Powerful structured THz source based on original photoconductive antennas based on III-V technologies applied to agronomy and environment monitoring

S. Blin et al., IES, Univ Montpellier, CNRS, Montpellier, France

stephane.blin@umontpellier.fr

Introduction

THz frequency range

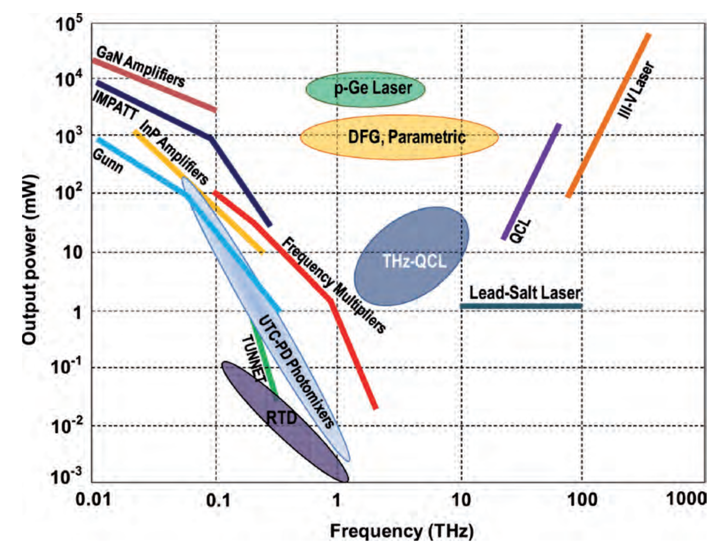
- Inbetween microwave and infrared ranges
- Frequencies 0.1 – 10 THz & Wavelengths 3 mm – 30 μm

Attractive properties at THz frequencies offering nascent applications

- Non-ionizing / UV or X rays
  ➲ Safe
- Transparency for dry and non-conductive material / optics
  ➲ (3D) imaging for industrial processes, security scanning
- Small-wavelength & high frequency / microwave
  ➲ High-resolution imaging & High-data rate communication
- Specific spectroscopic signatures
  ➲ Biology, medical & security applications

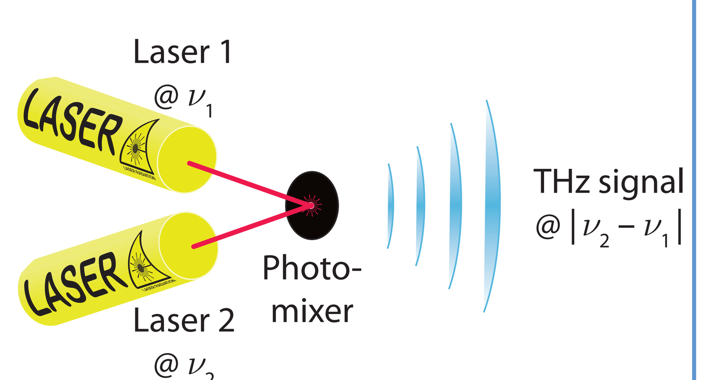
THz gap

- Lack of THz sources
  ➲ See Fig. from G. Chattopadhyay, IEEE Trans. THz Sci. Technol. **1**(1) 2011
- Need for THz sources
  Performant: tunable, coherent, powerful
  Practical: room-temperature operation, compactness & low-cost



CW THz emission by photomixing

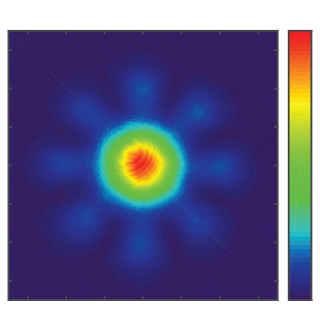
☑ Reliable & Flexible
based on photonics technology maturity
☑ Low frequency noise possible
using dual-frequency laser
☒ Low output power:
weak frequency conversion efficiency
and limited optical intensity breakdown



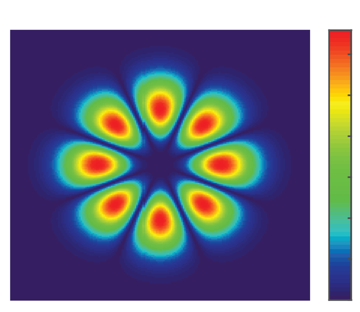
Improving the output THz power?

