A compact THz source for imaging and spectroscopy

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Abstract: We report of a easy-to-use terahertz radiation source, which combines a QCL operating at 3.1 THz with a compact, low-input-power Stirling cooler. The QCL, which is based on a two-miniband design, has been developed for high output powers and low electrical pump power. The whole system weighs less than 15 kg including cooler, power supplies etc. The peak output power is 8 mW at 3.1 THz. The applicability of the system is demonstrated by imaging and molecular spectroscopy experiments.

Terahertz (THz) quantum cascade lasers (QCLs) are very promising radiation sources for many scientific or commercial applications. Examples are high resolution spectroscopy in atmospheric research or astronomy, and imaging in the fields of security, non-destructive testing, or biomedicine.

For these applications the QCLs were either operated in a continuous flow liquid helium cryostat or in a liquid helium free mechanical cryocooler [1]. This has several disadvantages. First of all cooling with liquid helium is expensive and requires some experience and safety measures. Secondly the cooling capacity of a liquid helium flow cryostat is rather limited which prohibits continuous wave operation of more powerful QCLs. While these cooling approaches might be acceptable for scientific experiments in the laboratory they are prohibitive for most commercial applications.

Here we will report on the development of a compact, easy-to-use, cw THz source, which is based on a QCL operating at 3.1 THz and a compact, low input power Stirling cooler. The nominal cooling capacity of the Stirling cooler is 7 W at 65 K with less than 240 W electrical input power. The QCL has been designed to fit to this thermal boundary condition. Special care has been taken to achieve a good thermal coupling between the QCL and the cold tip of the cooler. The performance of the system and results of initial imaging and spectroscopy experiments are presented.

The QCL consists of a GaAs/AlGaAs superlattice with 85 repetitive modules. Each module has nine GaAs quantum wells. The design of the active region is somewhat similar to the LO-phonon bound-to-continuum design reported in [2]. A detailed description of the QCL is given in [3]. The current for the QCL was supplied by a home-made battery driven current source.

The QCL is integrated into a commercial miniature cryocooler. This is a twin piston linear integrated Stirling cooler which is dynamically balanced in order to minimize mechanical vibrations. It weights 9.5 kg and is $32.1 \times 13.9 \times 27.4$ cm^3 (length × width × height) large. The power supply for the cooler unit weights 2.6 kg and is $10.2 \times 13.0 \times 33.6$ cm^3 large.

In Fig. 1 the current-voltage and the light-current curve are shown. The emission from the QCL is measured with a Golay cell detector. The laser threshold is at 300 mA, 6 V, and 36.5 K. This corresponds to an electrical input power of 1.8 W and a threshold current density of 210 kA/cm^2. The output power is maximal in the range from 600 mA to 650 mA (approximately (5.0 – 5.8) W electrical input power) and laser operation drops steeply above 660 mA.

For imaging applications transforming the output beam of the laser into a Gaussian shaped beam with a small waist is a prime necessity. In order to achieve this, a TPX lens was positioned such that the QCL is approximately in the focus of the lens. The beam profile at the position of the minimum waist was measured by scanning a Golay cell detector with a 0.4-mm diameter aperture in a plane orthogonal to the emission direction of the QCL. The result is shown in Fig.2. A Gaussian profile was fitted to the measured profile.

As a first demonstration of the capability of the compact QCL source a high resolution spectrum of $^{12}CH_3OH$ at around 3.1 THz was measured.

We will present our ongoing results of imaging and spectroscopic experiments with this THz-source.

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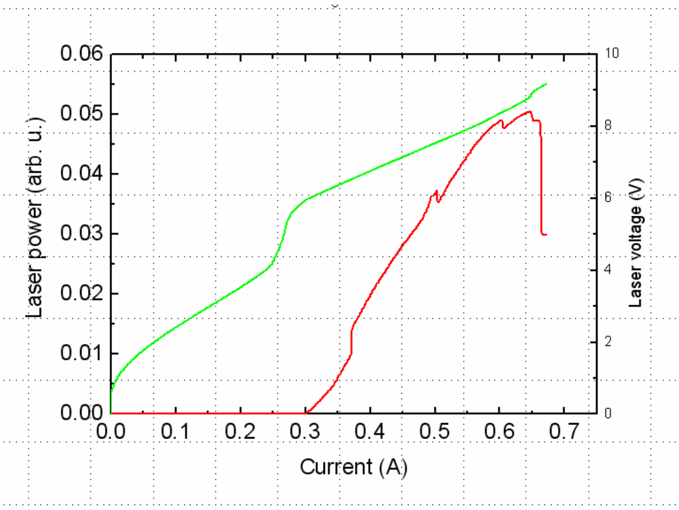

Fig. 1. Laser output power and voltage.

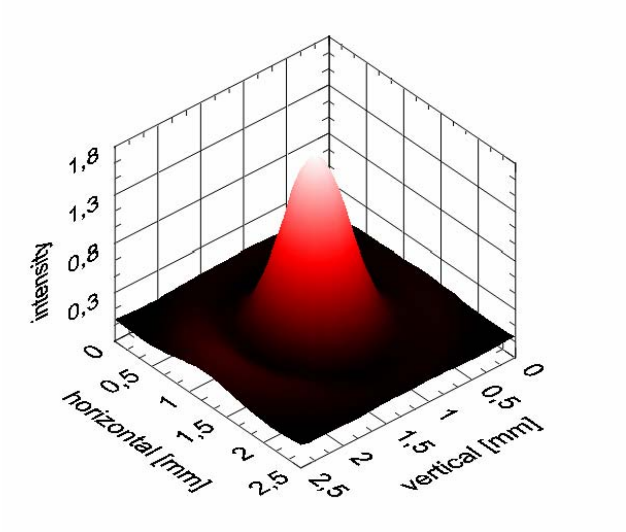

Fig. 2. Beam profile at the position of the waist.

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