Electrically tunable quantum cascade laser

Mikhail V. Kisin, Sergey Suchalkin, and Gregory Belenky

***Abstract*— We propose a concept of quantum cascade laser (QCL) tuning based on electric charge accumulation outside the optically active quantum wells. The outside charge accumulation allows above-threshold control over both the gain peak position and modal refractive index - the later achieved by a specially designed intersubband polarization transition in the accumulation region. This design provides a mechanism for fast single-mode wavelength tunability of the QCL.**

***Index Terms*—Quantum cascade laser, tunable laser, mid-infrared laser.**

Tunable mid-infrared sources are needed for high-resolution laser spectroscopy and optical communication systems. Currently, the most promising optical source in the mid-infrared range is the quantum cascade laser. Direct electrical tuning of the optical transition by the Stark effect remains an unsolved problem in QCL because, after the laser threshold is reached, the carrier concentration in the optically active quantum wells becomes clamped according to the threshold condition (gain equals loss) and, therefore, is not changed as the bias current increases. The concentration clamping pins the electric field in the active region to its threshold value thus preventing Stark tuning of the lasing transition. In this paper, we propose incorporating in each QCL cascade a double-quantum-well (DQW) accumulation region located outside the optically active quantum wells of the laser. The outside accumulation of electric charge is not clamped by the threshold condition and can be altered by the bias injection current [1]. The DQW structure in the accumulation region is specially designed to provide an intersubband polarization transition shifted in frequency from the main lasing mode of the QCL. The overall gain spectrum thus becomes asymmetrical and allows for non-zero alpha factor at lasing wavelength. In our tuning scheme, the refractive index change of the TM-polarized QCL optical mode at the lasing frequency due to intersubband carrier polarization in the accumulation region is directly related to the accumulated carrier concentration and, therefore, can be controlled by the injection current. This scheme provides a mechanism for ultra-wide quasicontinuous wavelength tuning in QCL.

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Authors are with the Electrical and Computer Engineering, SUNY at Stony Brook, NY 11794 (corresponding author Mikhail Kisin. Pone: 631-632-8421; e-mail: mvk@ece.sunysb.edu).

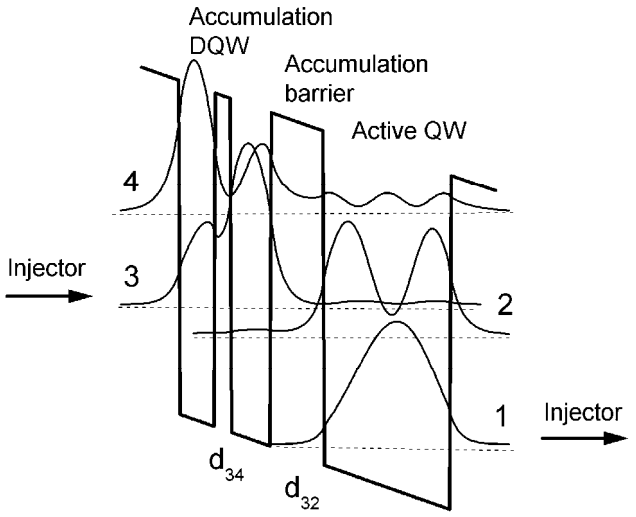

Fig. 1. Active region of a tunable QCL structure: optically active QW with lasing transition **2**–**1** and DQW accumulation region with polarization transition **3**–**4**. Accumulation barrier d_{32} controls the LO-phonon assisted iniection transition **3**–**2**.

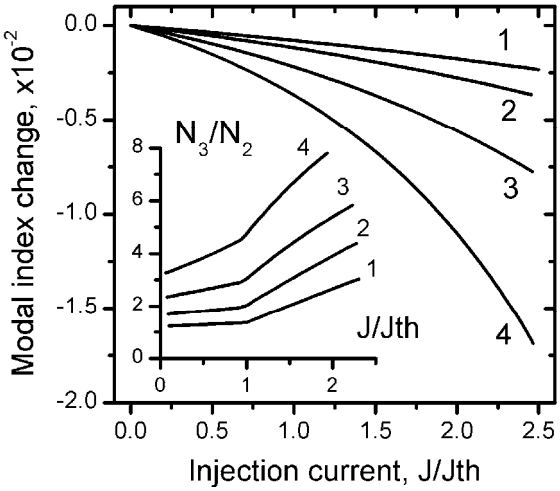

Fig. 2. Modal index change due to intersubband polarization in DQW accumulation region of QCL structure presented in Figure 1. The curves are numbered with respect to increased tunneling barrier width d_{32} from 3.4 nm (1) to 4.0 nm (4).

REFERENCES

[1] S. Suchalkin *et al*, *Applied Physics Letters,* vol. 88, pp. 031103-3, 2006.