# About Omics Group

CS Group International through its Open Ac
tive is committed to make genuine and rel
ributions to the scientific community. OM
p hosts over 400 leading-edge peer reviewed O
ess Journals and organize over 300 Internat
erences annually all over the world. OM
ishing Group journals have over 3 million readers
ame and success of the same can be attribute
strong editorial board which contains over 3
ent personalities that ensure a rapid, quality
k review process.

# About Omics Group conferences

MICS Group signed an agreement with more than ernational Societies to make healthcare inform pen Access. OMICS Group Conferences make rfect platform for global networking as it b gether renowned speakers and scientists across obe to a most exciting and memorable scientific e ed with much enlightening interactive sessions, w ss exhibitions and poster presentations

mics group has organised 500 conferences, works d national symposium across the major cities inclu nFrancisco,Omaha,Orlado,Rayleigh,SantaClara,C ,Philadelphia,Unitedkingdom,Baltimore,SanAntani i,Hyderabad,Bangaluru and Mumbai.

FIZINIŲ IR TECHNOLOGIJOS MOKSLŲ CENTRAS

# Compact solutions in room temperature operating terahertz imaging systems

Gintaras Valušis

Optoelectronics Department,
Center for Physical Sciences and Technology,
Vilnius, Lithuania
Department of Semiconductor Physics, Physics Fac
VIlnius University, Lithuania

gintaras.valusis@ftm

# hertz imaging –> real time cameras development



Video Camera for 0.7–1.1 Terahertz Imaging Applications in 65-nm CMOS | U. Pfeiffer ‘s team, IEEE Solid St. Circuits, 2012



High Sensitivity Real-Time Unco THz Imager | NEC production

**hertz imaging –> spectroscopic imaging – < 3 T**

**sibility to identify contents of various packages**

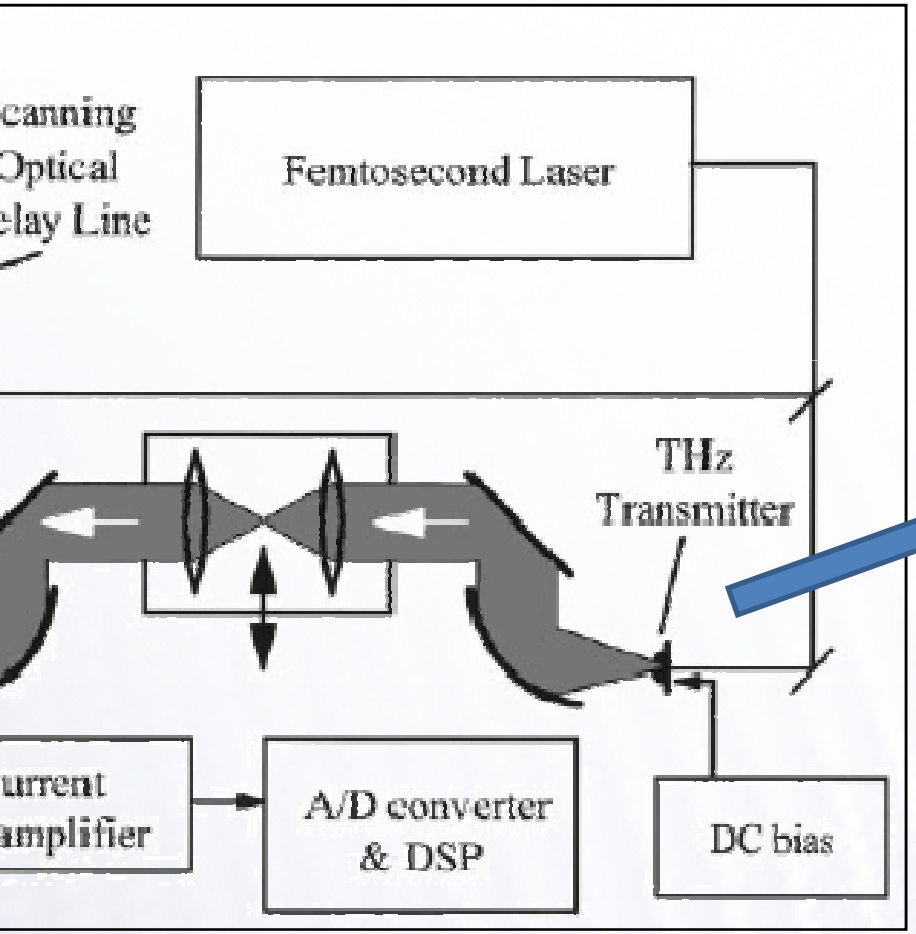
**ures of terahertz frequency range – physics behind a**

**ible solutions**

**rt story on compact THz sourses**

**e short stories on compact THz detection**

**pact optics issue and illustration of medical applicat**



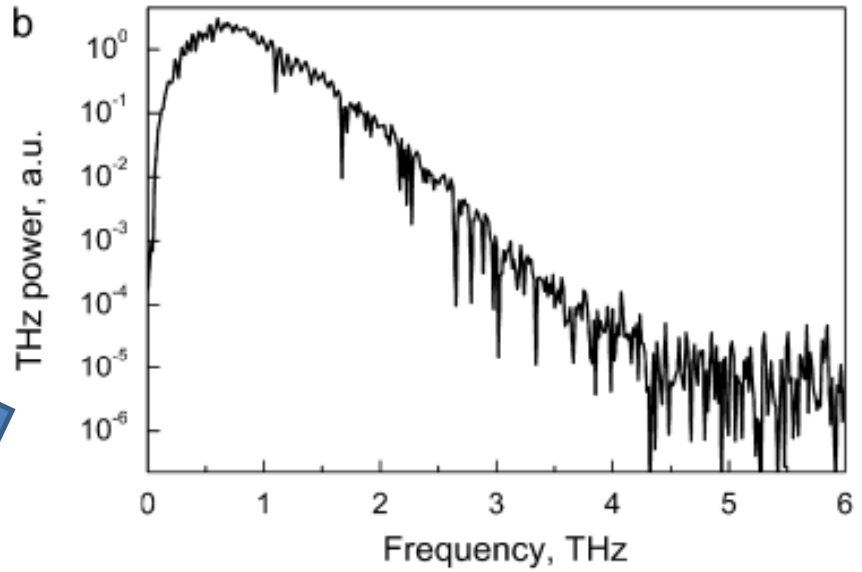



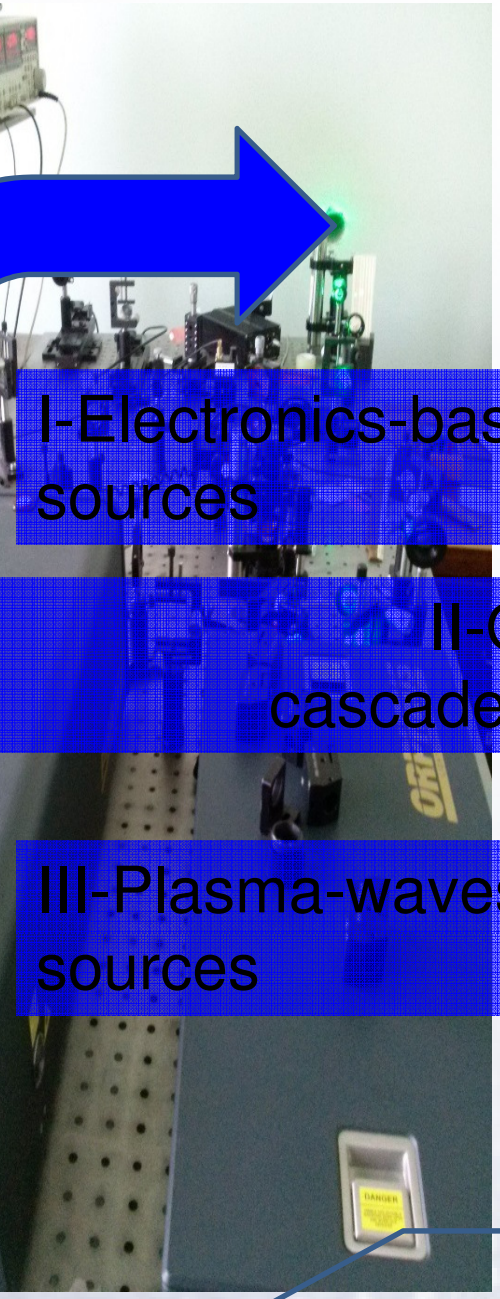

**Fig. 1.** THz pulse and its Fourier spectrum radiated from the surface of p-type InAs crystal and measured using GaBiAs detector.

A. Bičiūnas, V. Pačebutas, A. Krotkus, Physica B,

- **frequency range – up to 3**
- **THz power – in the range o**
- **Room temperature**

- **Integration time - 5 ms;**
- **signal-to-noise ratio > 100:1**
- **Pixel number -- semiconductor integrate chip) - 50,000**

m is massive and
expensive –
m is overcome
problems



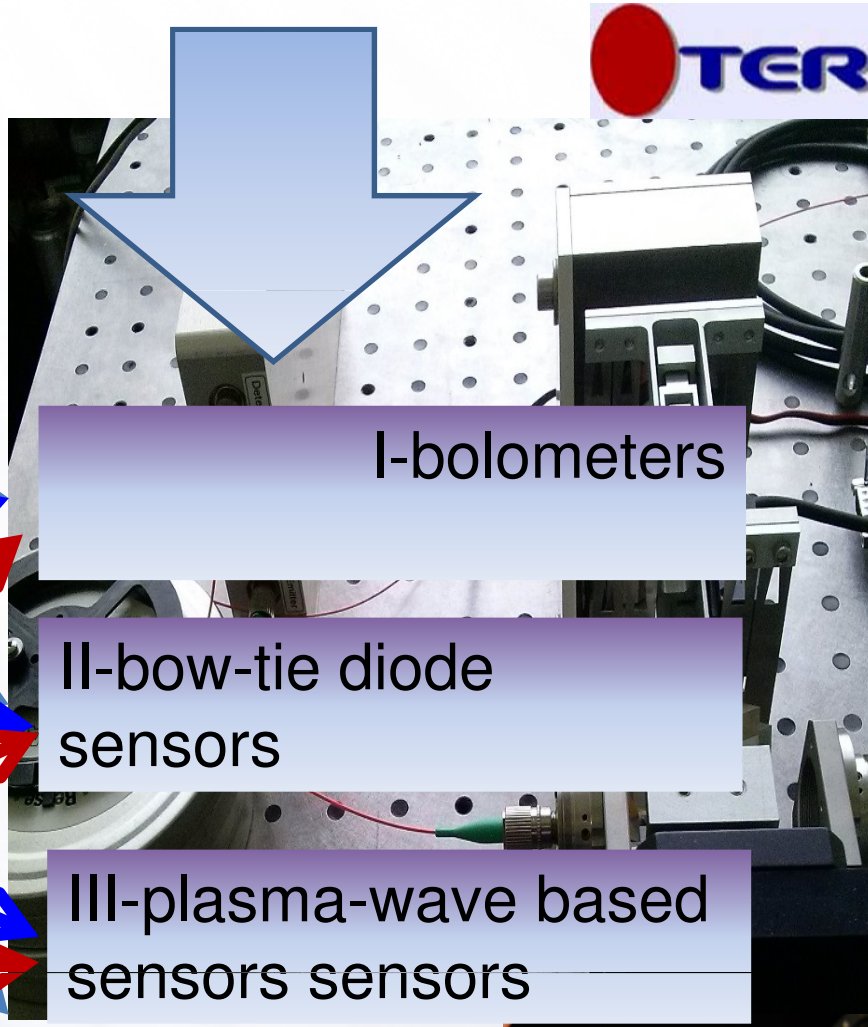
Standard TDS system with Ti:sapphire laser and LT GaAs components.

