Mid-IR Interband Cascade Lasers for Chemical Sensing

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Many gases of technological interest exhibit their fundamental absorption lines in the mid-IR (3-12 microns) wavelength range. Examples of these include C_2H_2 (3.07 microns), CH_4 (3.3 microns), HCl (3.4 microns), and H_2CO (3.53 microns), CO_2 (4.2 microns), CO (4.6 microns), NO (5.3 microns), and NH_3 (6.1 microns). Hence, the availability of compact and efficient mid-IR semiconductor lasers would dramatically enhance chemical sensing capabilities with significantly improved detection sensitivity. Here, we will describe our recent progress in the development of such needed mid-IR semiconductor lasers for chemical sensing. Our approach is based on interband cascade (IC) laser structures that utilize optical transitions between the conduction and valence bands in a staircase of Sb-based type-II quantum wells with quantum efficiencies exceeding the conventional limit of unity. By combining the advantages of quantum cascade lasers and type-II quantum well interband lasers, type-II IC lasers were projected by simulations to operate in cw mode up to room temperature with high output power, desirable for many practical applications.

We have recently grown type-II IC laser structures using molecular beam epitaxy (MBE) on GaSb and GaAs substrates. The laser samples have been examined by x-ray and exhibited many sharp satellite peaks, indicating good crystal structural quality. Lasers made from those samples lased at wavelength range from ~3 to 4.1 microns in a wide temperature range up to 325 K, the highest reported operation temperature to date for electrically pumped interband III-V mid-IR lasers. A laser with a 30-micron-wide mesa stripe was able to lase in cw mode at heat-sink temperatures up to 200 K with output power exceeding 1 mW. With further improvements in laser design, MBE growth, processing and mounting, operation in cw mode at temperatures (>230 K) accessible by thermal electric (TE) coolers should be realized in the near future.

The lasers made from a 23-stage IC laser sample grown on GaAs substrates also exhibited good performance. Our preliminary testing has demonstrated that these IC lasers on GaAs substrates can be operated at temperatures at least up to 250 K at wavelengths near 4 microns in pulsed mode. These results suggest the possibility of integrating type-II IC lasers with GaAs- and InP-based electronic circuits.

In conclusion, significant progress has been made in Sb-based type-II IC lasers in terms high operation temperatures and low threshold current density. The detailed characteristics of these lasers and updated results will be presented.