Development of photonic-crystal based mid-infrared quantum cascade lasers

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Quantum cascade lasers (QCLs) are unique solid-state lasers that operate in the mid-infrared range. They possess such good features as the wide tunability of the lasing frequency, compact device structures, and small power consumption. Their application to gas sensing is specifically promising, since the absorption lines of important gas molecules are covered by the QCLs. For the remote sensing of dangerous gases such as volcanic eruptions and for the extremely high-sensitivity gas analysis, high-quality laser beams with small divergence angles are needed because a long propagation length is required.

However, the conventional QCLs are of the edge emission type with small output apertures, so their divergence angles are generally large. The surface-emission device configuration, known as VCSEL (vertical-cavity surface-emission laser), improves this problem of the laser-beam quality. But because the emitted light from the active region of the QCLs, which utilizes the subband transitions of multiple quantum wells (MQWs), are transverse magnetically (TM) polarized, so there is a mismatch with the cavity electromagnetic resonance modes, and the VCSEL configuration is not applicable to QCLs. PC (photonic crystal) resonators are used instead [1-6].

In this presentation, we report on the development of the surface-emitting QCLs, which was carried out jointly by NIMS, Toshiba Corporation, and Tokyo University of Technology [4,5], focusing on the relationship between the structure of the PC resonator and the laser performance. We compare three cases of the PC unit-cell shapes as shown in Fig. 1.

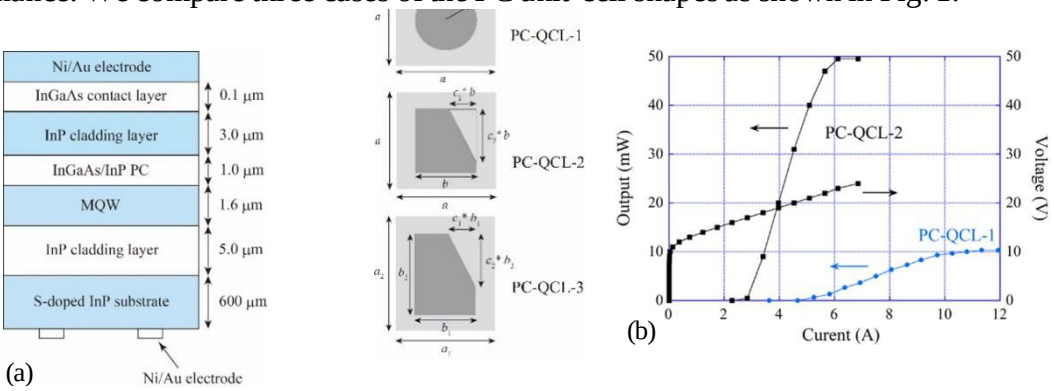

Figure 1. (a) Illustration of the side view of the device structure. (b) Left: top view of the unit cell composed of an InGaAs pillar (dark grey) buried with InP (light grey). Right: Peak output power of PC-QCL-1 and PC-QCL-2 with a pulsed excitation at 77 K. For PC-QCL-3, a peak output power more than 1 W was achieved.

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References

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