I-Electronics-based sources

II-Quantum cascade sources

III-Plasma-waves-based sources

**Compact optics issue**



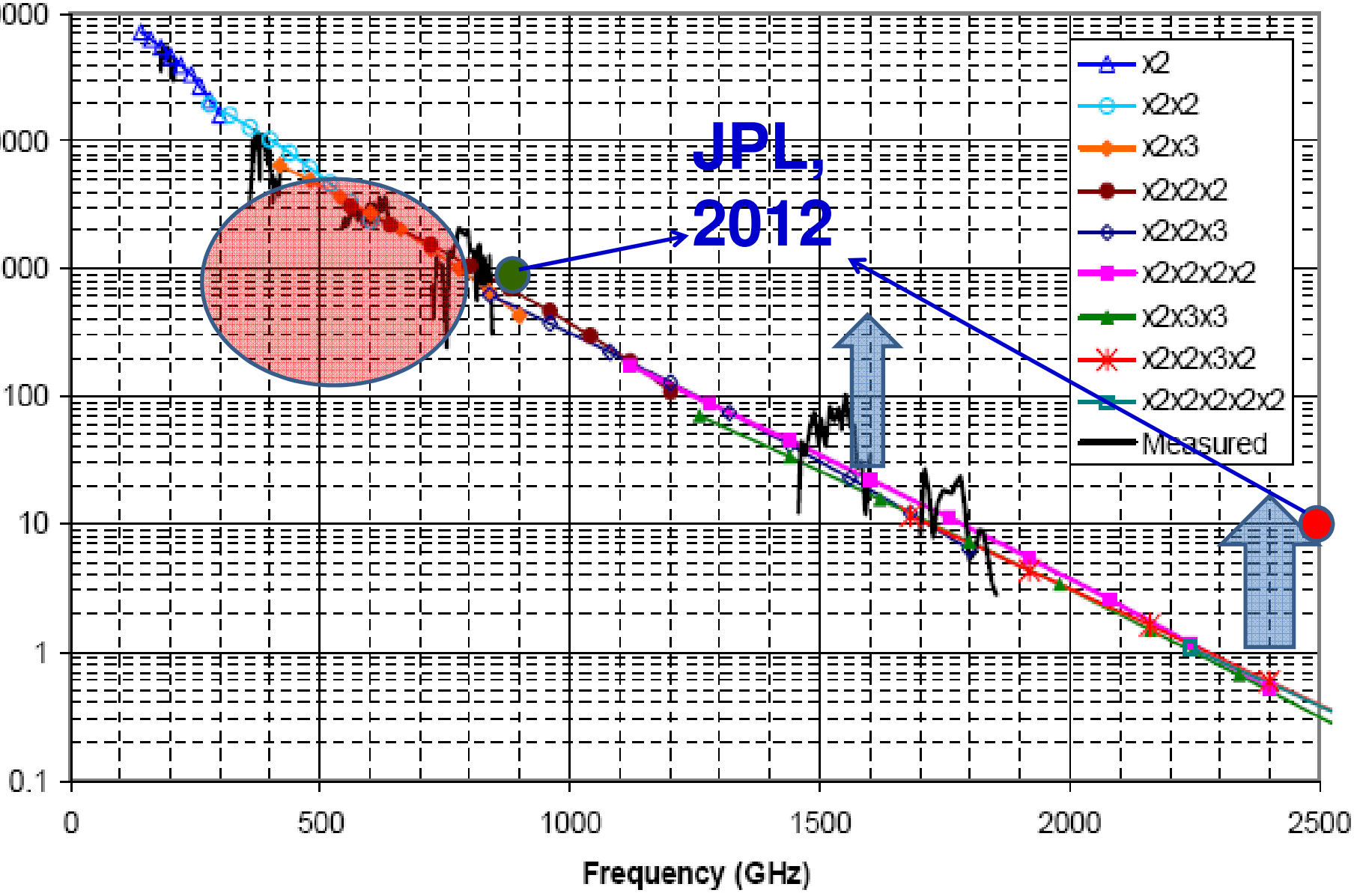
I-bolometers

II-bow-tie diode sensors

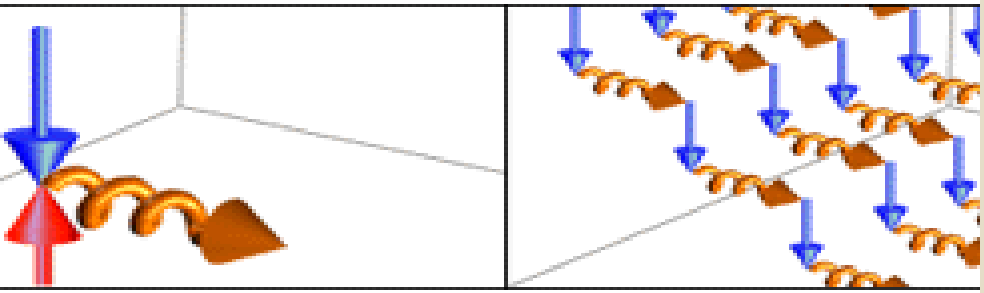
III-plasma-wave based sensors sensors

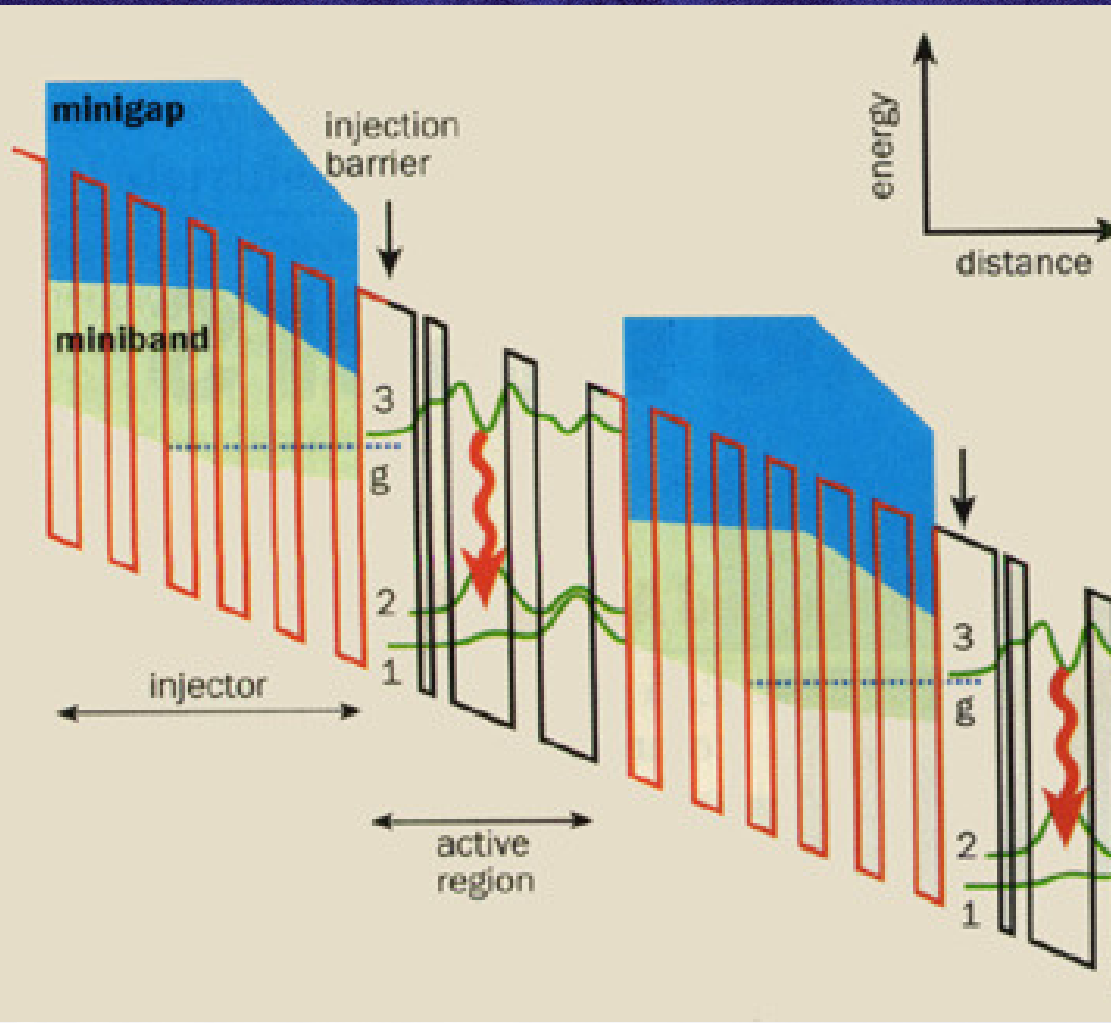


frequency, RT, emission/detection scale




*al, Capability of THz sources based on Schottky diode frequency*
*er chains*, 2004




## antum cascade lasers (QCLs):

range –
**1.2 – 4.9 THz;**
**4.2-186 K**
ower - 63 mW at 3.9 THz,

**5 mW, at 180 K,**
**<< 1 mW at 186 K,**

mar et al, APL **94**, 131105 (2009).

Highest QCL operation temperature (w.r.)

## 200 K at 3.2 THz

**Terahertz quantum cascade lasers operating up to ~ 200 K with optimized oscillator strength and improved injection tunneling**

Opti
Exp
201

APPLIED PHYSICS LETTERS **99**, 131106 (2011)

**n temperature single-mode terahertz sources based on intracavity rence-frequency generation in quantum cascade lasers**

APPLIED PHYSICS LETTERS **103**, 011101 (2013)

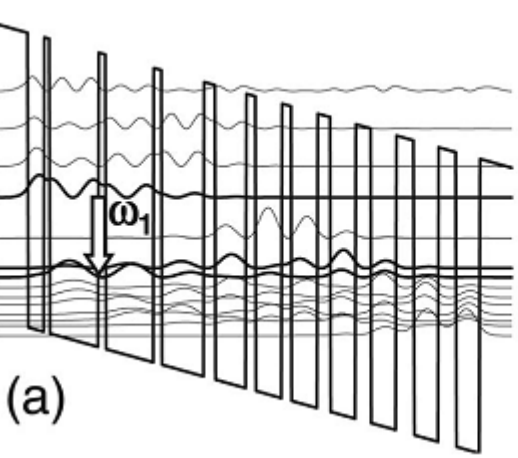
# Room temperature terahertz quantum cascade laser sources with 21 output power through epilayer-down mounting

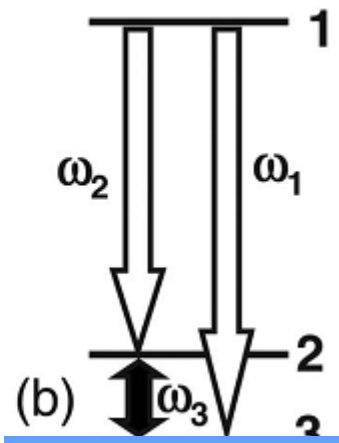
Q. Y. Lu, N. Bandyopadhyay, S. Slivken, Y. Bai, and M. Razeghi[a)]
*Center for Quantum Devices, Department of Electrical Engineering and Computer Science, Northwestern University, Evanston, Illinois 60208, USA*

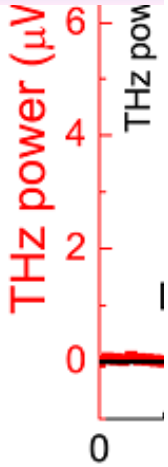
(Received 29 April 2013; accepted 16 June 2013; publish

