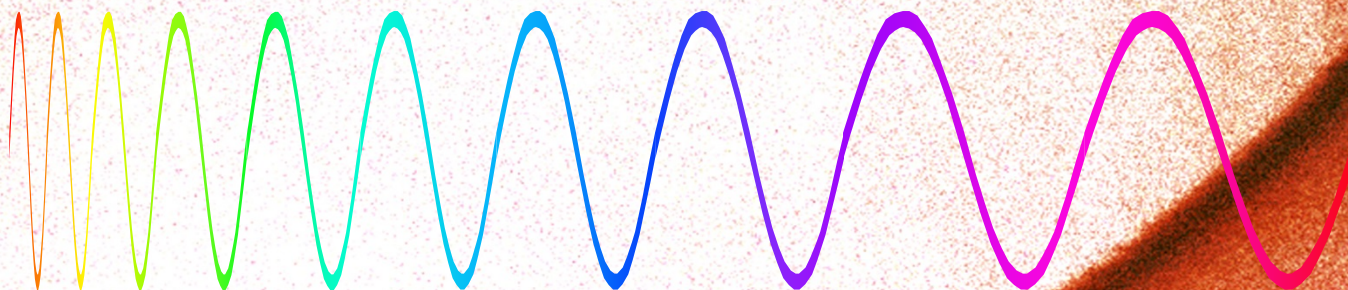


# Terahertz Photonics Group

from devices to applications



**Jean-François Lampin**

jean-francois.lampin@iemn.univ-lille1.fr





# Introduction

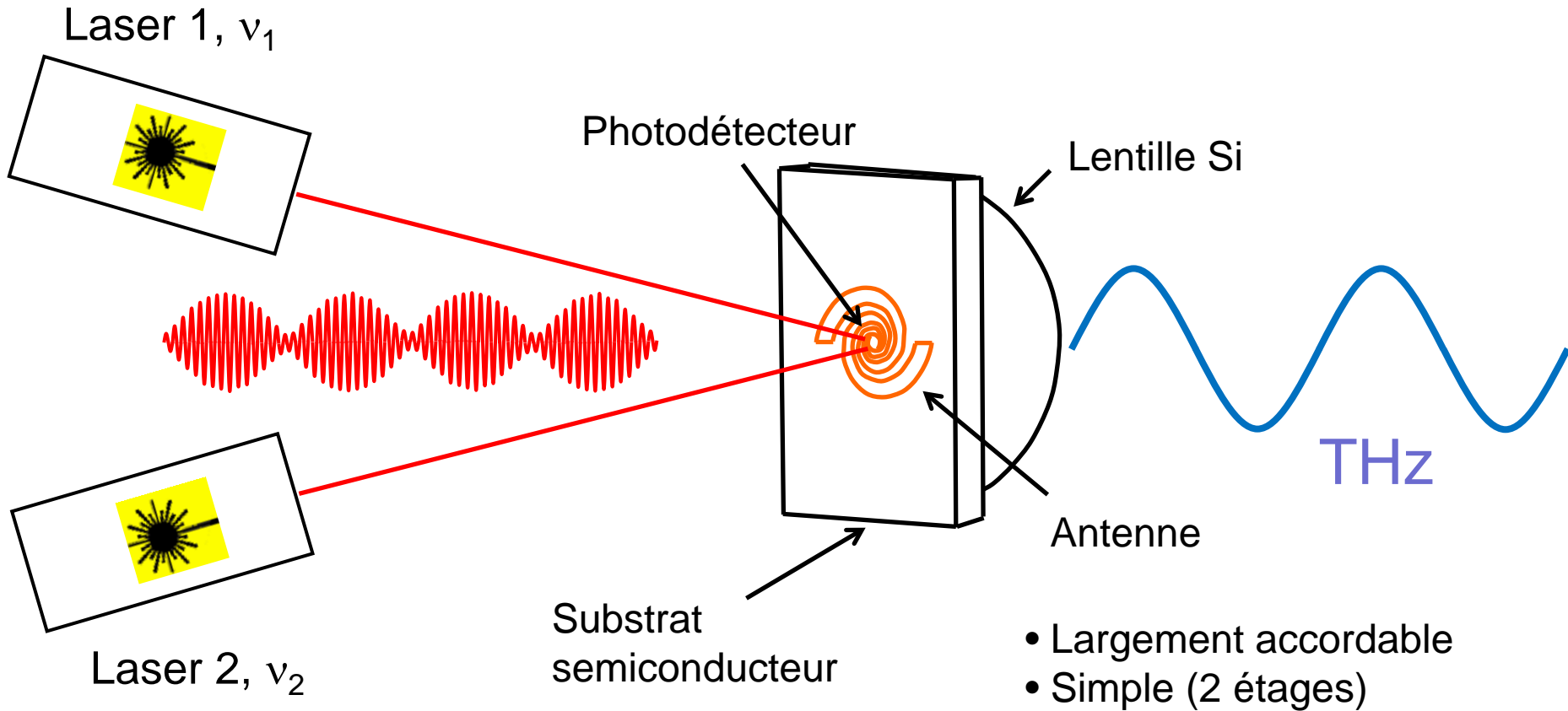
Institut d'Electronique de Microélectronique et de Nanotechnologies (**IEMN**)