- Use of a dual-frequency laser based on two transverse modes
  ➲ multiple beat spots allow for multiple photomixers excitation: transverse multiplexing

Laguerre-Gauss LG_{00} & LG_{04} Intensity map

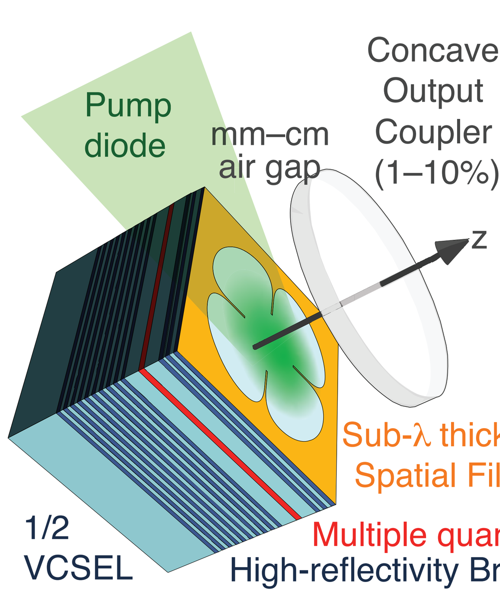


THz beat map 8 possible emitters

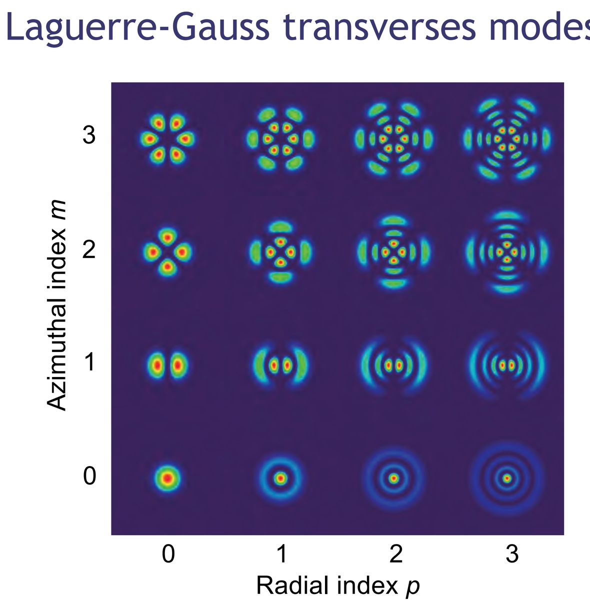


➲ transverse modes confinements requires study of multipolar antennas rather than antennas array ⇒ **we focus here on multipolar antenna design**

Dual-Frequency Vertical external-cavity Surface Emitting Laser (VeCSEL)

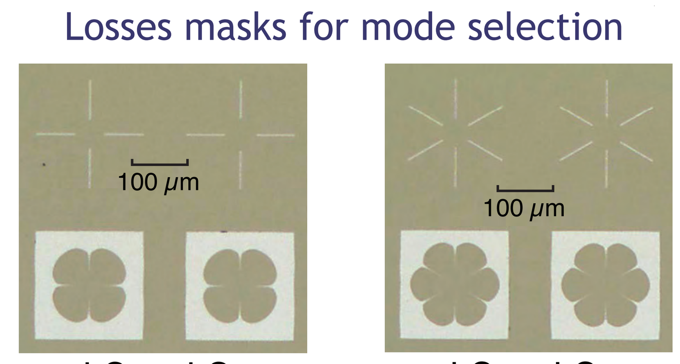


Laguerre-Gauss transverses modes



Selection of two transverse modes
within Laguerre-Gauss basis
with limited intensity overlap
➲ reduced competition
& possible dual-frequency operation
due to different modal temperatures

Losses masks for mode selection



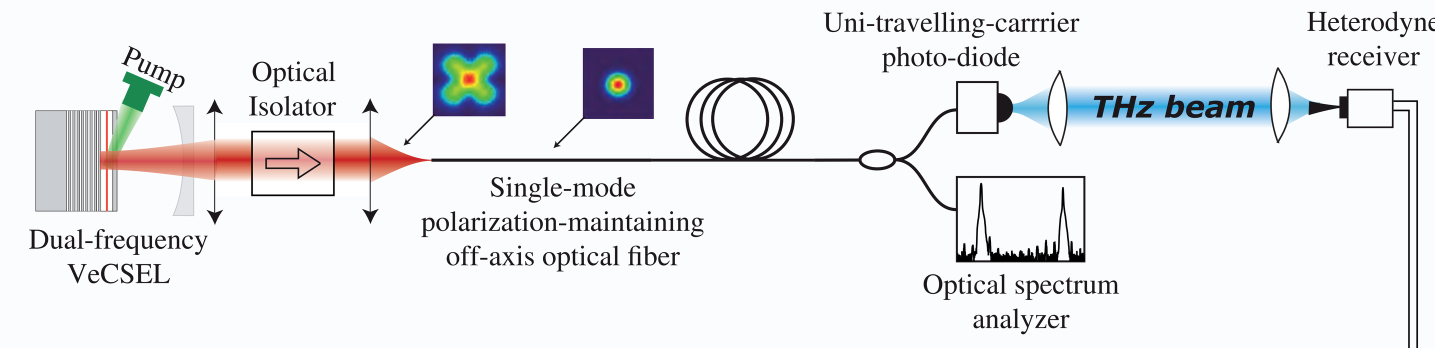
☑ **Highly-Coherent Emission:**
Transverse (M^2=1.06), **Polarization** (>45 dB), **Longitudinal** (55 dB)

