Short-wavelength InP quantum cascade laser sources by quasi-phase-matched intracavity second-harmonic generation

A. Vizbaras[1*], M. Anders[1], C. Grasse[1], S. Katz[1,2], G. Boehm[1], R. Meyer[1], M. A. Belkin[3], and M.-C. Amann[1]

[1]*Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany*
[2]*Osram Opto-Semiconductors, Leibnitzstr. 4, 93055 Regensburg, Germany*
[3]*Dept. of Computer and Electrical Engineering, The University of Texas at Austin, 78758 Austin, Texas, USA*

Since the first demonstration in 1994, quantum cascade lasers (QCLs) have undergone tremendous improvements. Today, GaInAs/AlInAs/InP based QCLs have turned into reliable, continuous-wave capable laser sources in the 3.8 µm – 10 µm wavelength range. However, wavelengths below 3.8 µm are challenging to generate due to the limited conduction band offset and increased carrier scattering into indirect valleys of the well and barrier material. An alternative way to generate shorter wavelengths is using materials with higher conduction band offsets such as Sb-based materials, or nonlinear frequency conversion techniques such as second-harmonic generation (SHG) or sum-frequency generation (SFG). The latter approach is particularly interesting as it can be implemented by using the well established InP manufacturing technology.

Here we report our recent results on short-wavelength GaInAs/AlInAs/InP based quantum cascade lasers by intracavity SHG. The device concept is based on an injectorless QCL active region used as a pump and a transversely integrated giant nonlinearity. Such nonlinearity is grown on top of the pump active region and can be structured into quasi-phase matching (QPM) gratings, which compensate the inherent wavevector mismatch between the pump and the SH signal. Using this design we were able to demonstrate room-temperature operation down to 2.7 µm.

In this work, we focus on the 3.3 µm-3.5 µm wavelength region, which is important for sensing trace gases, such as methane. We demonstrate that our $\lambda \approx 3.5\mu m$ device can deliver up to 500 µW at 80 K and around 30 µW at room-temperature at low current densities of operation. Further design improvements should lead to mW level output power at room-temperature.

Aside the experimental results we will also provide a brief outlook on the challenges and future design strategies to realize a high-performance laser source based on resonant second-harmonic generation in the entire wavelength range between 2 µm and 4 µm.

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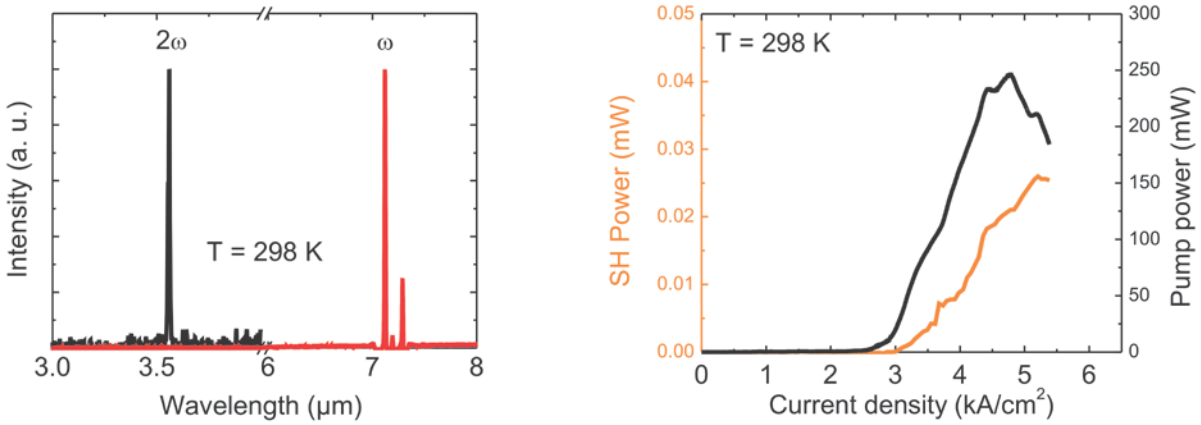
*Corresp. author: augustinas.vizbaras@wsi.tum.de, Phone: +49-089-289-12785, Fax: +49-089-289-12704

Figures



(a) (b)

Fig. 1. (a) Emission spectrum of a 3 mm long and 12 μm wide SHG-QCL with a QPM grating length of 800 μm. Device was driven in pulsed mode with 900 ns long pulses at a repetition rate of 8.3 kHz. (b) Output characteristics of the same device. During the measurement of the SH output, the fundamental signal was filtered out with two short-wave pass filters with a total attenuation of round 70 dB.