## The **Terahertz Photonics Group**:

- THz photomixers
- THz detectors
- THz communications
- THz non-reciprocal devices
- THz/MIR s-SNOM
- GHz/THz sampling
- Molecular THz lasers
- THz biophotonics



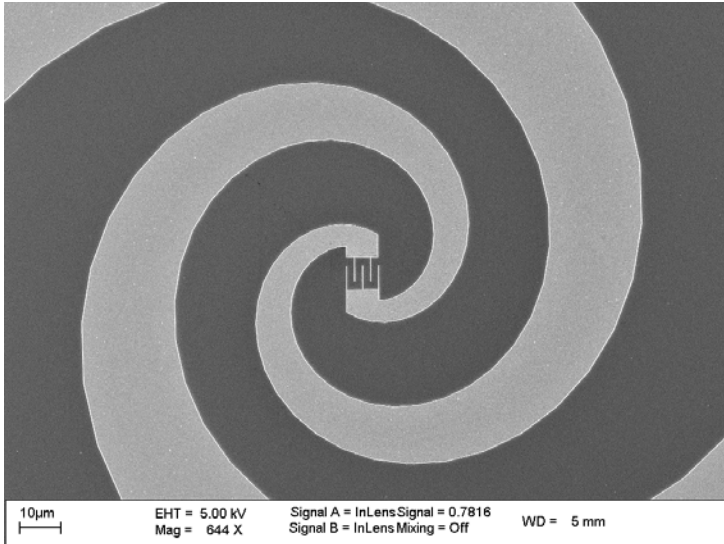
# THz CW: Photomixing



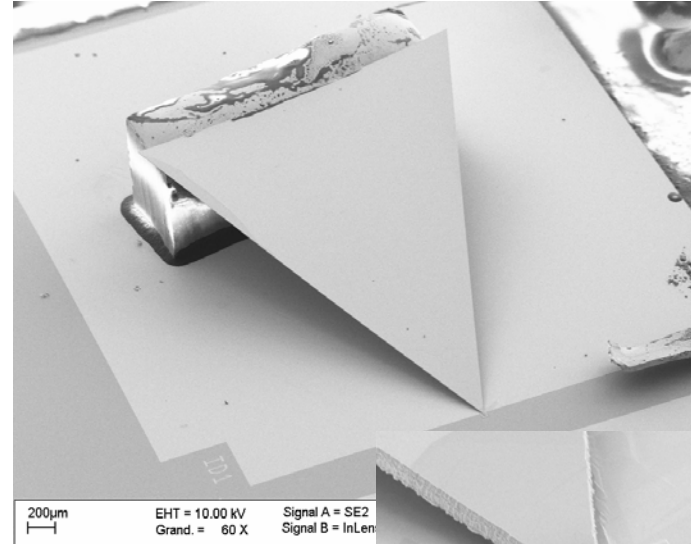
$$f_{\text{THz}} = \nu_2 - \nu_1$$

# THz photomixers

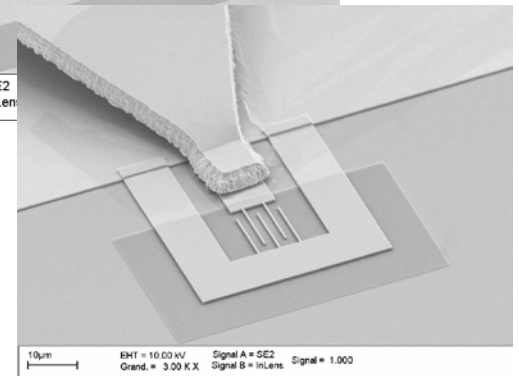
Photomélangeur = photodétecteur + antenne



