Novel type-I quantum well interband cascade lasers

Rui Liang, Leon Shterengas, Gela Kipshidze, Takashi Hosoda, and Gregory Belenky
State University of New York at Stony Brook, New York, USA

The effectiveness of employing the carrier recycling scheme [1] in the design of semiconductor lasers definitively demonstrated itself in the development of quantum cascade (QCL) and interband cascade (ICL) lasers. In QCL, the laser active region is designed based on intersubband carrier transitions. In ICL, the active regions are designed based on type II interband transitions. Taking into account the high oscillator strength of interband optical transition in type I quantum wells (QWs), it was attractive to utilize the carrier recycling scheme in the development of type I QW interband lasers. This task was accomplished in vertical cavity surface emitting lasers where *pn* junctions provide carrier transport between the device gain sections to ensure carrier recycling. The success of the design was based on the ability of placing heavily-doped tunnel junctions near the optical field nodes to avoid parasitic internal losses. Because of geometrical considerations and the necessity to preserve the high quality of the laser far field it is difficult to use this approach for successful fabrication of edge emitting devises. At the same time, GaSb based (2–4 μm) interband edge emitting diode cascade lasers with type I QW active regions appear especially attractive since the carrier recycling scheme serves to minimize the threshold carrier concentration and correspondingly to suppress the intensity of Auger processes that detrimentally affect the infrared device performance.

We have shown [2, 3] that the antimonide material system allows utilizing the carrier recycling scheme in the development of type I QW interband lasers. The approach provides efficient carrier recycling between gain stages leading to internal efficiencies in excess of 100%. Devices with two and three gain stages and 100-μm-wide apertures demonstrated peak power conversion efficiency of 16% and continuous wave output power of 960 mW. Corresponding narrow ridge lasers demonstrated above 100 mW of output power.

1. R. F. Kazarinov and R. A. Suris, *Fiz. Tekh. Poluprovodn.* 5, 797 (1971) [*Sov. Phys. Semicond.* **5**, 707 (1971)].
2. L. Shterengas, R. Liang, G. Kipshidze, T. Hosoda, S. Suchalkin, and G. Belenky, *Appl. Phys. Lett.* **103**, 121108 (2013).
3. L. Shterengas, R. Liang, G. Kipshidze, T. Hosoda, G. Belenky, S. S. Bowman, and R. L. Tober, *Appl. Phys. Lett.* **105**, 161112 (2014).