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Sb-based Mid-IR lasers grown by MBE on Silicon(001)

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ABSTRACT. We present our results on the growth of GaSb-based laser diodes (LDs) and InAs/AlSb quantum-cascade lasers (QCLs) on GaSb/Si(001) templates. We show that thanks to a dedicated nucleation strategy these structures are free of emerging anti-phase boundaries. LDs operate in cw mode up to >80 °C without thermal roll-over but with a threshold ~5 times higher than that of LDs grown on GaSb whereas the QCLs exhibit similar properties when grown on Si or on their native InAs substrate.

Keywords: III-V/Si heteroepitaxy, monolithic integration, laser diode, quantum cascade laser.

Antimonide-based materials are well suited to the development of a wide variety of IR optoelectronic devices for various applications, from telecom to sensing. In this presentation we review the recent results obtained on the epitaxial integration of antimonide-based optoelectronic devices on Si substrates.

Early work focused on 6°-offcut Si substrates [1], an orientation that allows preventing the formation of so-called anti-phase domains and boundaries (APBs), crystal defects which create shorts and are device killers.

More recently, we have developed an alternative III-V-on-Si nucleation strategy which allowed us to achieve APB-free layers and heterostructures grown on on-axis (001) substrates. We have fabricated LDs emitting near 2.3 µm that exhibited better performances than those of LDs grown on 6°-offcut substrates (Fig. 1) [2]. QCLs emitting near 7.5 µm have also been demonstrated (Fig. 2). Again, their performances are similar to those of QCLs grown on native InAs substrates (Fig. 3) [3]. Finally, we also developed etched-facet LDs, an important asset for their future integration with photonics integrated circuits [4].

These results show that this technology is very attractive for the epitaxial integration of III-Vs on Si. In particular, the availability of mid-IR integrated lasers is in line with the current evolution toward smart, integrated, sensors.

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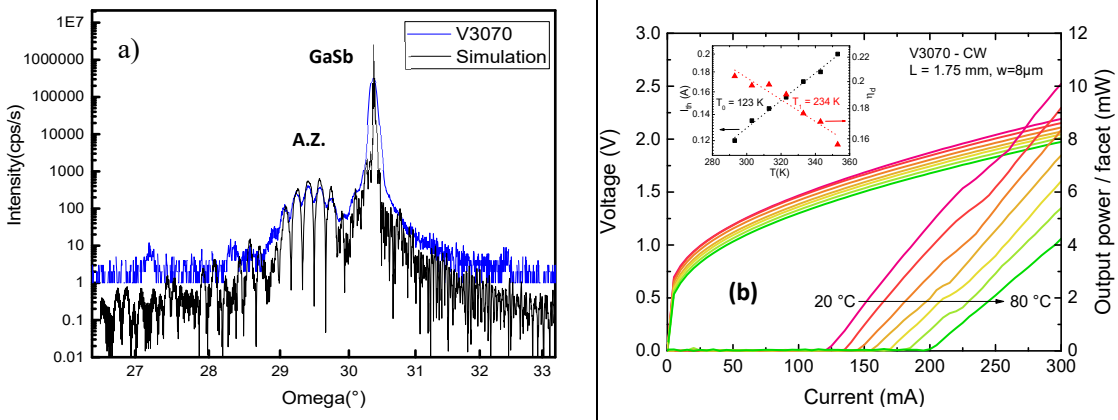

Figure 1. (a) HRXRD curve around the GaSb peak (blue curve), together with the simulated pattern (black curve) assuming fully strained active zone. (b) L – I – V curves taken under cw operation between 20 °C and 80 °C from a LD with an 8 µm ridge width and 1.75 mm cavity length. The inset shows the semi logarithmic variation of Ith and □d with temperature.

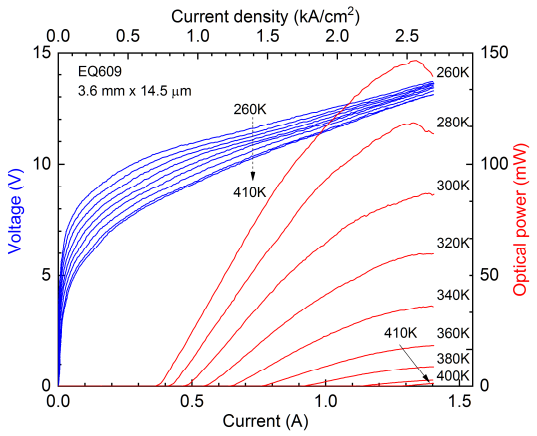

Figure 2. Voltage-current and light-current characteristics of a QCL grown on a Si substrate measured in pulsed mode at different temperatures.

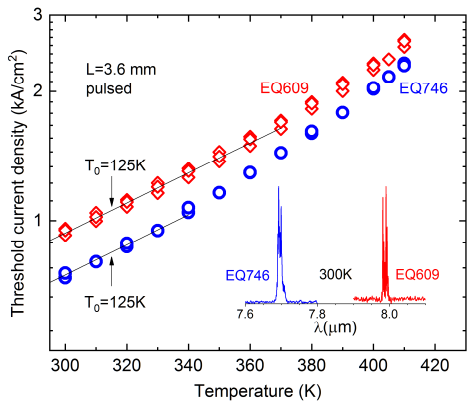

Figure 3. Threshold current density of QCLs grown on Si (EQ609) and on InAs (EQ746) as a function of temperature (semi-logarithmic scale). Emission spectra measured at a current of 0.6 A at 300K are shown in inset.