Photoconducteur GaAs-BT + antenne spirale



Photoconducteur GaAs-BT + antenne corne

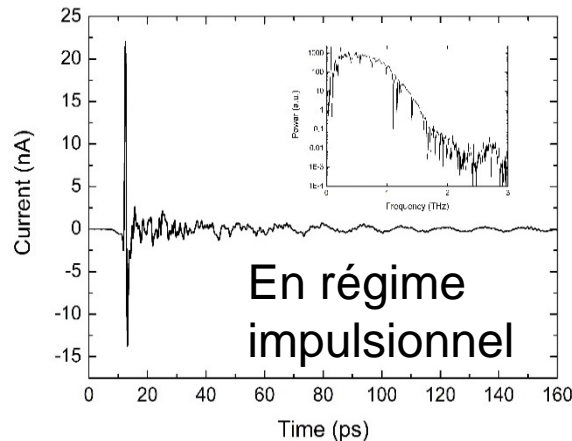
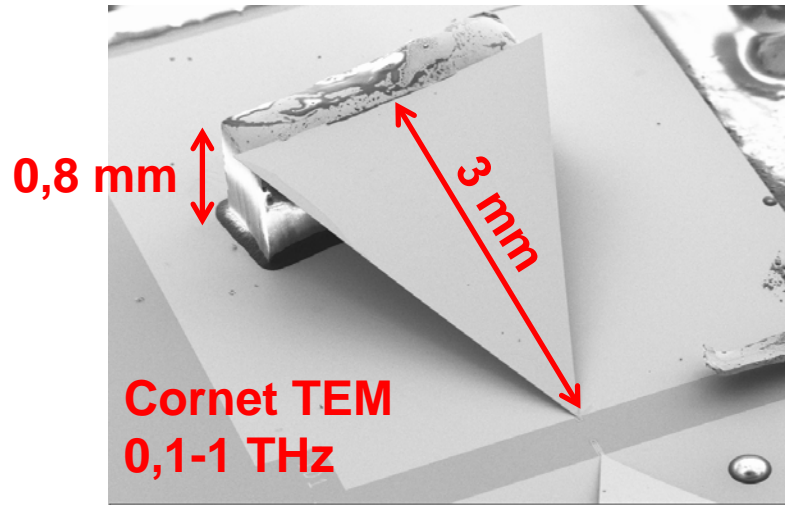


Ce couple doit être le plus performant possible !

**Verrous** : densité de courant et adaptation d'impédance

# Antennas

Problème des antennes THz monolithiques: rayonnement dans le substrat



- **Large bande et peu dispersive**  
(utilisable en impulsionnel ou en CW)
- Pas de THz dans le substrat
- Intégrables avec tous composants THz
- Monolithique, pas de gravure profonde

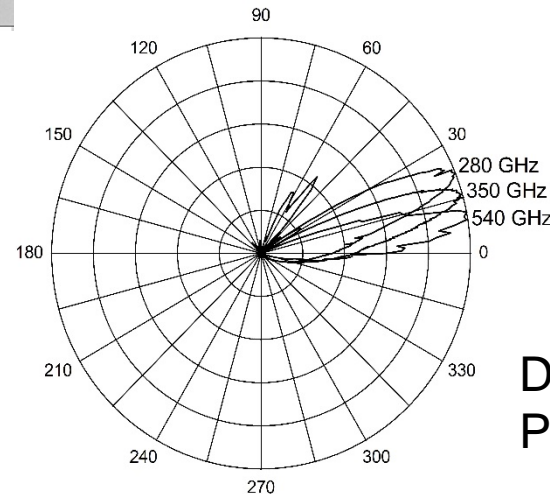
J.-F. Lampin, E. Peytavit  
Brevet FR2908931 (2006)

Peytavit *et al.*, EL **43**, 73,  
(2007)

Peytavit *et al.*, APL **93**,  
111108 (2008)

Prissette *et al.*, IEEE  
MWCL **21**, 49 (2011)

Beck *et al.*, C.R.  
Physique **11**, 472 (2010)

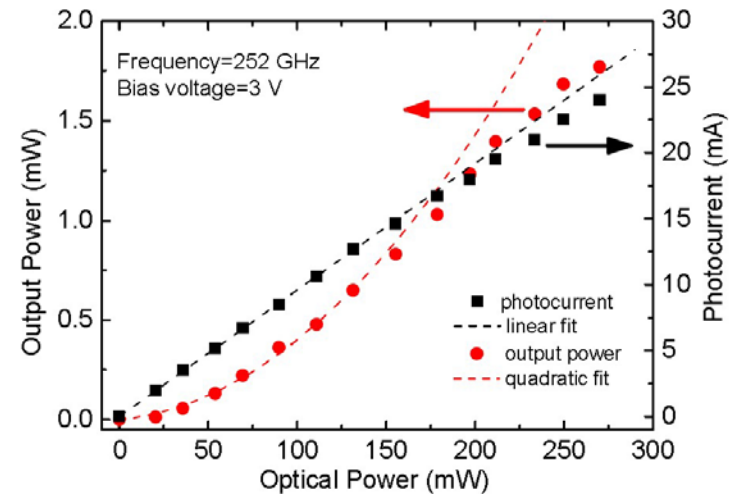
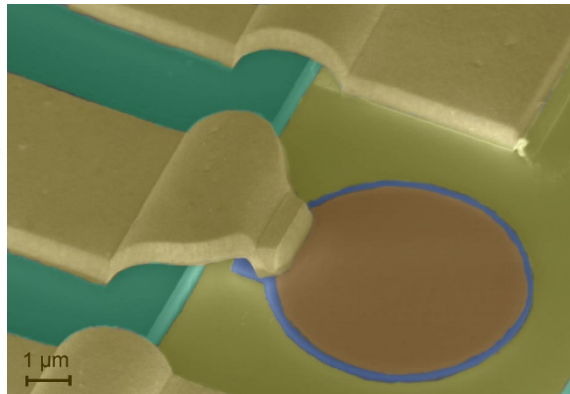
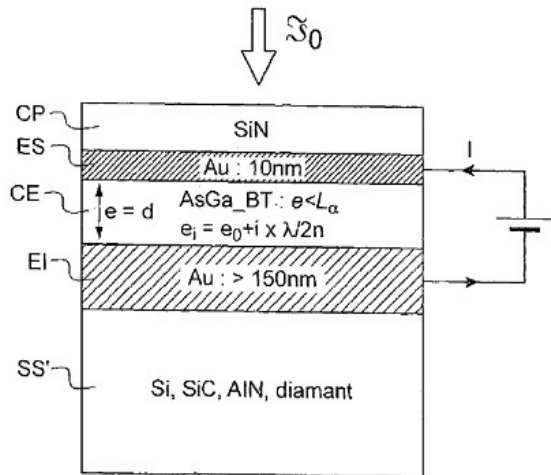