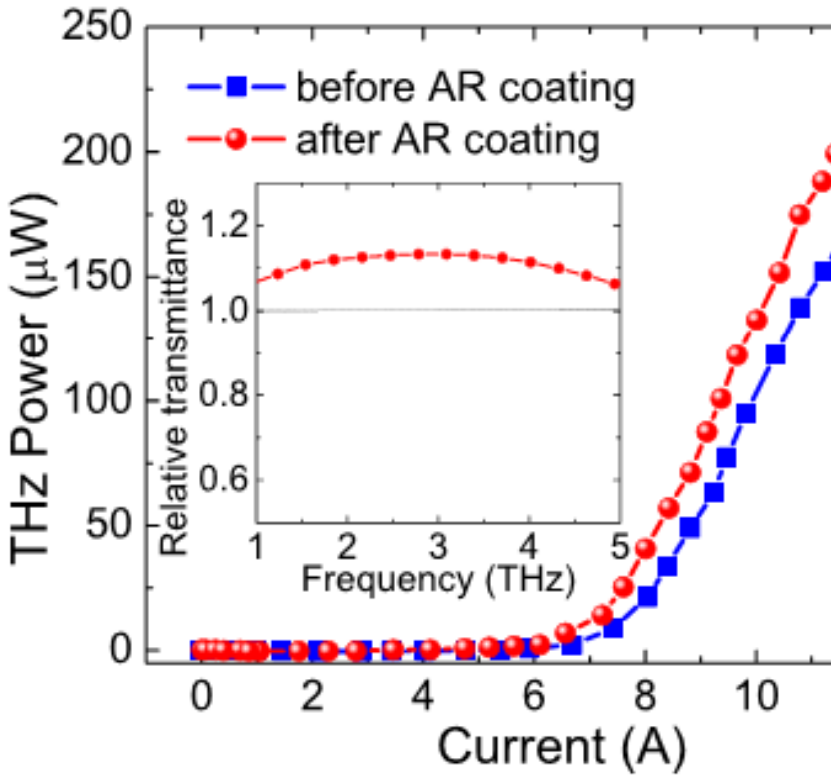
**azeghi group : 193 μW at 3 T**



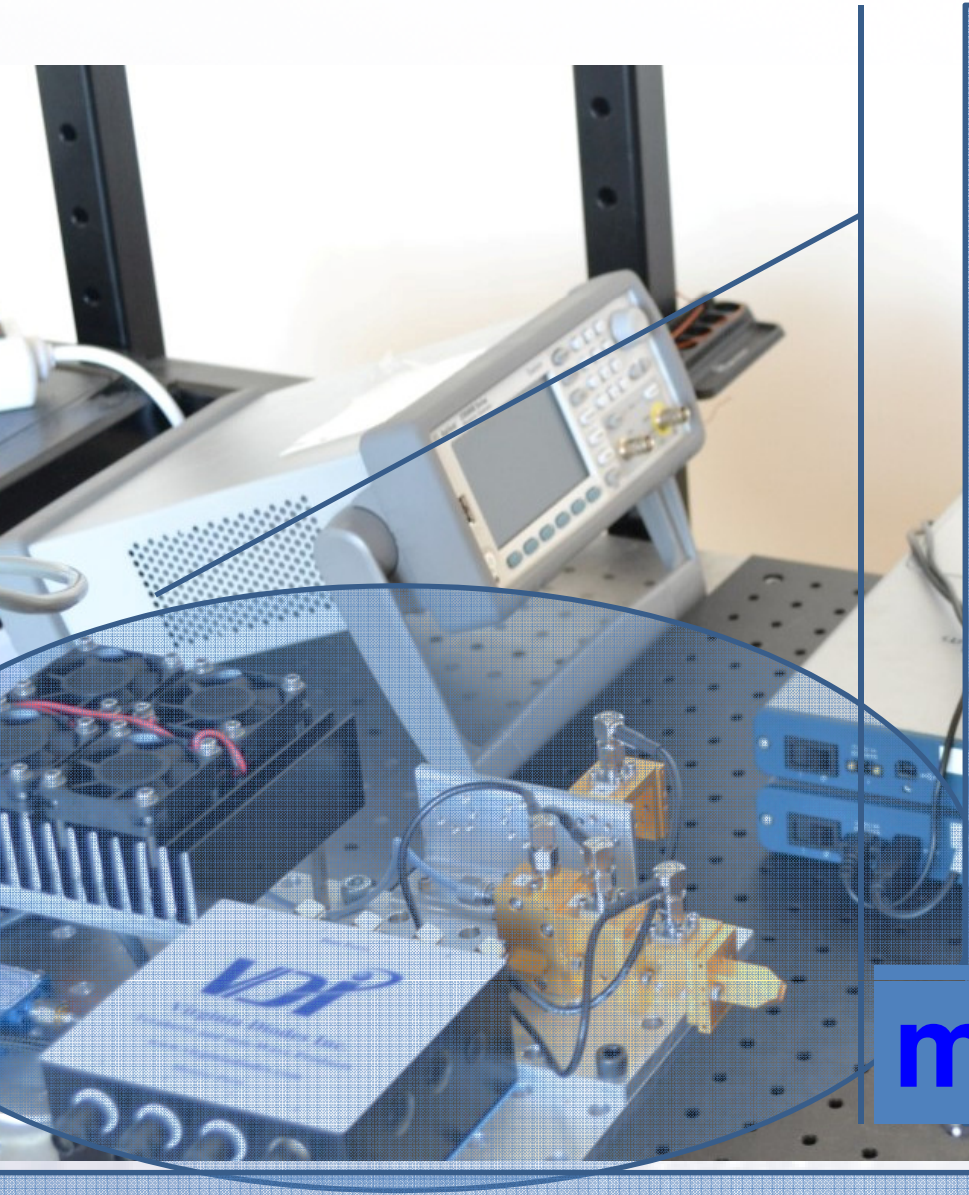


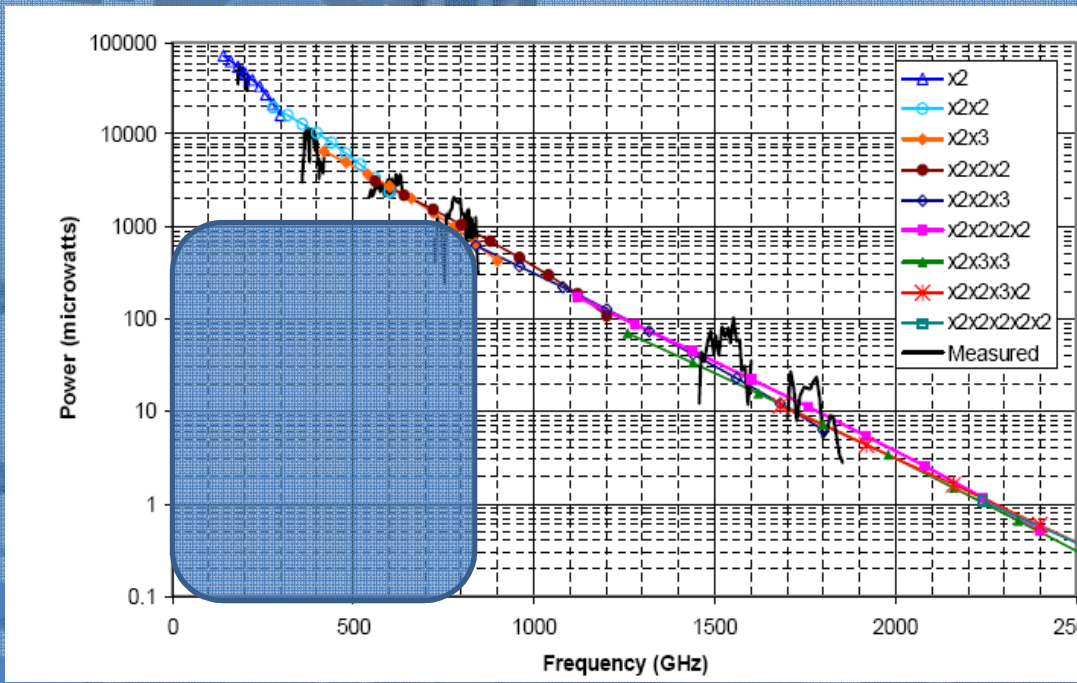



# medical applications

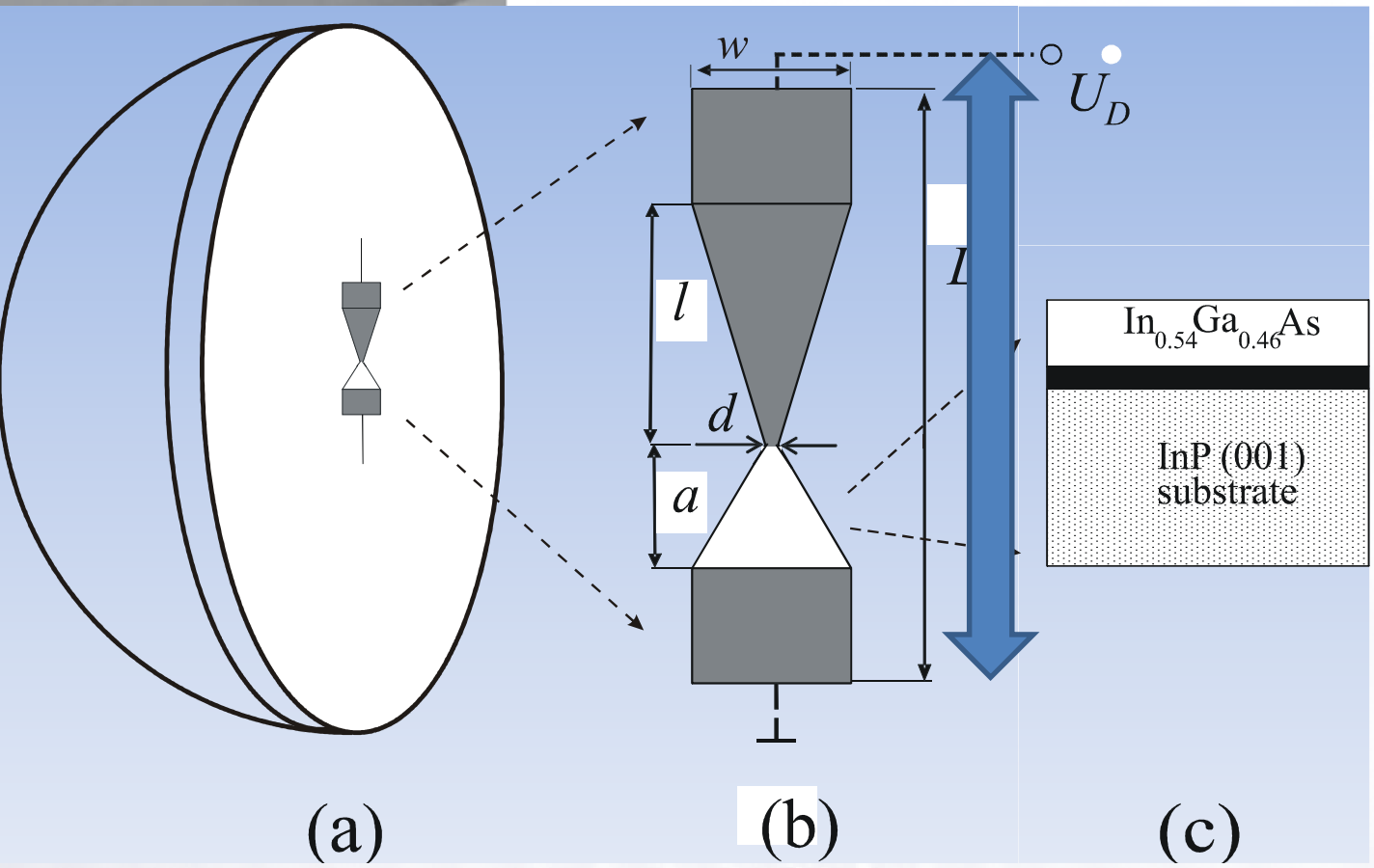


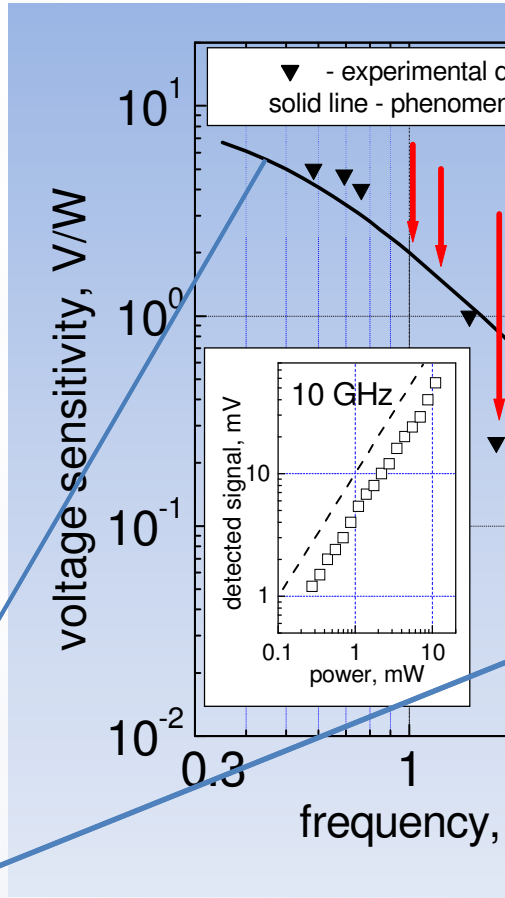
## Arguments:




## mW of power in subTH

## Requirements for sensors? – frequency, sensitivity, NEP, operation mode




liuta, I. Kašalynas, V. Tamošiūnas, S. Balakauskas, Z. Martūnas, montas, G. Valušis, A. Lisauskas, H.G. Roskos, and K. Köhler, *Silicon coupled bow-tie InGaAs-based broad band terahertz sensor operating at temperature*, Electron. Lett. **42**, 825 (2006).

