ELECTRON TEMPERTUARE IN DOUBLE QUANTUM WELL CASCADE COOLING STRUCTURES

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Managing rapid increase in thermal power densities associated with device miniaturization is a major technological challenge. Development of new efficient cooling technologies is therefore urgently required for future progress in electronics. Solid-state cooling devices can be one answer, owing to their high efficiency and compatibility for integration.

In this work, we have studied AlGaAs/GaAs double quantum well (QW) structures as a model for the quantum cascade cooling (QCC) structures (see Fig. 1(a)). As an electron cascades through the double QW structure, it can absorb multiple LO phonons, which can improve the cooling efficiency, when compared with a single QW structure [1,2]. To clarify the electron cooling behavior, we measured voltage (V)-dependent photoluminescence (PL) of the sample (Fig. 1(b)). The high energy tails of the PL peaks from bulk n-GaAs, the first QW (QW1), and the second QW (QW2) were analyzed and electron temperatures (Te's) in the respective layers were determined as a function of V (Fig. 1(c)).

We observe electron cooling effect in both QWs by several tens K with anti-correlated oscillatory behavior, showing characteristic features at V = ~0.2 V/~0.4 V/~0.6 V. We have found that the anti-correlated oscillation in Te between in QW1 and in QW2 occurs due to the competition of LO phonon scattering, quasi-elastic scattering, and resonant tunneling between the quantized electronic subbands E1 (QW1) and E2 (QW2). Furthermore, evaporative electron cooling in QW2 by as much as 70 K is observed, which is much larger than that in the former single QW structures [1,2].

References:

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