Diagrammes  
Plan E (CW)



# Resonant vertical photomixer

Puissance **record** dans la bande 220-325 GHz (photomélange) :  
**1.8 mW @ 0.25 THz**, amélioration **100×** pour LTG-GaAs !



- Cavité Fabry-Pérot miroirs métalliques
- Photoconducteur LTG-GaAs sur Si

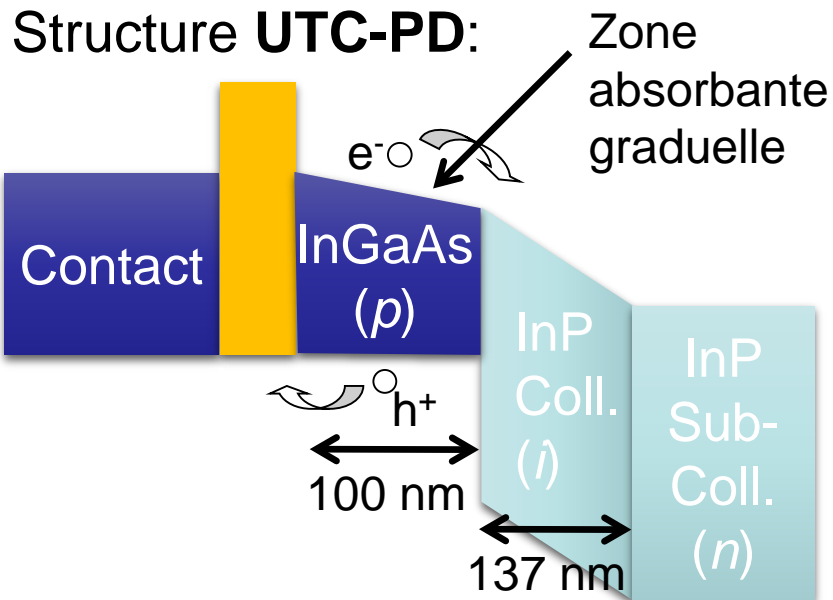
**Etat de l'art:**

0.6 mW @300 GHz (UTC-PD, NTT)

E. Peytavit, J.-F. Lampin  
 Brevet FR2949905 (2009)

Peytavit *et al.*, Appl. Phys. Express **4**, 104101 (2011)  
 Peytavit *et al.*, Appl. Phys. Lett. **99**, 223508 (2011)  
 Peytavit *et al.*, IEEE Electron. Device Lett. **34**, 1277 (2013)

# 1.55 $\mu\text{m}$ THz UTC-photodiodes

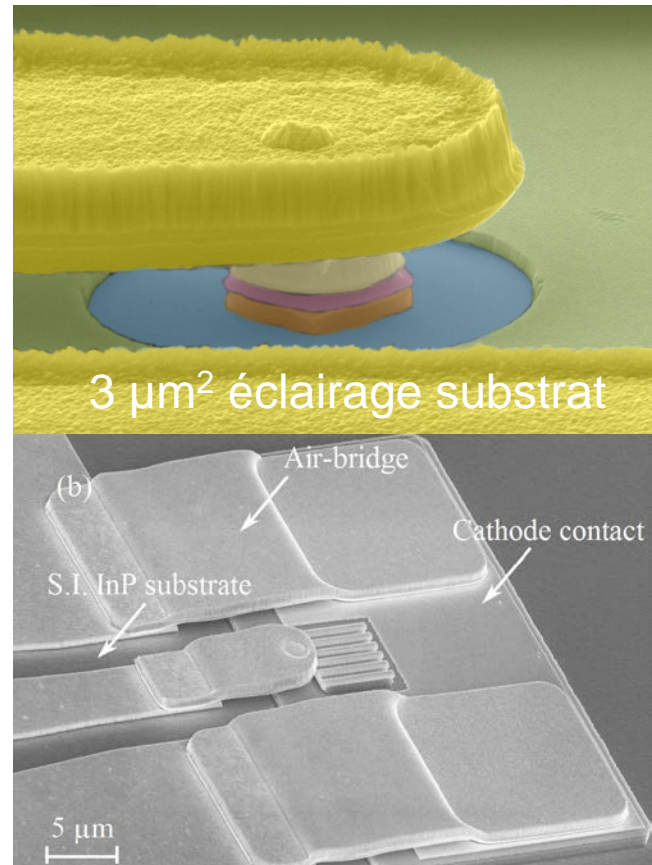


↗ fréquence de coupure :