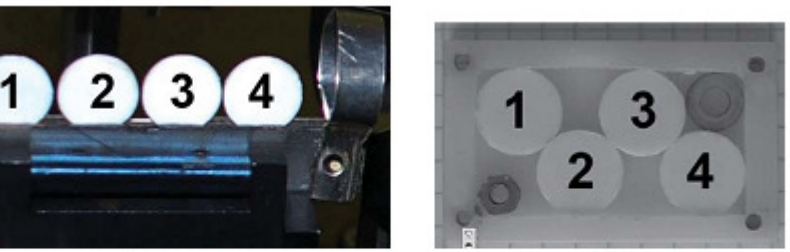
freq.- up to 2.5 THz, sensitivity – 6 V/W, NEP - 4 nw/√Hz, **RT**

# v-tie diodes

IEEE SENSORS JOURNAL, VOL. 13, NO. 1, JANUARY 2013

## ontinuous Wave Spectroscopic Terahe
## maging With InGaAs Bow-Tie Diode
## at Room Temperature

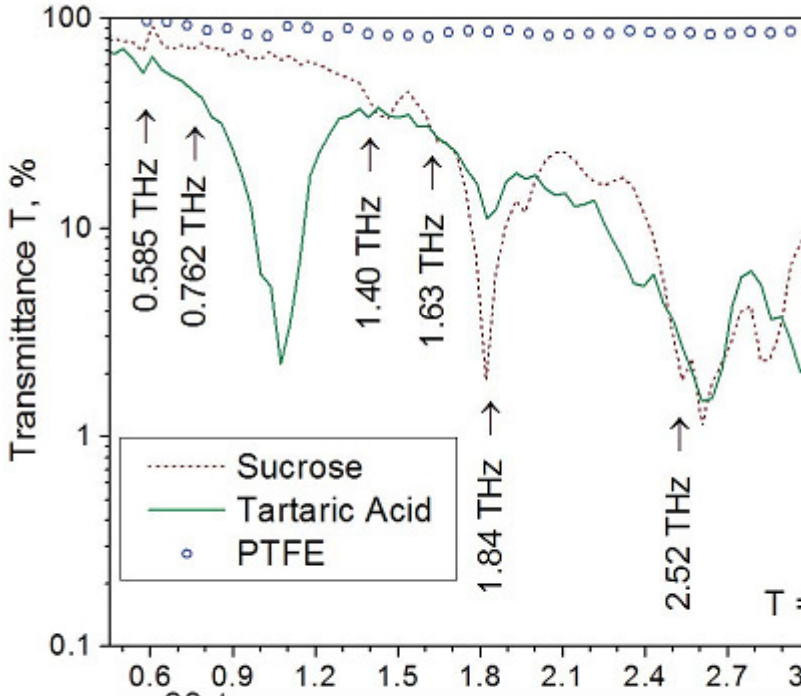
mantas Kašalynas, *Member, IEEE*, Rimvydas Venckevičius, and Gintaras Valušis




(a)

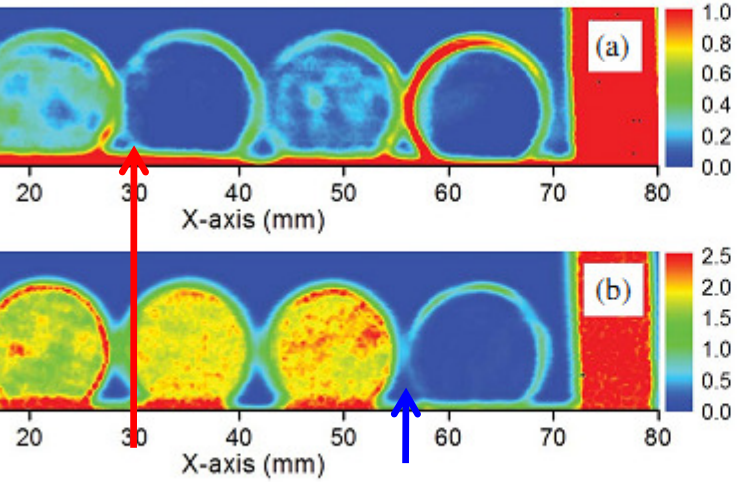


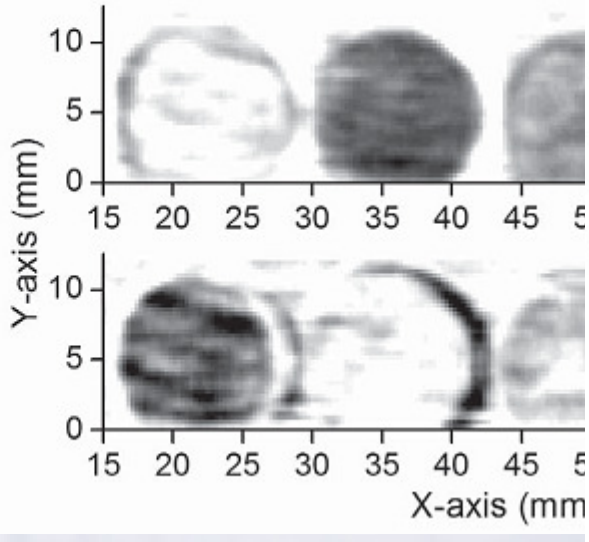

(b)

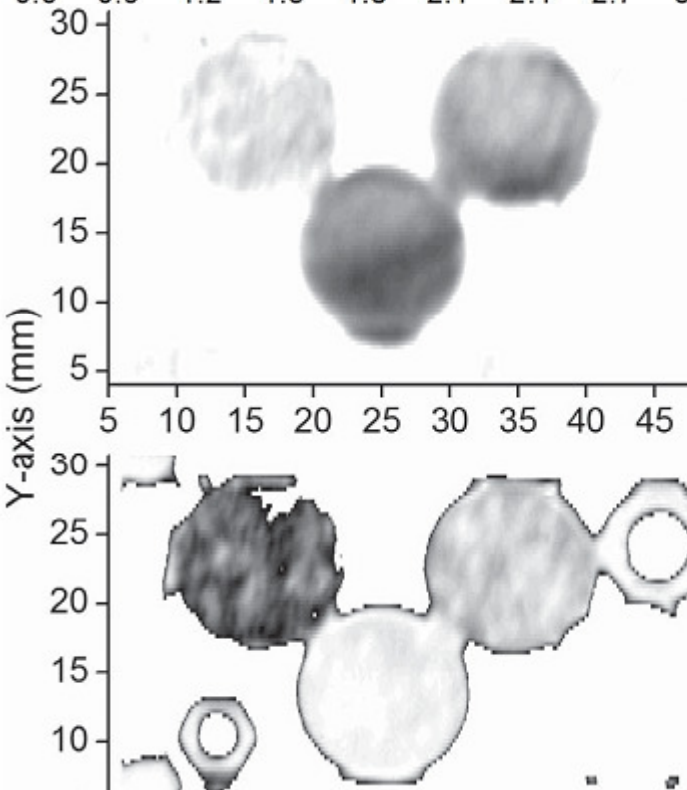



-10%; 2- TA-10%; 3- TA-SC-5%-5%;
PE –ref.

