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Design considerations for optically pumped Ge/SiGe intersubband lasers

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Quantum cascade lasers (QCLs) based on III-V materials have matured into operating devices covering significant parts in the mid-IR and THz regions of the spectrum. In the last decade a considerable research effort has been put in Si (or SiGe) based QCLs, with the prospect of using the mature Si process technology. Although mid-IR and THz luminescence from p-type SiGe/Si cascades has been achieved, lasing has not yet been demonstrated. In recent years, attention has switched to n-type Ge/SiGe devices, where a low effective mass and large usable L-valley band offset enable good gain and emission frequency range. An intermediate step en route to QCLs is the optically pumped intersubband laser. In this work, we report on the design of such lasers, based on asymmetric double, triple, or step quantum wells. Simulations are based on rate-equation approach, with self-consistent Schrodinger/Poisson solver and calculation of all relevant scattering processes: acoustic and deformation-potential optical phonon scattering (intra- and inter-valley), alloy disorder, interface roughness, impurity and electron-electron scattering. The design guidelines are here very different from those used in III-V based lasers, due to the absence of resonant, polar LO-phonon scattering, and the appearance of gain relies on favourable overlaps of wavefunctions and the energy dependence of scattering processes, hence the gain optimisation is based on extensive search over the design parameters space.

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