- Zone absorbante graduelle
- Petite section
- Collecteur court

Beck *et al.*, *Electron. Lett.* **44**, 1320 (2008)

**1  $\mu\text{W}$  @ 1 THz Record de rendement**



**UTC-PD à grille métallique**  
**400  $\mu\text{W}$  @ 300 GHz**

# Sub-THz communications

- Emetteur 1 Gb/s @ 200 GHz télé-alimenté
- Test dans un système complet

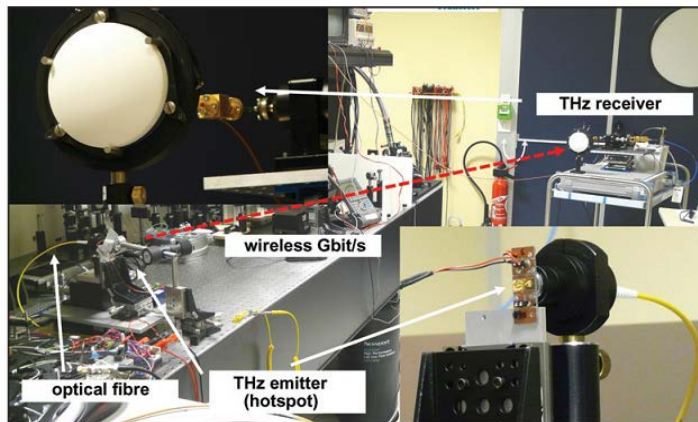
**HDTV @ 0.6 THz !**

Ducournau *et al.*, *Electron. Lett.* **46**, 1349 (2010)

A wireless gigabit hotspot that is powered by existing fibre networks in buildings has been demonstrated by researchers in France

G. Ducournau,  
P. Szriftgiser,  
D. Bacquet, A. Beck,  
T. Akalin, E. Peytavit,  
M. Zaknoun and  
J.F. Lampin

## putting THz on the spot<sup>\*</sup>



**Highlight in Electronics Letters (2010)**



J.-F. Lampin

### TERAHERTZ TV

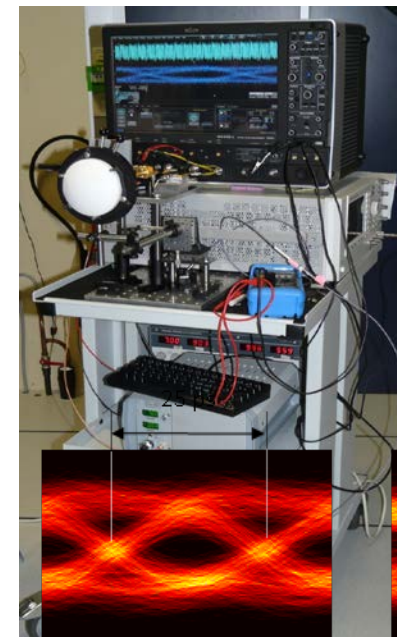
**PAGE 413** Researchers in France have demonstrated a novel method using THz transmission of a high-definition television signal, achieving high data rate wireless links for end-users. The new method has the benefits of having very low power requirements and low exposure to electromagnetic emissions, resulting in a high degree of safety with the new architecture.



Novel HDTV transmission method reduces end-user power requirements and exposure to electromagnetic emissions

**330** *ELECTRONICS LETTERS* 27th February 2014 Vol.50 No.5

Ducournau *et al.*, *EL* **50**, 413 (2014)



**46 Gbps @ 0.4 THz**

Ducournau *et al.*, *IEEE TTST* (2014)

