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Low electric field silicon-based THz quantum cascade laser employing *L*-valley intersubband transitions

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Since their first demonstration in 2002, terahertz (THz) quantum cascade lasers (QCLs) have become established as compact, coherent sources with applications ranging from astrophysics to gas spectroscopy and medical imaging[1]. Every QCL demonstrated to date has been based on III-V heterostructures such as GaAs/AlGaAs, but there are compelling motives for developing Si-based devices[2]. Aside from the possible cost reduction due to the maturity of silicon processing technology, Si may allow higher temperature operation due to its greater thermal conductivity and the absence of polar LO-phonon interactions. Ultimately, CMOS integration and optoelectronic system-on-a-chip applications may be possible.

Although the indirect bandgap hinders the development of interband SiGe-based lasers, there is no such obstacle for *intersubband* transitions in a QCL. Most previous SiGe QCL designs have employed transitions within the valence band[3], but the lower effective mass of conduction band *L*-valleys allows higher optical gain. Uniaxial strain effects, which complicate the valence band structure, are also avoided.

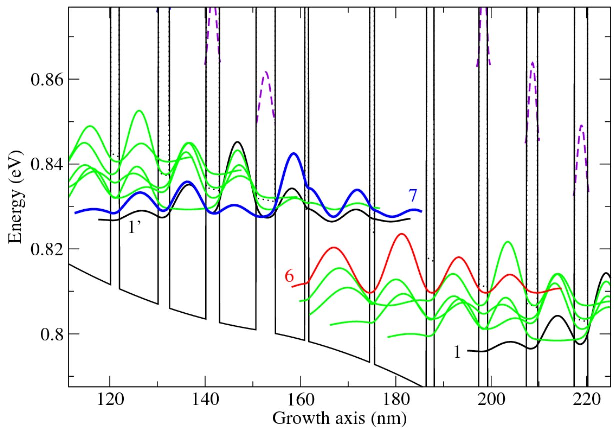

Figure 1: Confining potential and electron probability densities for L-valley subbands in the QCL design at an electric field of 4 kV/cm

We show that previous *L*-valley designs[4], which operate at a high electric field, yield high electron temperatures and relatively low gain. In this paper, we present a bound-to-continuum QCL design operating at much lower electric field. Using a self-consistent (effective mass) Poisson-Schrödinger calculation, with semi-classical rate equation modelling of charge transport, we show that sufficient gain is achievable with our design to overcome the losses in double-metal QCL waveguides.

References

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