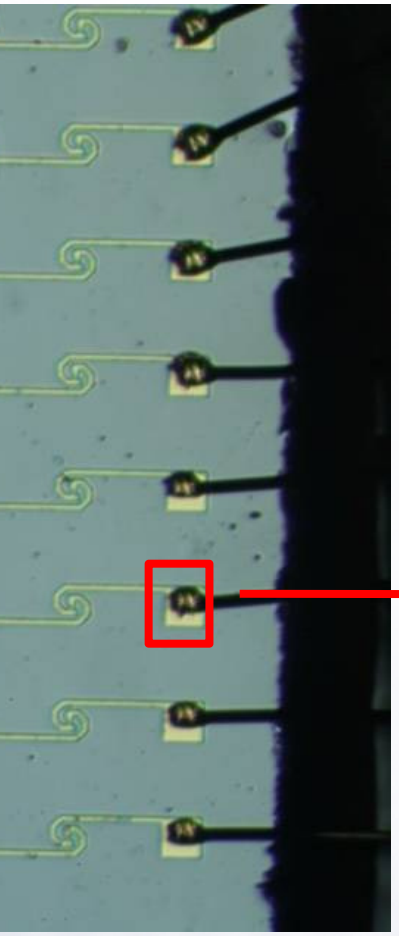
Fig. 6. (
in PTFE
thickness

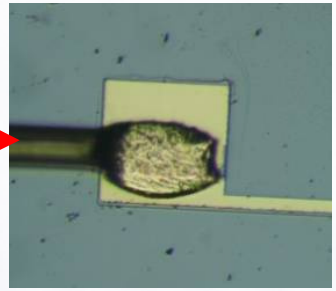


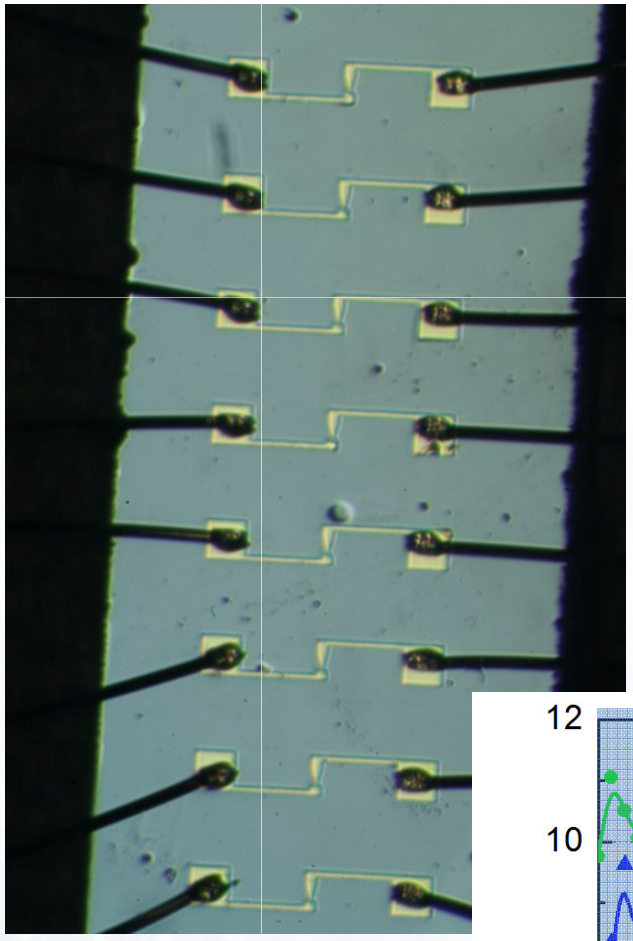




**at 0.76 and 2.52 THz**

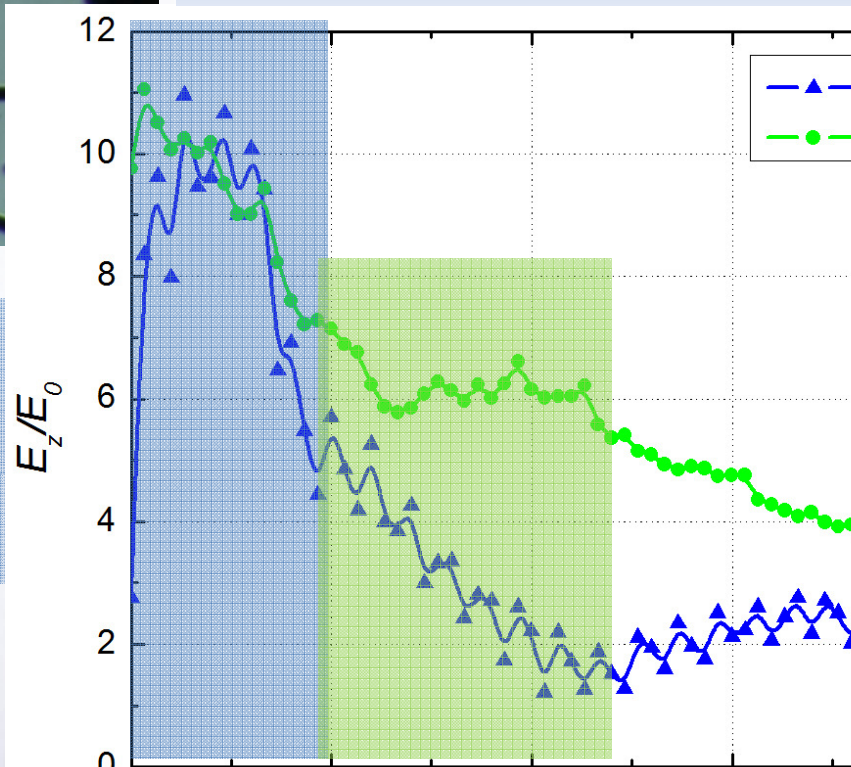






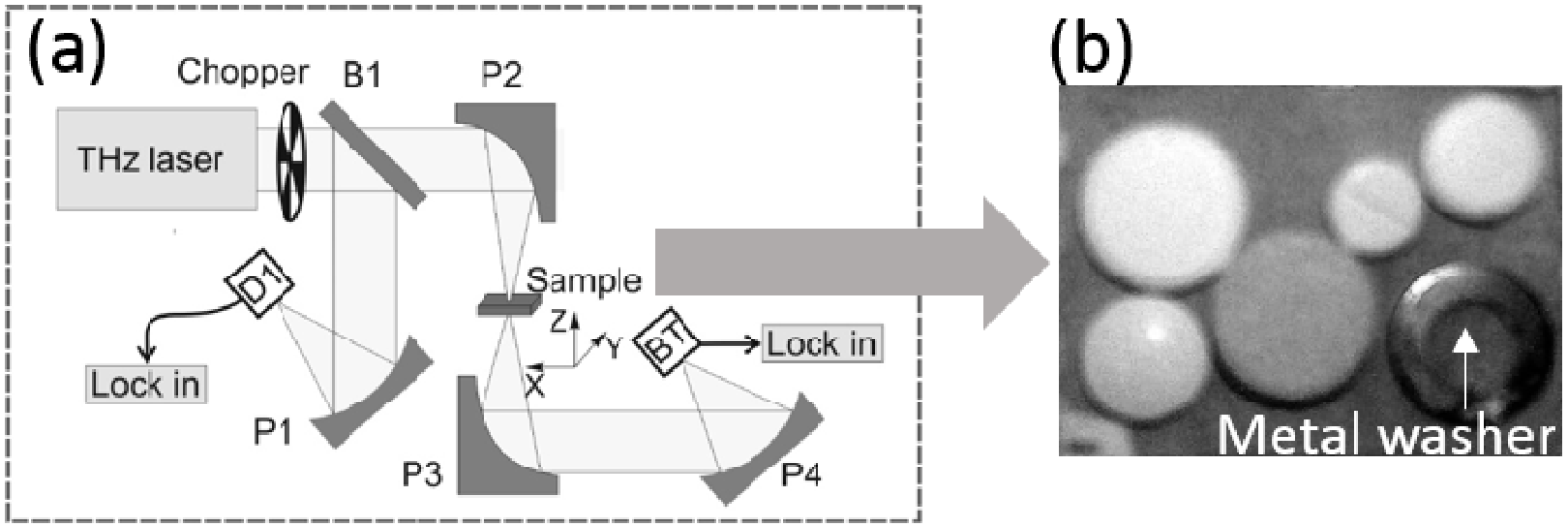
**Bow-tie**
(narrow band)
and
**spiral**
(broadband)

**3D FDTD calculatio**

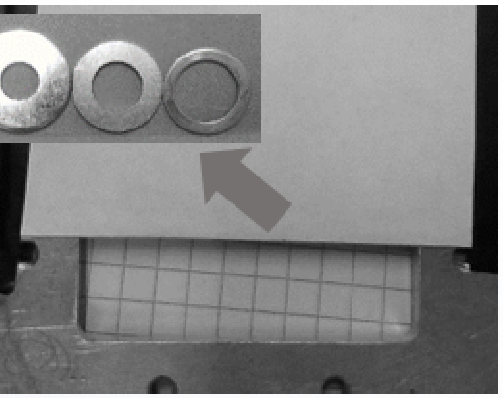



**own structure: $In_{0.46}Ga_{0.54}As$, 534**
**s monolayer/InP (001) substrate, 500 µm**

**lithography and wet etching**




THz source – optically pumped molecular laser, power – 2 mW,
pixel size ~300 μm, 159x105 pixels



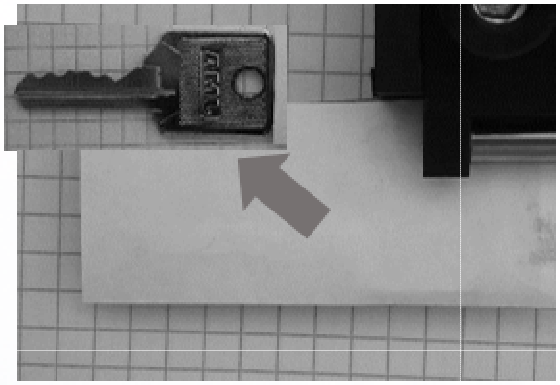


Image with single pixel

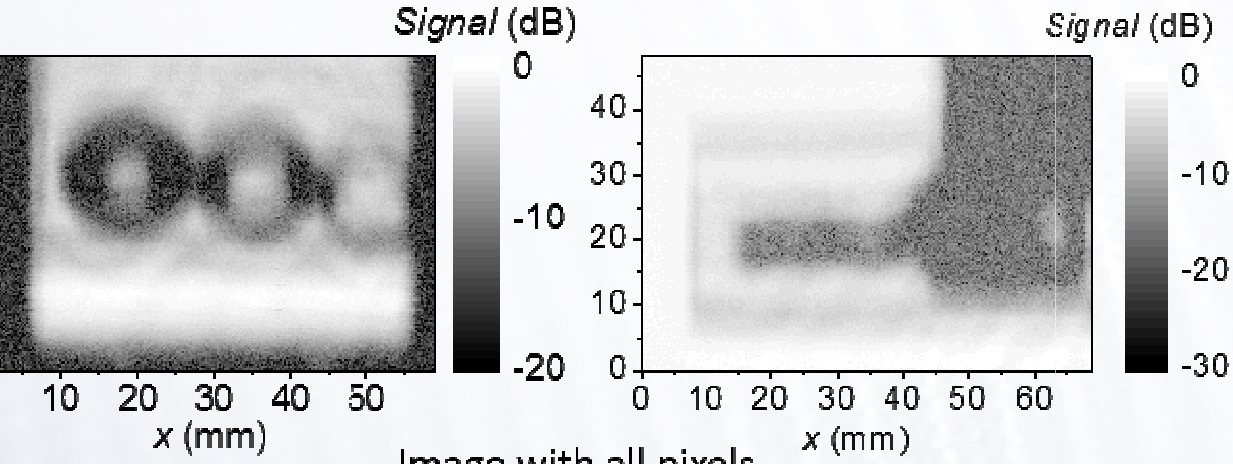
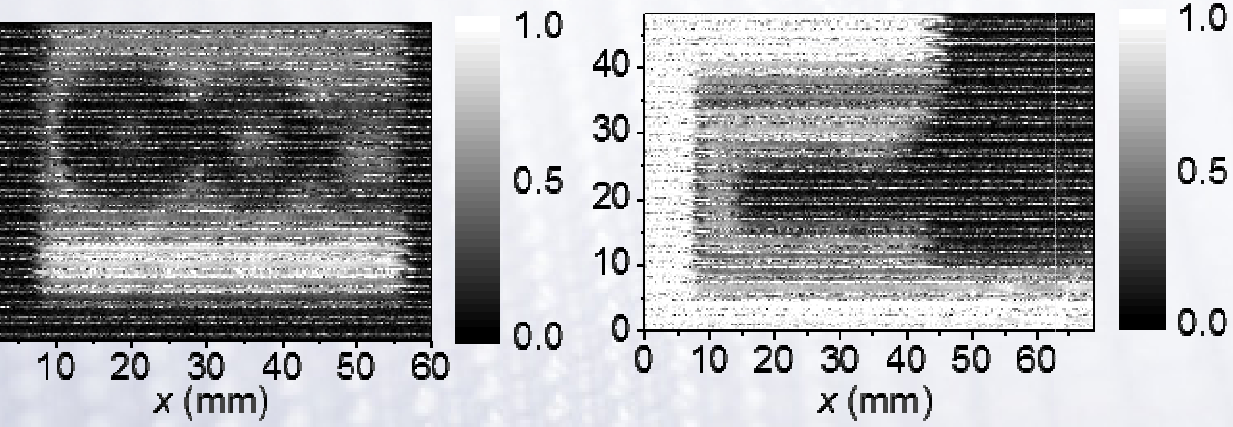



Image with all pixels




269x160 pixels (key
230x160 pixels (was

stage moving speed
32 mm/s; step – 256

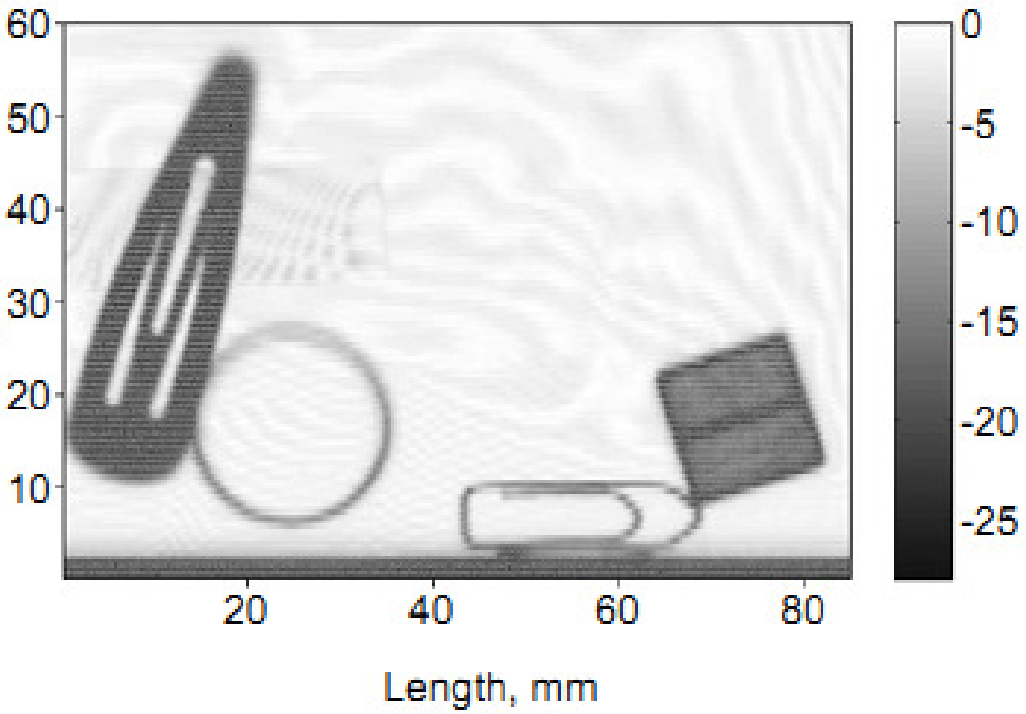
THz source – optically pumped molecular laser, 0.76 THz; 2.5 m