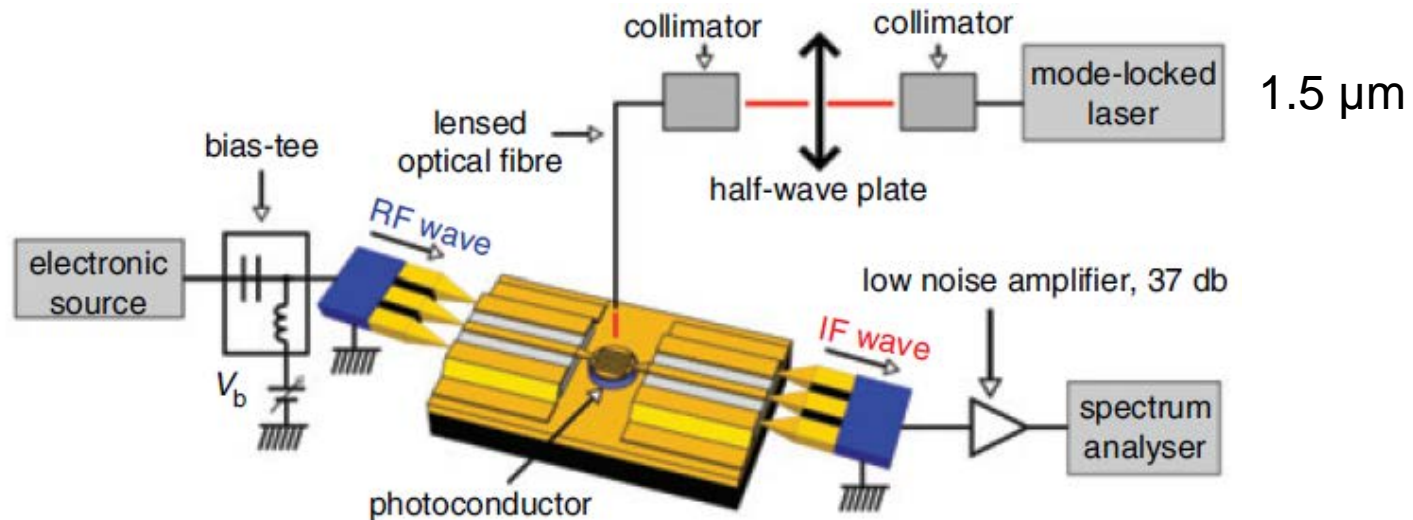
21.7 ps

40 Gbps

46 Gbps



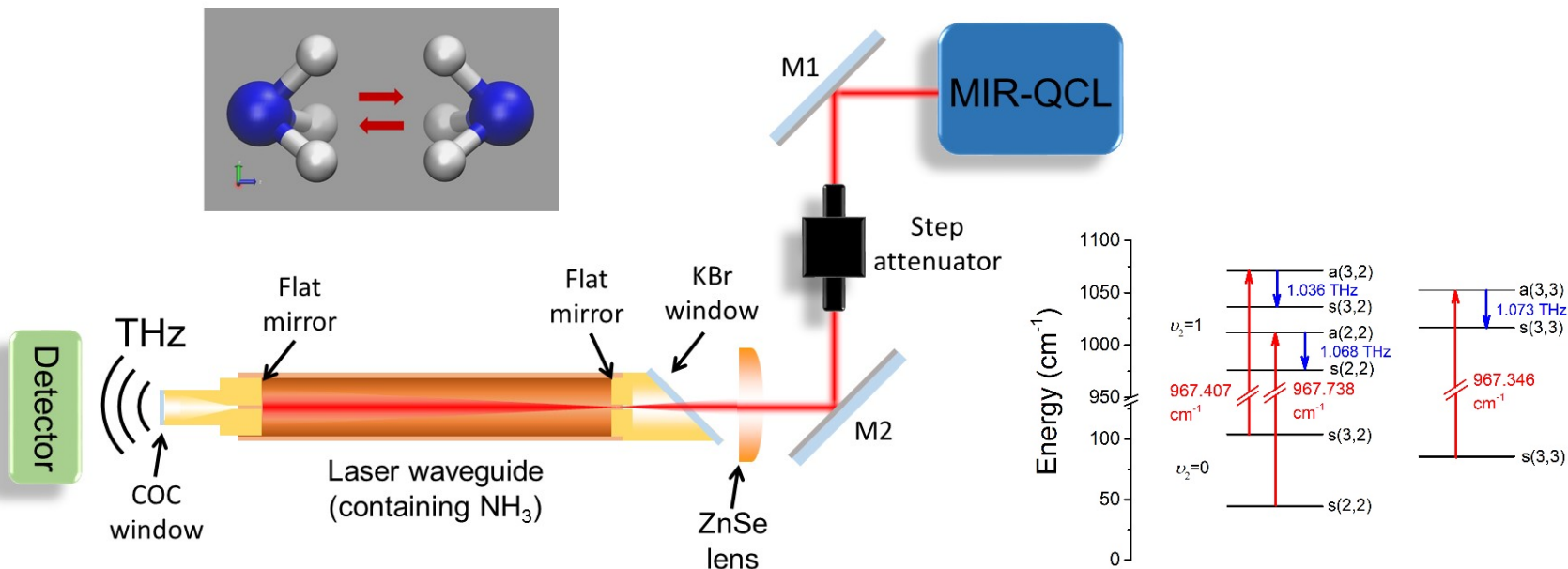
# *Sub-sampling @ 300 GHz with 1.5 $\mu\text{m}$ comb ML laser*