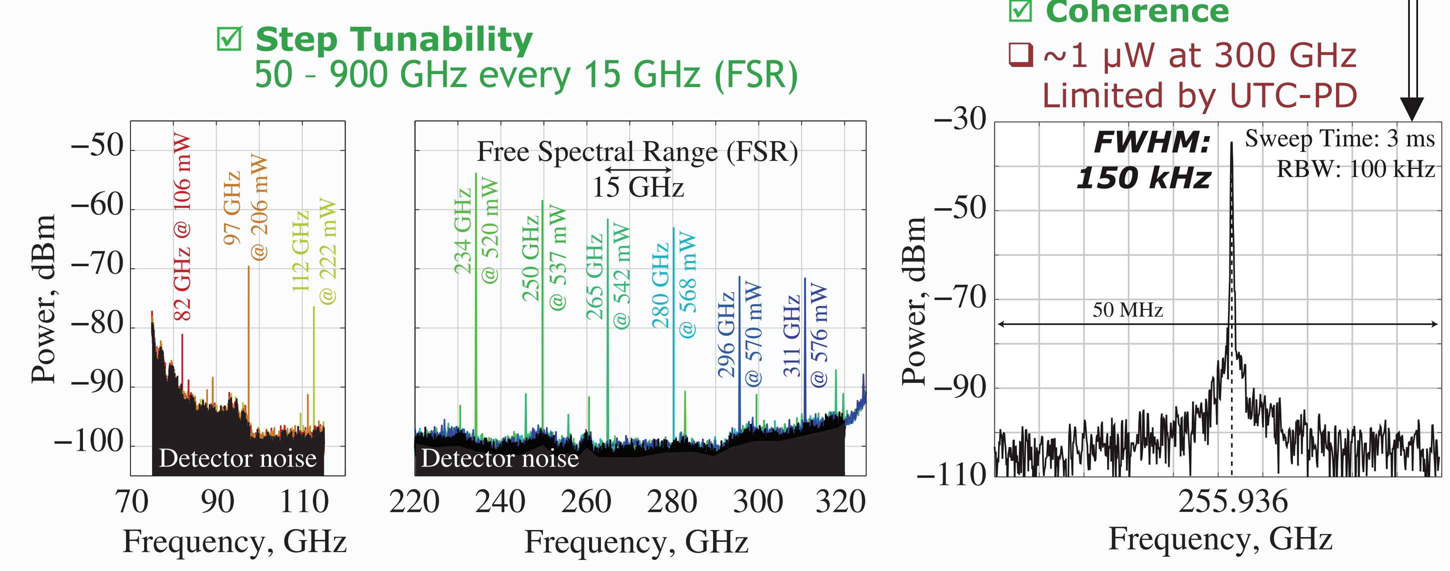
R. Paquet et al., Optics Lett. **41**(16), pp. 3751-3754 (2016)

III. THz Emission

State of the art: dipolar bow-tie antenna

- Integrated bow-tie antenna with uni-travelling carrier photodiode as photomixer
  single beat spot excitation within optical fiber



