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Novel Helmholtz-based photoacoustic sensor for trace gas detection at ppm level using GaInAsSb/GaAlAsSb DFB lasers

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The mid-infrared 2-2.5 µm region is attractive for trace gas sensing due to the presence of quite strong absorption bands of several species, including CO, CH_4, NH_3 and HF, and its location in the so-called atmospheric window, where absorption from the main infrared active atmospheric compounds (H_2O and CO_2) is rather weak.

The recent developments of novel antimonide-based semiconductor laser diodes have opened new perspectives for infrared spectroscopy. The improvement of the general performances of these lasers, and particularly the realization of distributed feedback (DFB) structures enabling single-frequency and continuously tunable emission, makes them suitable for gas sensing applications.

We report here the development of a photoacoustic (PA) sensor based on GaInAsSb/GaAlAsSb DFB lasers in the 2.2-2.3 m range. The structures, based on a three compressively strained quantum wells active region, were grown by molecular beam epitaxy on N doped GaSb substrates. The technology used for DFB fabrication is based on a patented development using a ridge-waveguide structure with a lateral metal grating for distributed feedback. This technology has successfully been applied to a variety of material systems leading to DFB lasers in a wavelength range from 760nm up to 2.8µm.

The highly divergent emission of these mid-infrared lasers makes an efficient coupling of the laser power into a resonant PA cell difficult. In order to fully benefit from the characteristics of the antimonide-based lasers and to achieve optimal power collection, we have designed a novel configuration of PA cell, based on a Helmholtz resonator. In this type of resonator, the excitation of the acoustic signal is independent of the laser beam geometry. We used this property to design a configuration that directly exploits the diverging laser emission to excite the acoustic resonance in one volume of the Helmholtz resonator, without any collecting optics. This geometry enables multiple reflections of the laser beam in this volume, in order to increase the photoacoustic signal.