Carrier dynamics in type-II quantum well Sb-based MIR lasers

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Friday, May 14th, at 3 PM

Center for High Technology Materials, Room 101

The results of our carrier dynamics investigation in InAs/InGaSb/InAs type-II 4 μm lasers using luminescence correlation and band-edge nonlinear pump-probe spectroscopy techniques are presented. The laser samples incorporated 6 type-II quantum wells, each comprised of 24 Å thick InGaSb hole well sandwiched by two 21 Å InAs electron wells. In the nonlinear pump-probe technique two pump beams chopped at different frequencies excite the sample and the spectrally resolved probe absorption nonlinearity is measured at the sum frequency. The magnitude and signature of the nonlinear signal determines the position of the quasi Fermi energy and the carrier temperature. We are able to resolve the contribution of the intervalence absorption process (IVA) from the dominant interband gain dynamics since these contributions have different characteristic nonlinear signals. The IVA absorption occurs at in-plane momentum $k_{\|} \sim 0.025$ Å^{-1} and is not resonant with the interband lasing energy, therefore does not compete with the interband transition at low temperature and low carrier densities. A density dependent interband transition matrix element of $N^{0.17}$ was deduced reflecting the enhancement of the electron-hole wavefunction overlap due to the space-charge fields in the type-II wells. Significant lattice heating observed above 80 K is reflected in the growth of an out of phase slow signal, resulting from the reduction of lattice thermal conductivity and the IVA resonance enhanced nonradiative Auger recombination transitions at higher temperatures. Thermal diffusion times of the order of ~ 100 μs that increases with temperature were measured.