# con nanoFETs – for THz imaging

JOURNAL OF APPLIED PHYSICS **105**, 114511 (2009)

## nal design of high-responsivity detectors of terahertz radiation based stributed self-mixing in silicon field-effect transistors

Alvydas Lisauskas,[1,a)] Ullrich Pfeiffer,[2] Erik Öjefors,[2] Peter Haring Bolìvar,[3] Diana Glaab,[1] and Hartmut G. Roskos[1]



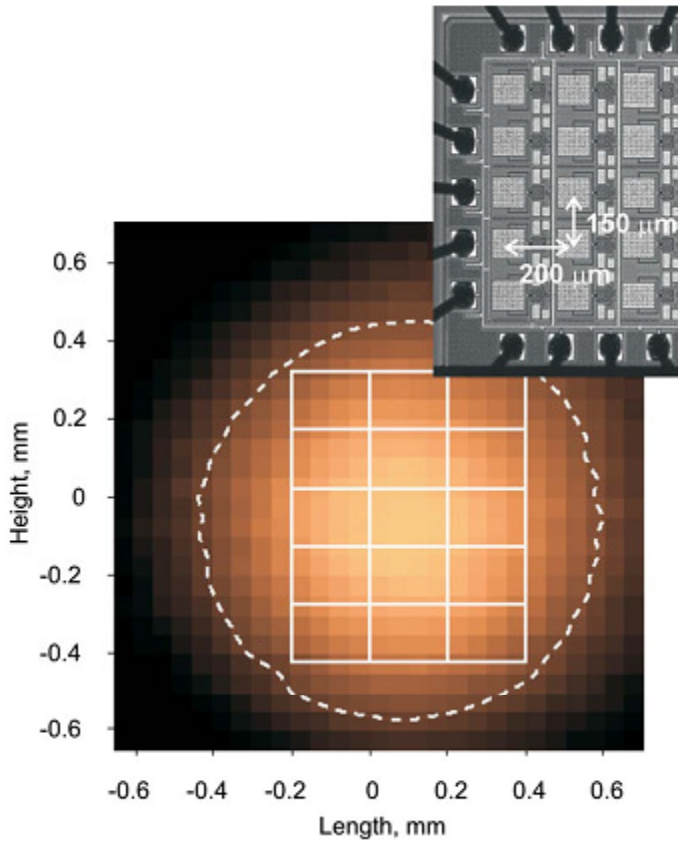




FIG. 5. (Color online) Upper panel: micrograph of the 3×5 FPA 200×150 $\mu$ m$^2$. Lower panel: Measured beam intensity profile tral pixel of the FPA.

**ency – 0.65 THz, sensitivity – 70 kV/W, – 300 pW/√Hz! : gate – 250 nm**

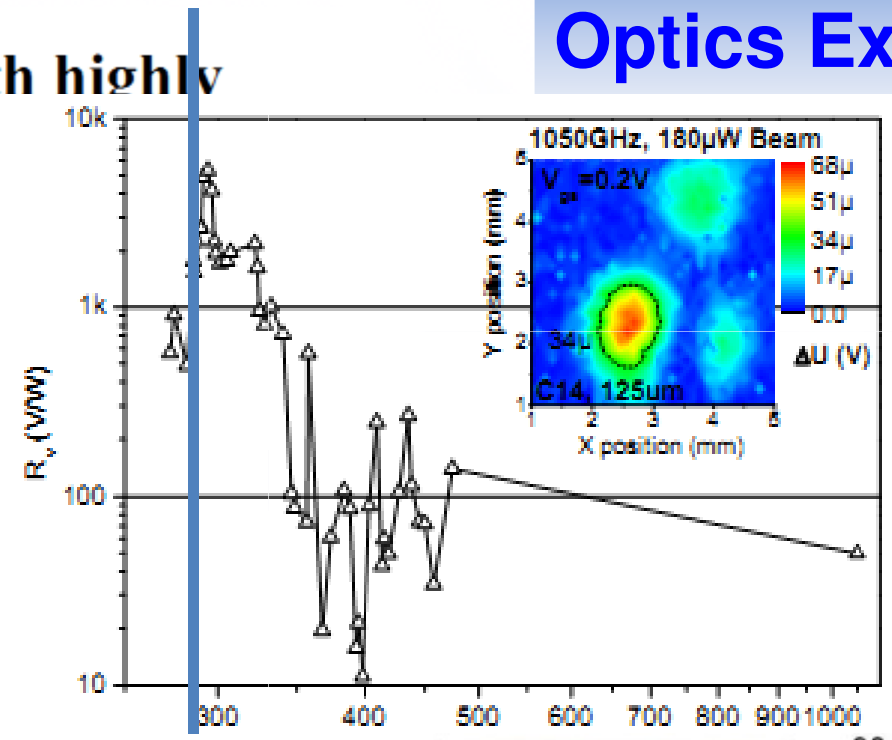
# S transistors

## Optics Express 2011

**dband terahertz imaging with highly**
**sensitive silicon CMOS dete**


uster,[1,2*] Dominique Coquillat,[2] Hadley Videlier,
Frédéric Teppe,[2] Laurent Dussopt,[1] Benoît Gi
Thomas Skotnicki,[3] and Wojciech Knap

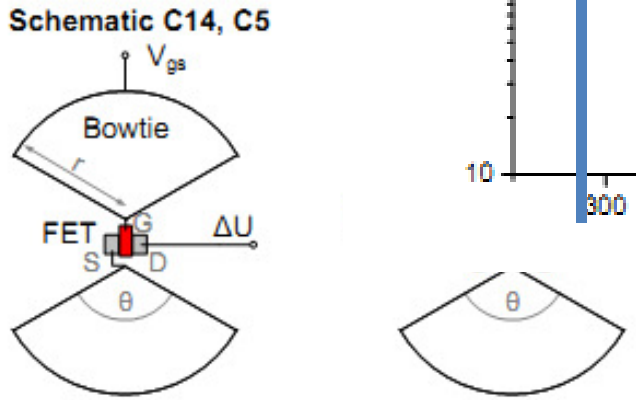
[1]CEA-LETI, MINATEC Campus, 38054 Grenoble, FRA
Montpellier 2 and CNRS, TERALAB-GIS, L2C UMR 5221, 3409.
[3]STMicroelectronics, 38926 Crolles, FRANCE





(a)




(b)

**Detector Characteristics**

| | L (nm) | W (nm) | r (μm) | θ (deg) | Antenna Connection |
|---|---|---|---|---|---|
| C14 | 130 | 250 | 60 | 120 | gate-source |
| C15 | 130 | 250 | 60 | 120 | source-drain |
| C5 | 300 | 500 | 60 | 120 | gate-source |

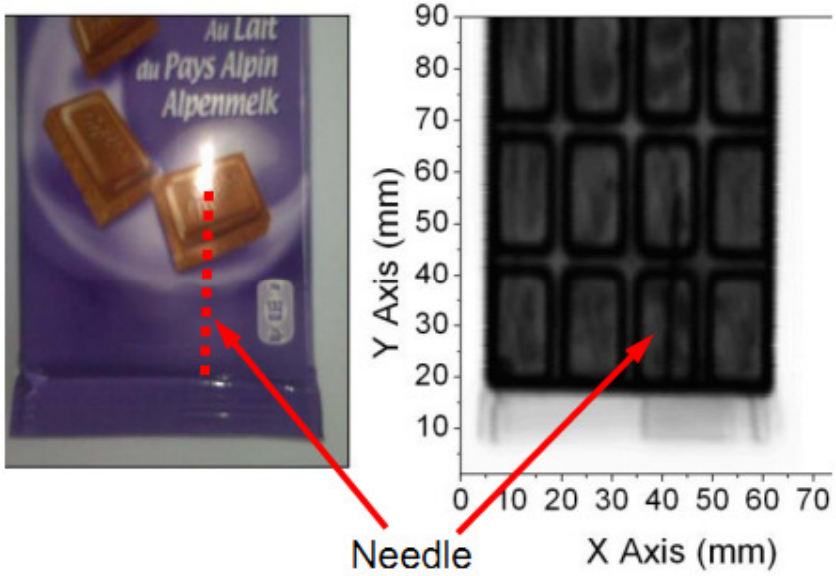
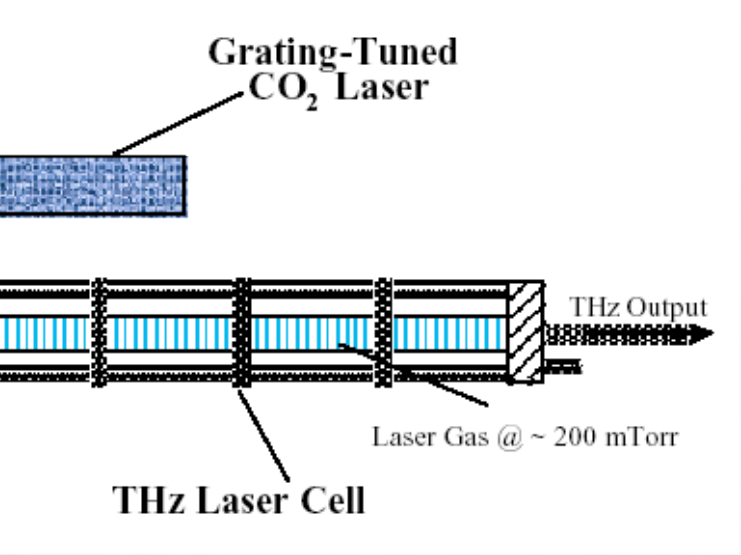



Fig. 5. Photograph and 292 GHz transmission mode image of a chocolate bar with a met
needle inside. The THz image consists of 225x300 scanned points and the used detector
C14 on the 125 μm substrate.