M. Billet *et al.*, EL **53**, p.1596 2017

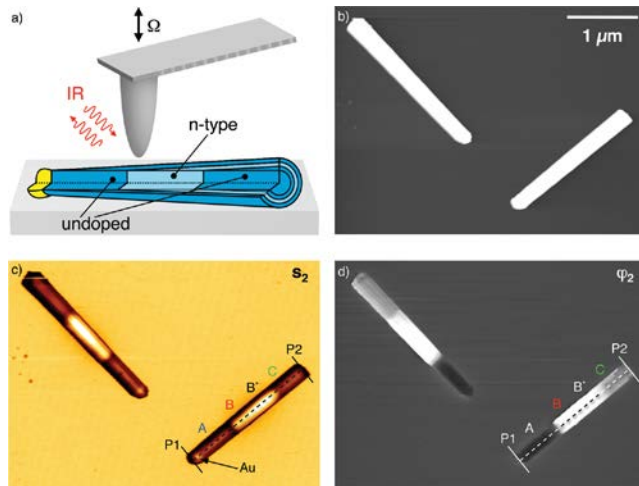
# New THz laser

## MIR-pumped molecular THz laser

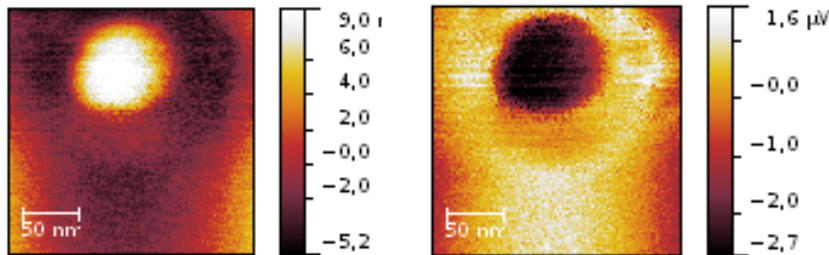
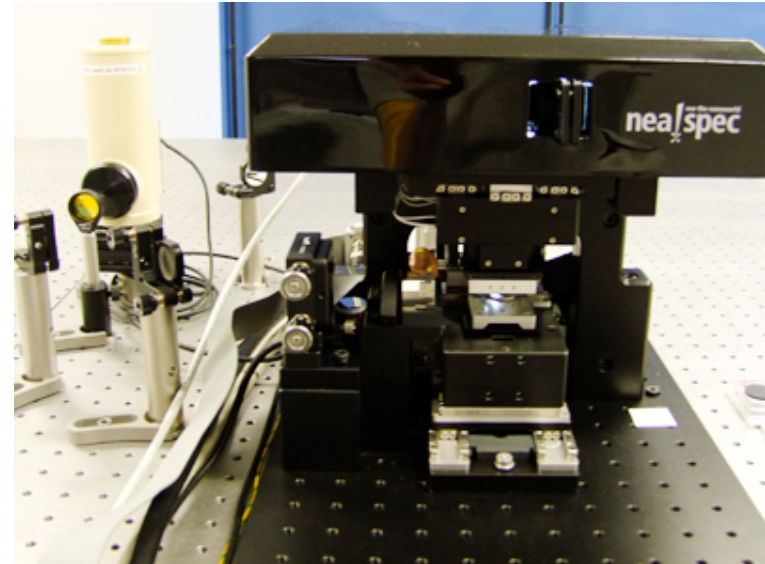


***1<sup>st</sup> molecular pumped by a QCL***  
***1 mW @ 1THz, high efficiency, room temperature***

# THz near-field microscopy



Sieger *et al.*, Nanoletters (2010)



Nanopart. Au 15 nm  
sous 6 nm de SiO<sub>2</sub>  
( $\lambda = 10 \mu\text{m}$ )

Topographie

S-SNOM

**EQUIPEX EXCELSIOR**



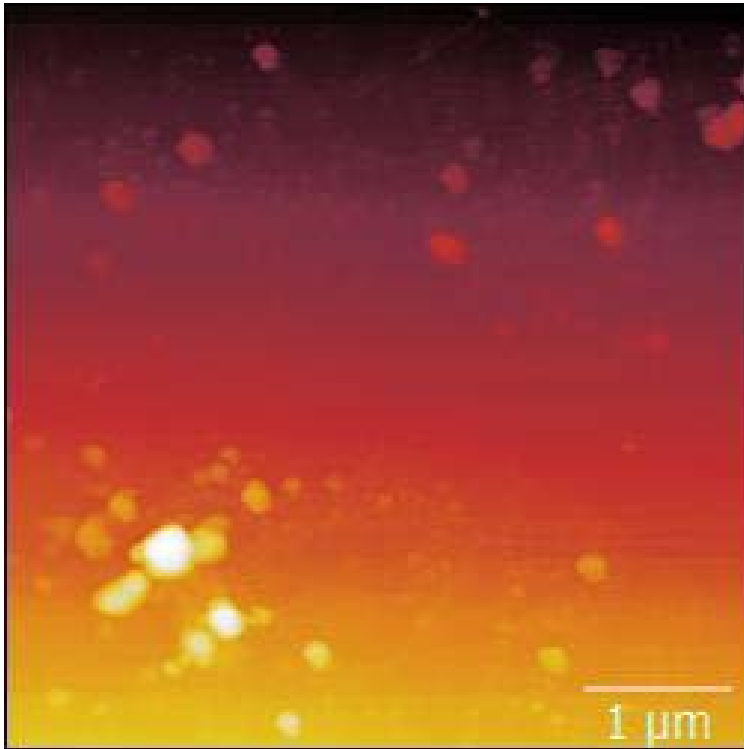
Institut d'Electronique, de Microelectronique et de Nanotechnologie  
UMR CNRS 8520

