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Temperature characterization of gain in the active region for quantum cascade laser

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Quantum cascade lasers (QCLs) are unipolar semiconductor lasers covering a wide range of the infrared and terahertz spectrum. The best QCL performance is archived in the mid-infrared spectral range, where QCLs operate at room temperature and above.

We describe threshold current density characteristic for temperatures in range from low (80 K) up to room (300 K) by phenomenological scattering-rate approach, which includes main scattering processes in semiconductor heterostructures. Total transition rate between separated levels in conduction band is presented as a sum of different averaged actual transition rates and is proportional to overlap of wave functions for these levels. The scattering processes are investigated as the functions of energy between levels and temperature in active region of device.

So-called “characteristic temperature T_0” describes temperature dependence of the laser threshold and is proven to be useful for QCLs as well as for conventional semiconductor lasers. We investigated this characteristic for current pulse duration in the range 100-500 ns for description of the thermal conductance for active region. For this purpose the threshold current as a function of temperature for the one-side HR-coated 4mm-long QCL stripe is measured in pulse and cw regimes. The temperature shift of these dependences allows to determine a difference between the effective active region temperature in cw mode and the heat sink temperature. It is shown that the cw threshold current follows a mono-exponential growth rate and then rapidly increase together with approximately 0.2 V increase of the threshold bias up to 4.2 V. We assume this behavior to be associated with the approach of the critical electric field, when the upper laser state and the injector state start to become misaligned. Such data allow the better understanding the mechanisms of media heating in practically important class of devices.