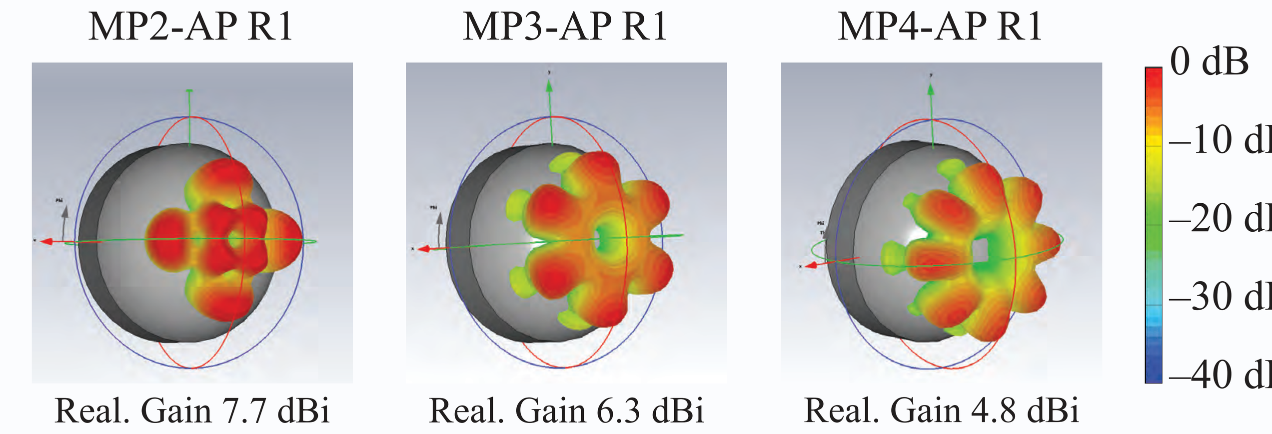


S. Blin et al., IEEE Selec. Topics in Quantum Electronics **23**(04), 3754 (2017)

THz multipolar antenna?

- Possible **multipolar (MP) designs**:
  Multi dipolar structure only,
  multi bowtie structure limited
  by coupling between neighbored arms

- **Dipolar arm lengthes** to ensure resonance at first, second or third order (R1, R2, R3)
- Each arm can be excited by a given **polarity** (+/–)
  Focus on two configurations:
  Super Dipole (SP): Given polarity for one half, opposite polarity for the other half
  Alternate polarity (AP): alternate polarity for neighbored arms
  Intrinsinc Laguerre-Gauss mode corresponds to alternate polarity configuration
  ➲ CST microwave Studio used for simulations **at 100 GHz** using multipin port excitation



Alternative adequate photoconductive materials?

- Attracted properties for photoconductive material:
  - High absorption at 1064 nm
  - Short lifetime (< 10 ps)
  - High electrical resistivity (> 10^6 Ω/cm)
  - High mobility (> 2000 cm^2/V/s)
- Possible candidate: Sb-based materials
  - Limited studies reported, see N.M. Burford et al., *Opt. Eng.* **56**(1) 010901 (2017)
  - Availble epitaxy in Montpellier (IES, CTM)

Example of application for agronomy environment

- THz attractive for in-vivo rota-vibrationnal spectoscopy
- As an example, possibility to separate Chlorophylle A & Chlorophylle B in leaves:

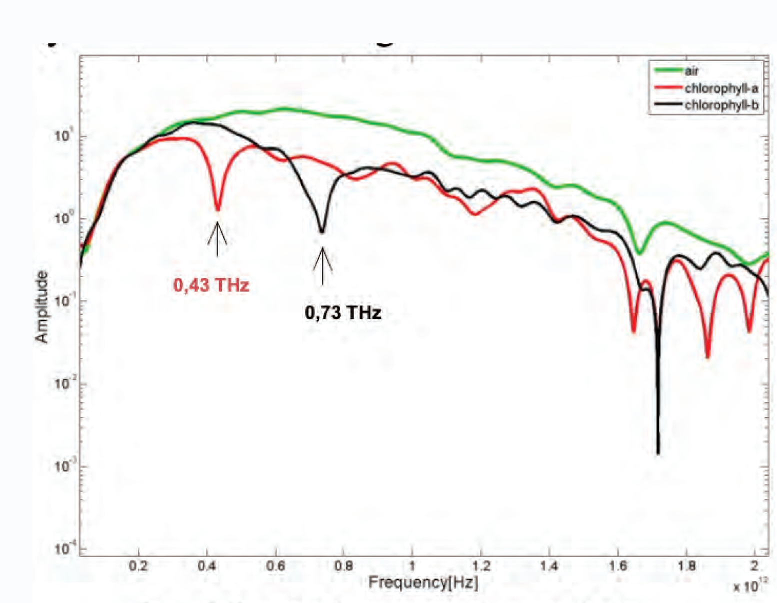


Fig. 1: Spectra from pure chlorophyll a/b

From C.Wagner et al., *IRMMW* (2011)

Using cumbersome and costly time-domaine spectroscopy

Could we prove lower-cost & compact CW spectroscopy based on photo-mixing sources ?

Funding: ANR Spatiotera, Région Occitanie Pyrénées Méditerranée (GEPETO Hermès-Obi-@), European Regional Development Fund, I-SITE MUSE AAP2021 (STAE) & Réseau Renater