J.-F. Lampin

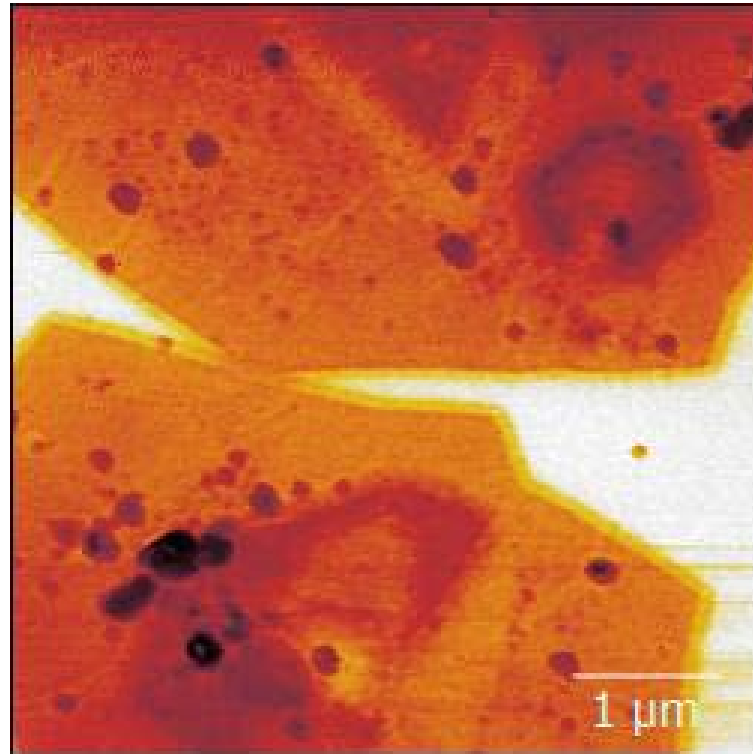


# s-SNOM: islands of graphene

Collab: D. Vignaud



Topography

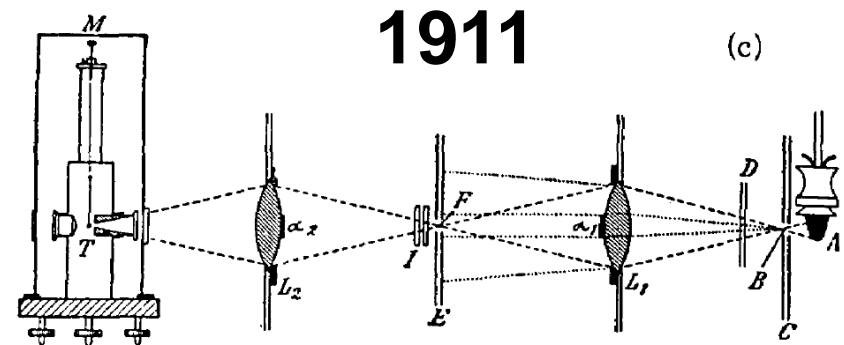


O2 Signal (966 cm<sup>-1</sup>)

# Rubens experiment



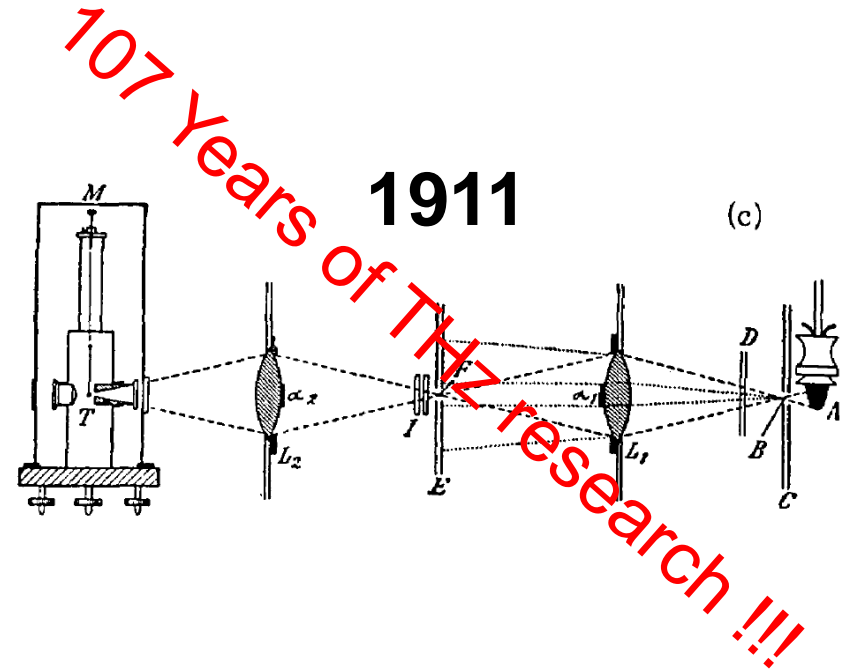
Heinrich Rubens at work in the laboratory  
(Physical Institute, Univ. Berlin)



# Rubens experiment



Heinrich Rubens at work in the laboratory  
(Physical Institute, Univ. Berlin)



107 Years of THz research !!!