**ncies – 0.27-1.05 THz,**

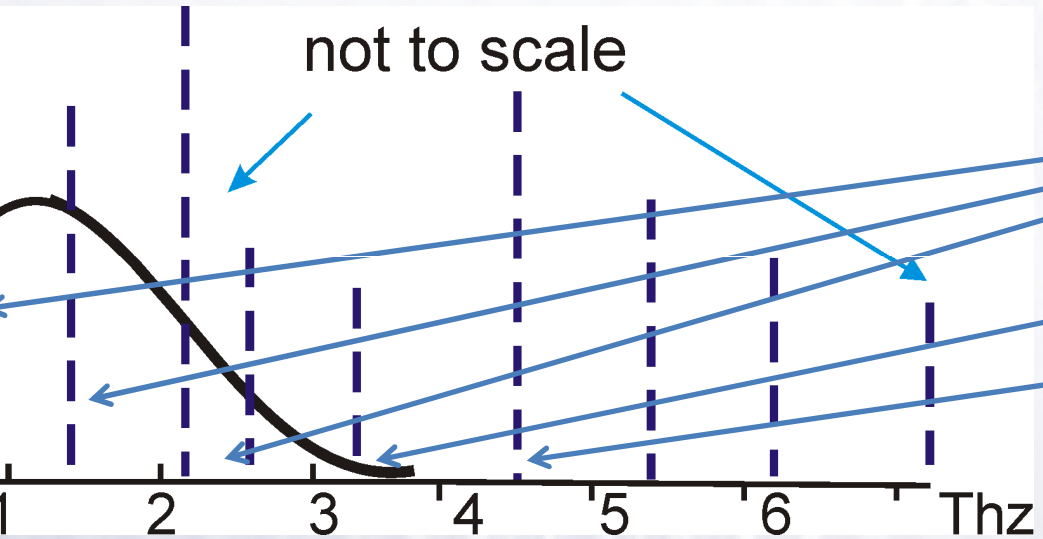
**tivity – 5 kV/W, noise-equivalent power (NEP) – 10 pW**

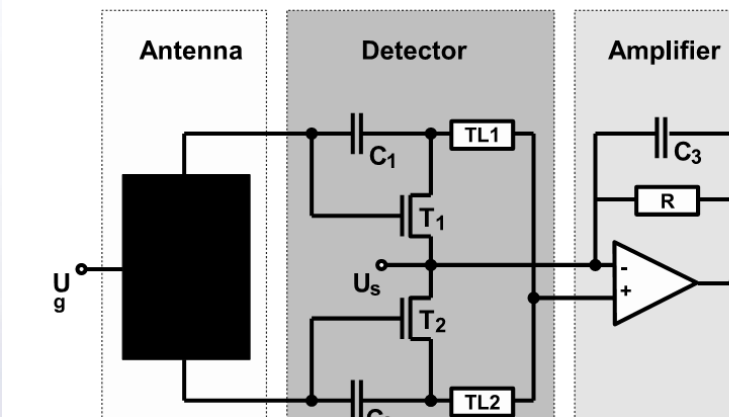
# n nanoFETs – spectral properties




Lines of optically-pum
molecular THz laser:

0.76 THz, 1.41 THz,
1.63 THz, 2.52 THz,
3.1 THz, 4.3 THz,
5.6 THz, 6.2 THz. 7.

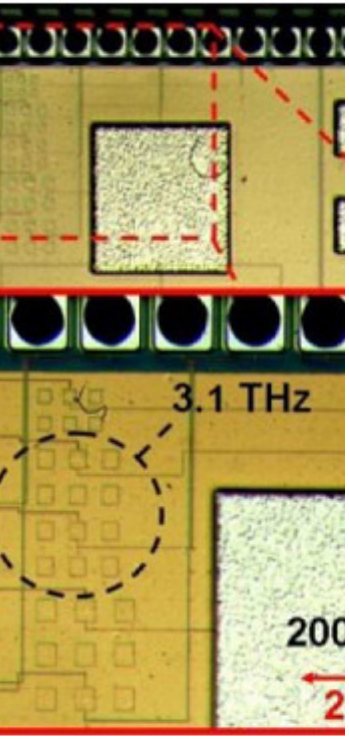


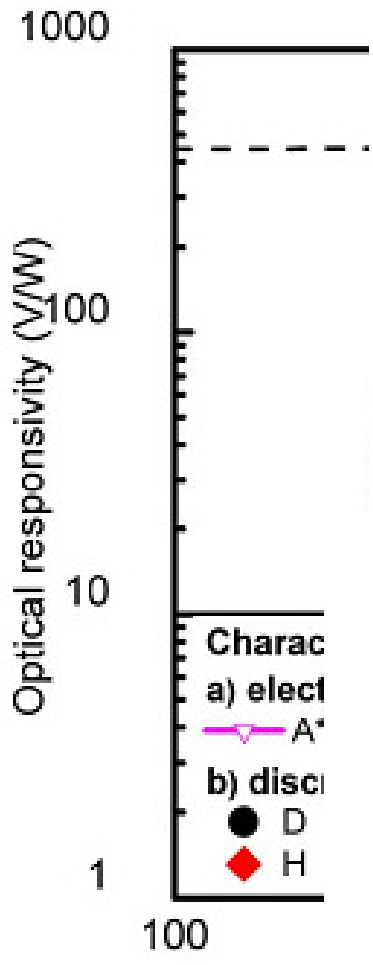
IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 60, NO. 12, DECEMBER 2012

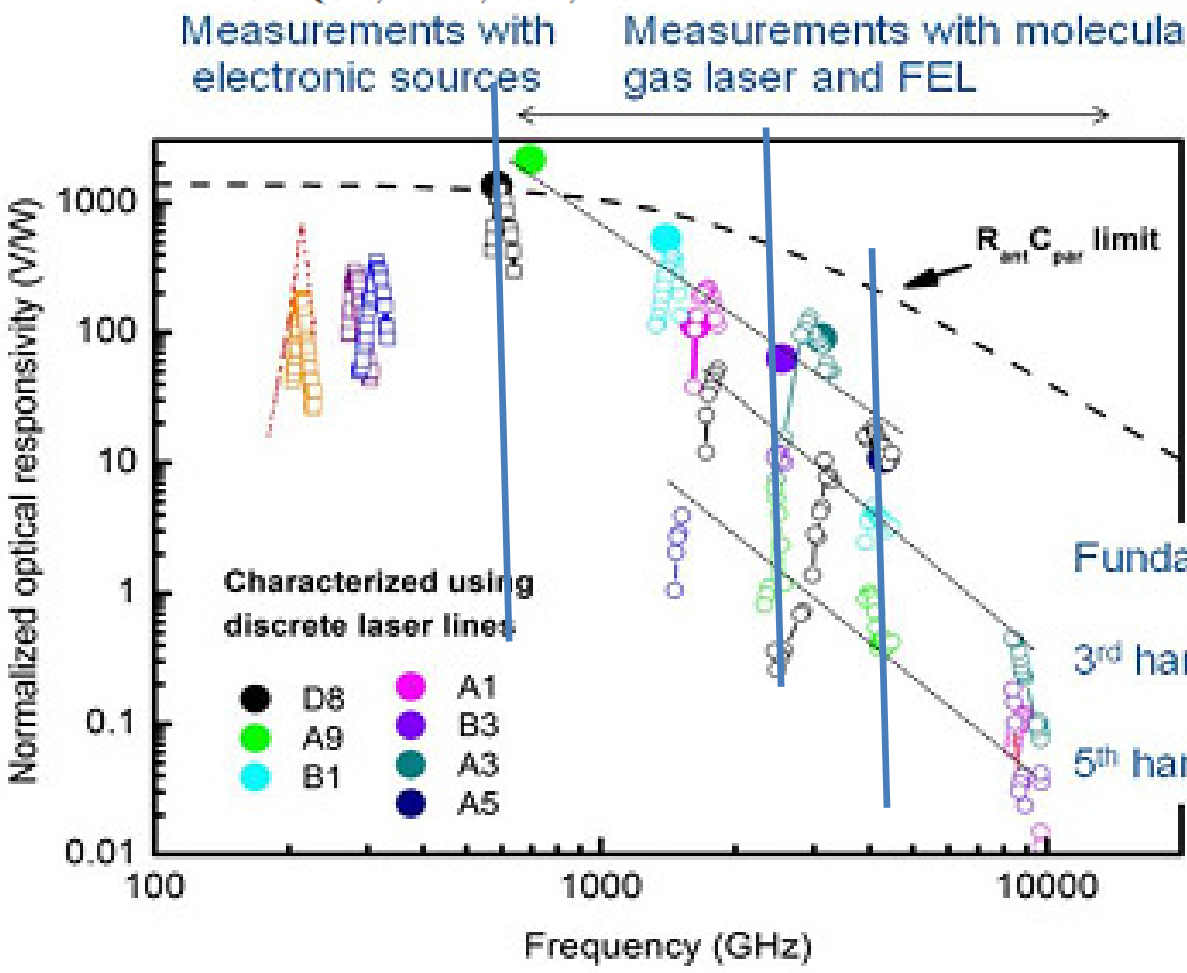
# MOS Integrated Anten
# Transistors for t
# Radiation From

Sebastian Boppel, Alvydas Lisauskas, Martin
rmantas Kašalynas, *Member, IEEE*, Gintaras V
Viktor




aph of a 1.5 × 2.5 mm² larg
or ten different terahertz freq
requency section (for frequen




LM4A.1.pdf Latin America Optics and Photonics

# Terahertz Sensing and Imaging with Silicon Field-Eff
# Transistors up to 9 THz

Alvydas Lisauskas[a], Sebastian Boppel[a], Dalius Seliuta[b], Linas Minkevičius[b], Irmantas Kašaly
Valušis[b], B. Khamaisi[c], Viktor Krozer[a], E. Socher[c] and Hartmut G. Roskos[a,*]

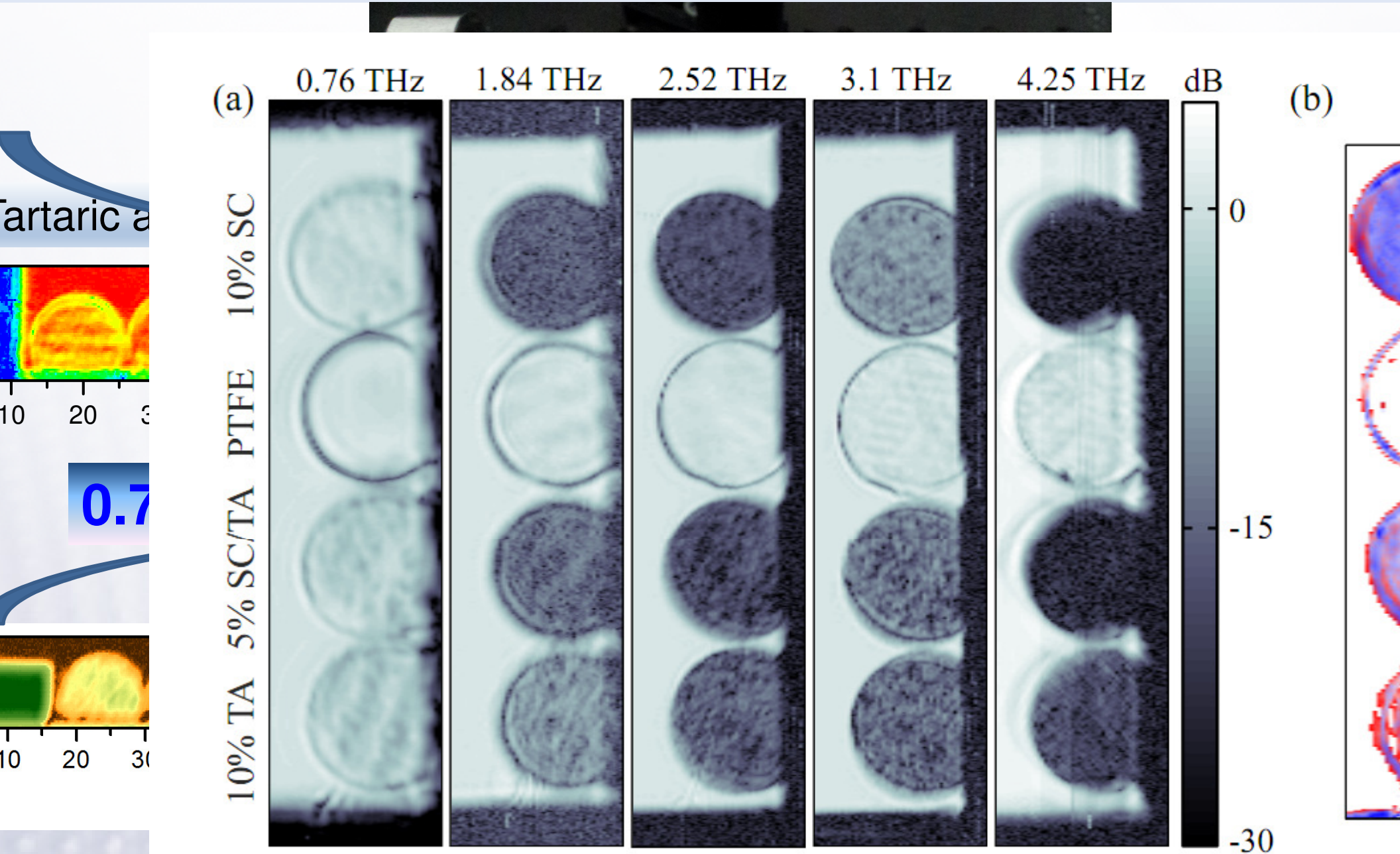
1000

n transistors

ed" photos in THz range – sensors of 90 nm CMOS technology

**urt/M (Germany) – Vilnius (Lithuania) cooperation**

Express **22**, n16, 19235 (2014)



