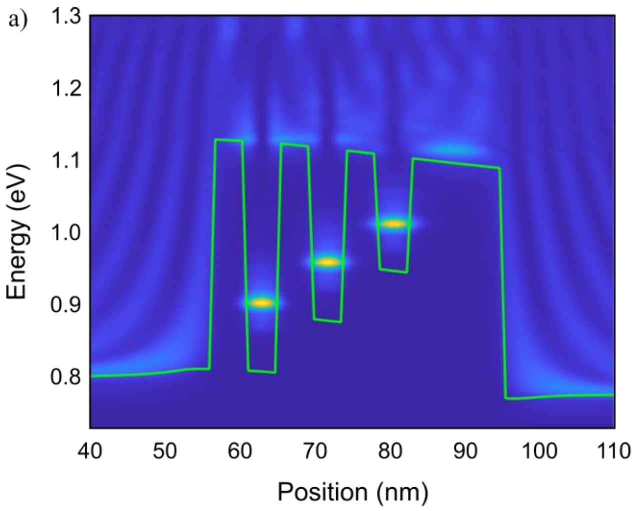
[1]Institute of Industrial Science - University of Tokyo, [2]LIMMS-CNRS

E-mail: csalhani@iis.u-tokyo.ac.jp

Technological advances in high-speed, densely packed electronic/photonic devices have brought unprecedented benefits to our society. However, this technological trend has also led to a tremendous increase in the generation of waste heat, which degrades device performance and lifetimes. Consequently, there is a scientific and engineering challenge in the development of novel cooling technologies.

Asymmetric AlGaAs/GaAs double barrier heterostructures have yielded promising results for thermionic cooling [1-3]. Building upon these results, we developed a new device architecture based on a staggered multiple-quantum-well structure, the quantum cascade cooler (QCC).

We report on evaporative electron cooling in AlGaAs/GaAs QCCs. Electron temperatures in the quantum wells (QW) are determined from photoluminescence (PL) measurements as a function of bias. The experimental data are compared to a full quantum transport simulation calculating electron temperatures inside the device using the nonequilibrium Green's function framework.



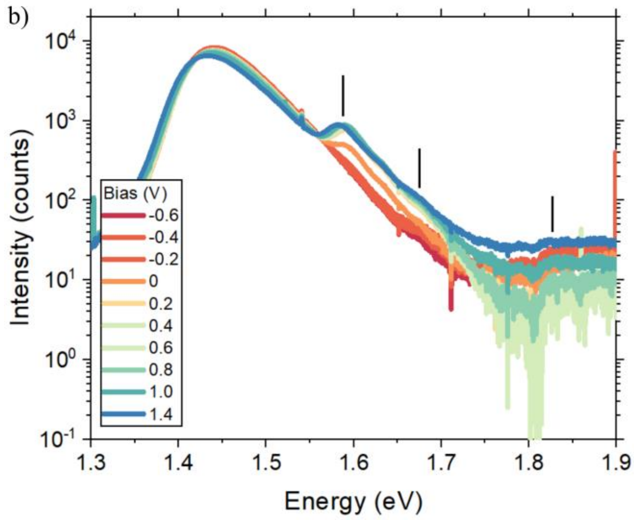


Figure 1: a) NEGF simulation showing the electron density across a three-well QCC. Staggered confined levels are visible in the QWs. b) PL specter of the QCC under bias. The three highlighted peaks are signatures of electron-hole recombination inside the three QWs.

REFERENCES:

[1] Chao, K. A. et al., *Appl. Phys. Lett.* **87**, 022103 (2005)

[2] A. Yangui et al., *Nature Communications* **10**, 4–6 (2019)

[3] X. Zhu et al., *Physical Review Applied* **16**, 064017 (2021)