



**HAL**  
open science

## Towards transverse multiplexing of THz photo-driven emitters driven by a dual-transverse-mode dual-frequency laser

A. Abbes, B. Chomet, M. Myara, A. Garnache, Stéphane Blin, G. Beaudoin,  
I. Sagnes

► **To cite this version:**

A. Abbes, B. Chomet, M. Myara, A. Garnache, Stéphane Blin, et al.. Towards transverse multiplexing of THz photo-driven emitters driven by a dual-transverse-mode dual-frequency laser. French-German THz Conference, Apr 2019, Kaiserlautern, Germany. hal-04283810

**HAL Id: hal-04283810**

**<https://hal.umontpellier.fr/hal-04283810>**

Submitted on 14 Nov 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Towards transverse multiplexing of THz photo-driven emitters driven by a dual-transverse-mode dual-frequency laser

A. Abbes<sup>1</sup>, B. Chomet<sup>1</sup>, M. Myara<sup>1</sup>, A. Garnache<sup>1</sup>, G. Beaudoin<sup>2</sup>, I. Sagnes<sup>2</sup>, and S. Blin<sup>1\*</sup>

<sup>1</sup> IES, Univ Montpellier, UMR CNRS 5214, Montpellier, FR

<sup>2</sup> C2N, CNRS, Univ. Paris-Sud, Université Paris-Saclay, FR

\*Correspondence e-mail: [stephane.blin@umontpellier.fr](mailto:stephane.blin@umontpellier.fr)

**Abstract:** Recent performances of vertical-external-cavity surface-emitting lasers that operate at two frequencies for THz photo-generation, thanks to a dual-transverse-modes operation, are presented. THz emission is demonstrated from 50 GHz up to few THz with a linewidth of 150 kHz (during 3-ms), for a power of 1  $\mu$ W at 260 GHz, limited by the photo-mixer. Possibility of power upscaling is discussed by taking advantage of the optical transverse coherence to realize a network of photo-emitters, thus paving the way to compact and agile coherent THz sources offering an output power over few mW's at frequencies of 100's of GHz.

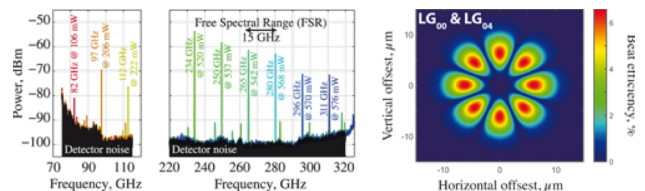
Coherent, tunable and compact continuous-wave Terahertz (THz) sources are required for many applications, such as bio-medical sensing and imaging, communications, or security. A large variety of solutions exists for THz emission, from optics to electronics, but existing solutions are often cumbersome or limited in terms of output power, tunability and/or modulation bandwidth. Photo-mixing techniques offer precious advantages such as wideband tunability and high-modulation bandwidth at room temperature.

In order to preserve longitudinal coherence, dual-frequency lasers are usually recommended, most of technical frequency noise being possibly correlated for the two emitted frequencies, thus offering a reduced frequency noise at the beat frequency (in the THz range). Among the possible laser designs, Vertical-external-Cavity Surface-Emitting Lasers (VeCSEL) are very promising solutions as they are relatively compact, wavelength flexible, widely tunable, powerful and highly coherent (spectrally, spatially and in terms of polarization). However, as homogeneous-gain leads to modal competition, dual-frequency operation requires to separate the modes to ensure sufficient stability, using either polarization, longitudinal or transverse mode splitting. Dual-frequency operation has been already demonstrated using a VeCSEL by stabilization of two polarization modes [1] or two longitudinal modes [2], but do not provide an inherently robust, compact/integrated and flexible solution for cw, coherent and tunable beat signals in the GHz–THz range as proposed thanks to the stabilization of two transverse modes in a single-axis cavity VeCSEL [3].

The dual-frequency VeCSEL based on two transverse modes is based on the stable simultaneous operation of two Laguerre–Gauss (LG) transverse modes in a single-axis short cavity, using an integrated sub-wavelength-thick metallic mask. We demonstrated a >80 mW output power at 1064 nm for an optical pump of 400 mW, diffraction-limited beam, narrow linewidth of <300 kHz,

linear polarization state (>45 dB), and low intensity noise class-A dynamics of <0.3% rms.

By exciting a single commercial uni-traveling carrier photodiode (UTC-PD) by a single lobe of the LG<sub>03</sub>/LG<sub>00</sub> transverse overlap, as reported in [4], coherent and tunable THz emission was demonstrated. Modes frequency difference is driven by thermal effects, band-filling effects and/or phase masks, allowing THz emission from 50 GHz to few THz. Coherent THz emission spectra are presented in Fig. 1 (left), with a linewidth of about 150 kHz for 3-ms acquisition time, and an output power limited by the photodiode (typically 1  $\mu$ W at 300 GHz).



**Fig. 1.** Left: THz spectra for various pump power showing coherent and tunable THz emission within the available heterodyne receiver ranges (75–110 GHz and 220–325 GHz), for the LG<sub>00</sub> & LG<sub>03</sub> transverse modes couple. Right: Beat efficiency map for LG<sub>00</sub> & LG<sub>04</sub> transverse modes couple proposed for transverse multiplexing of THz emitters.

In order to increase the output power, that is a key-point for THz applications, we will discuss about the possibility to exploit all the possible lobes of a given LG-couple transverse overlap. To do so, one straightforward solution is to increase the number of lobes. We were able to demonstrate a laser operation for the LG<sub>00</sub>/LG<sub>04</sub> mode couple, and to calculate the possible beat efficiency as shown in Fig. 1 (right). Therefore, by implementing a transverse network of 8 photo-mixers, the output power could be multiplied by the same number. Additionally, the commercial UTC PD we used was designed for a 1550-nm excitation, so a higher THz output power could be expected for a specifically-designed photo-mixer at 1064 nm, either a UTC PD or any other photo-mixer.

## REFERENCES

- [1] S. De et al., “Class-A dual-frequency VECSEL at telecom wavelength,” *Opt. Lett.*, **39**(19), pp. 5586–5589 (2014).
- [2] M. Wichmann et al., “Systematic investigation of single- and multi-mode operation in vertical-external-cavity surface-emitting lasers,” *SPIE LASE*, p. 660N-89 (2014).
- [3] R. Paquet et al., “Coherent continuous-wave dual-frequency high-Q external-cavity semiconductor laser for GHz–THz applications,” *Opt. Lett.*, **41**(16), pp. 3751–3754 (2016).
- [4] S. Blin et al., “Coherent and tunable THz emission driven by an integrated III-V semiconductor laser,” *J. of Select. Topics in Quant. Electron.*, **23**(4), pp. 1–11 (2017)