Intracavity Generation of Continuous Wave Terahertz Radiation in the Milliwatt Regime

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Abstract: We present a terahertz source based on intracavity difference frequency generation within a dual color vertical external cavity surface emitting laser. The generation of continuous wave terahertz radiation in the milliwatt regime is demonstrated.
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1. Introduction

Terahertz (THz) sources emitting continuous wave (CW) THz radiation are highly desirable for a plethora of applications ranging from spectroscopy to quality inspection to THz astronomy. Yet, it is still challenging to generate decent power levels with tunable room-temperature operating devices particularly in the frequency window between 1 and 5 THz. One promising technique for accessing this frequency window is the parametric frequency conversion of infrared laser light into THz waves. The generation of several µW's of narrow band pulsed THz radiation has been shown recently using Q-switched pump lasers [1]. Yet, to generate pure CW THz radiation, CW pump lasers are required and thus, a low parametric conversion efficiency results due to the lower intensities. Up to now even sophisticated optical parametric oscillator schemes deliver only CW THz powers below 10 µW [2].

Here, we present a compact, tunable room temperature operating CW THz source capable of generating milliwatt power levels. The system is based on intracavity difference frequency generation (DFG) within a dual color vertical external cavity surface emitting laser (VECSEL). Utilizing the extremely high circulating intracavity fields results in a high generation efficiency of the nonlinear mixing process. The direct conversion within the laser cavity does not only provide the access to the highest infrared intensities but also allows for a relatively simple and robust setup

2. Experimental Setup

In aprevious work, it was demonstrated that a VECSEL can emit two wavelengths simultaneously using an intracavity filter to select the desired laser modes [3]. The high bandwidth of tens of nm of the quantum wells used as gain region is favorably for the generation of a wide range of THz frequencies.

The heart of our new THz source is a VECSEL chip with an emission wavelength around 1030 nm that is mounted on a water cooled heat sink and is pumped by an external, fiber coupled semiconductor laser bar. The maximum pump power used was 50 W. By inserting an etalon into the cavity, we force the laser to run simultaneously on two wavelengths with a predefined frequency spacing.

As nonlinear mixing element we chose a slanted periodically poled lithium niobate crystal [4] that exhibits a phase matching bandwidth of about 250 GHz. We used a Golay cell to detect the THz waves and a set of polyethylene lenses to span a THz beam path to the detector. For the first demonstration of the proposed concept we designed two individual nonlinear crystals with appropriate poling periods for generating 1 THz and 1.9 THz, respectively. Also, we used two etalons with different free spectral range (FSR).

3. Measurements

In the Fig. 1 the measured THz power for an emission at 1 THz and 1.9 THz is shown as a function of the intracavity power. As expected for a DFG process, the measured power scales quadratically with the infrared intensity. For the extremely high laser intensity inside the cavity the THz emission reaches the milliwatt regime. The total achievable intracavity power was limited by the available pump power and can further be increased by using either more powerful pump lasers or intracavity optics with lower losses.

To validate that the detected signal is caused by THz radiation and not by thermal emission, we used different filters in front of the detector. In addition, we set up a Michelson Interferometer to determine the emitted THz frequency.

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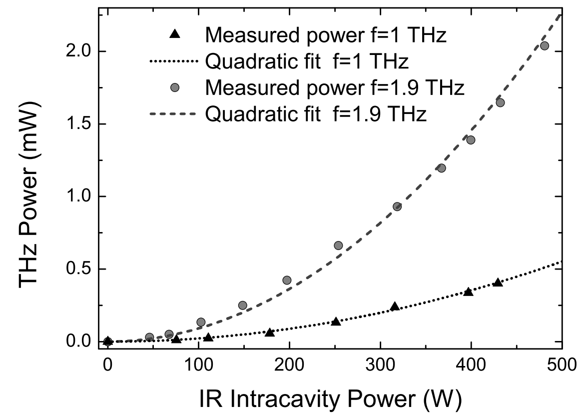

Fig.: 1 Measured THz power as a function of the intracavity power for the two frequencies of 1.0 and 1.9 THz.

To characterize the beam shape the Golay cell was translated in x and y direction at a distance of 30 cm from a cylindrical collimation lens. To increase the spatial resolution, we placed a 3 mm diameter aperture in front of the detector. The intensity profiles of the two axes shown in Fig. 2 exhibit an almost perfect Gaussian shape. Similar results are obtained from measurements with different spacing between the detector and the lens indicating a preferable beam profile of the emitted radiation.

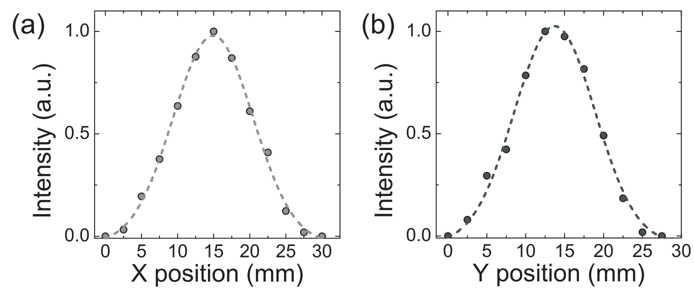

Fig. 2. Beam shape of the collimated THz radiation measured trough a 3 mm aperture before the Golay cell. Measured values for a scan along the x (a) and y (b) axis together with a Gaussian fit.

4. Conclusion

In conclusion we present a milliwatt room temperature THz source based on intracavtiy difference frequency generation within a dual-color VECSEL. The system can easily be adapted to emit any frequency between 0.3 and 5 THz by using a set of different crystals or an emitter designed for a higher phase matching bandwidth. We characterized the source in terms of power, wavelength and beam profile.

5. References

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