# ing of broadband terahertz beams using an ray of antenna-coupled microbolometers operating at room temperature

an Oden,[1] Jérome Meilhan,[2] Jérémy Lalanne-Dera,[2] Jean-François Roux,[1,*]
Frédéric Garet,[1] Jean-Louis Coutaz,[1] and François Simoens[2]

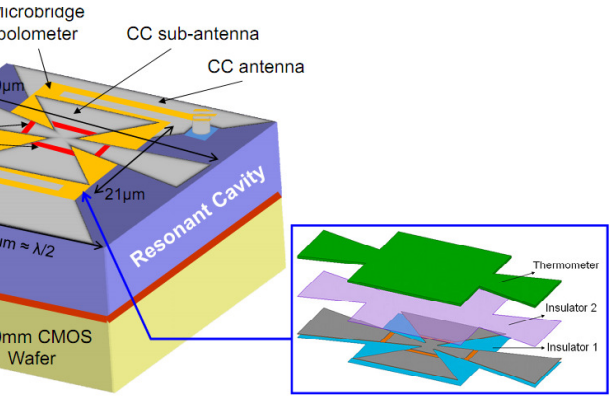
*MEP-LAHC, UMR-CNRS 5130, University of Savoie, 73376 Le Bourget du Lac Cedex, France*
*[2] CEA-Leti, Minatec Campus, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France*
*[*] roux@univ-savoie.fr*

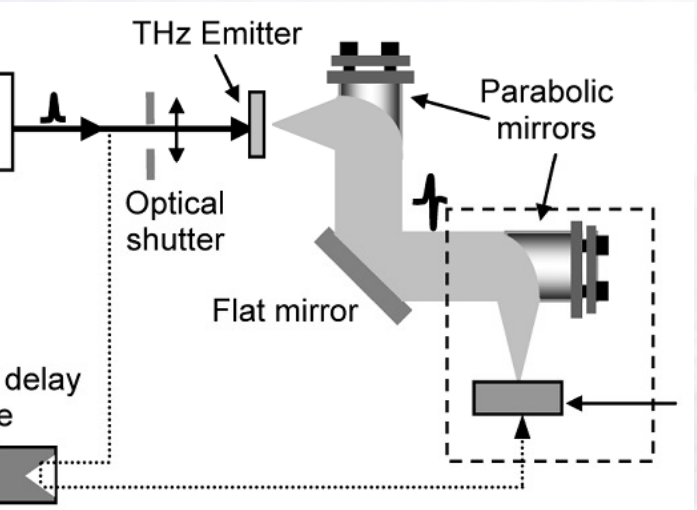
**Optics Express, 2013:**

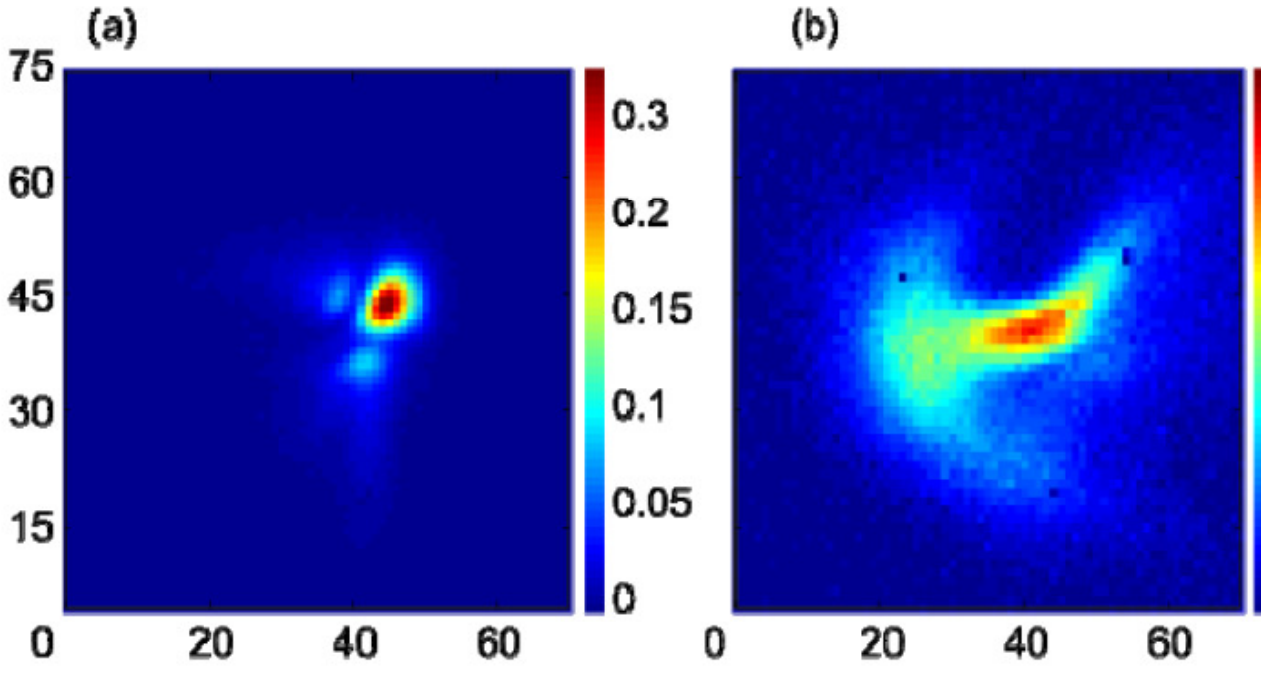
320 x 240 array
of antenna-coupled a-Si
microbolometers with integ
CMOS read-out electronics.

**Frequencies - 0.1—**

**power to single pixel – 25**
**sensitivity – 18 MV/W !**

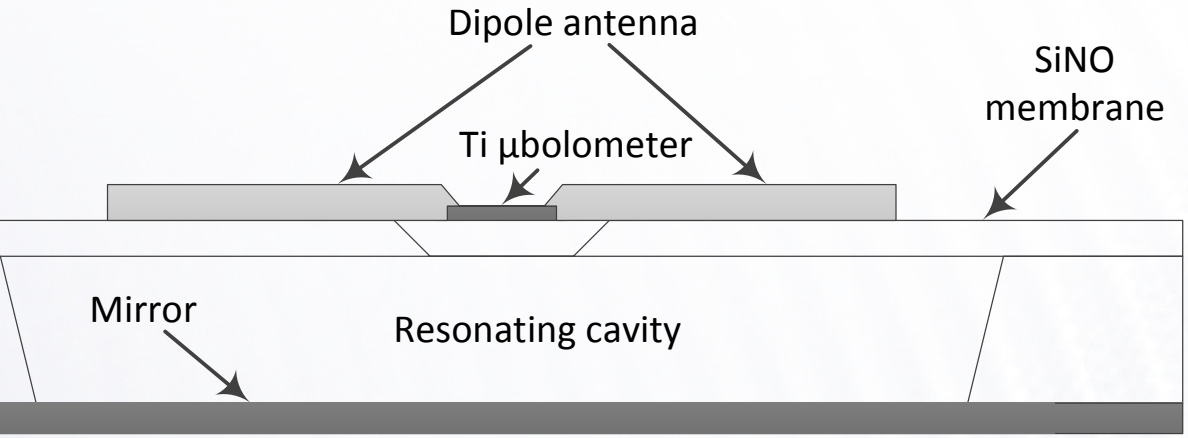


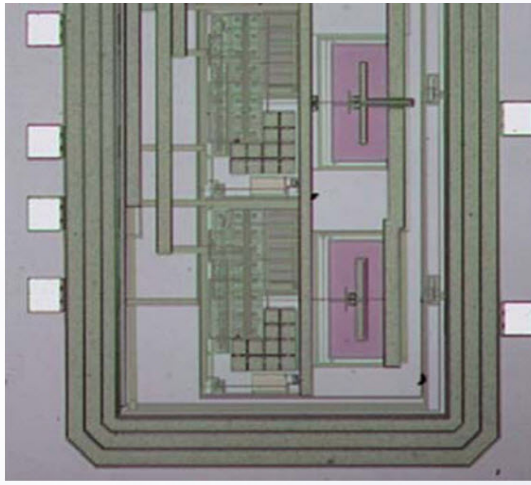



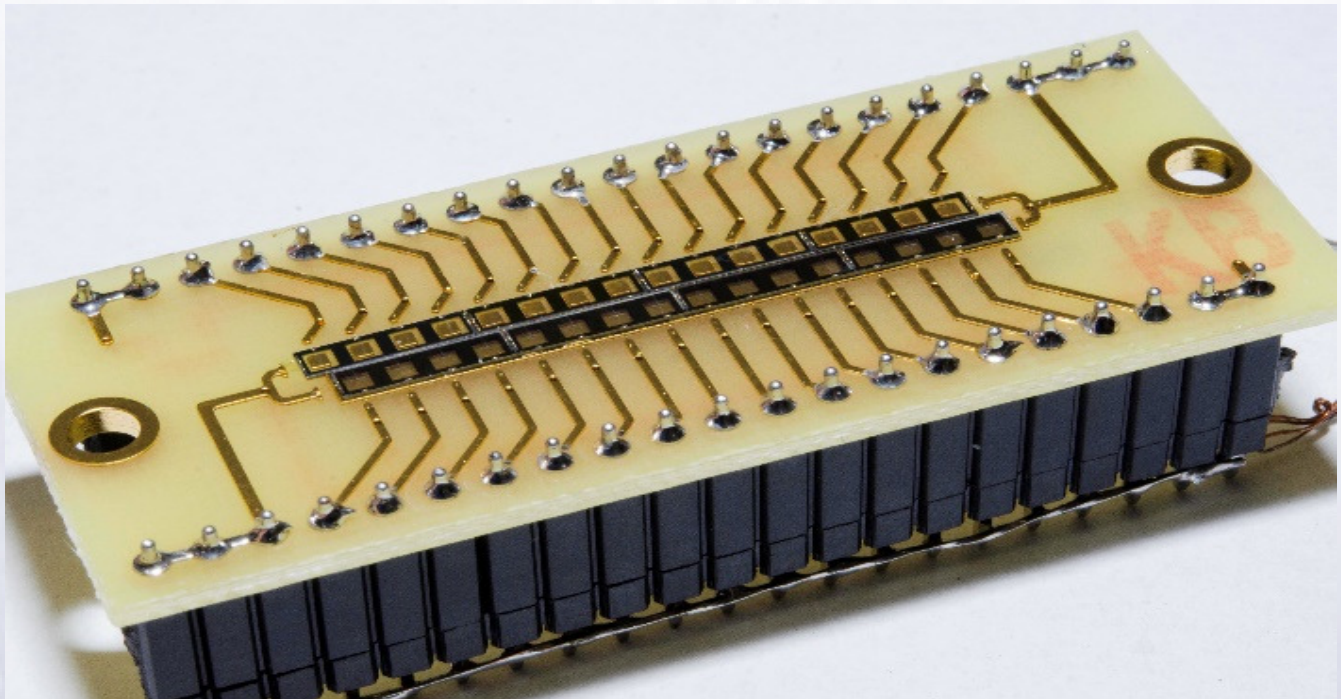



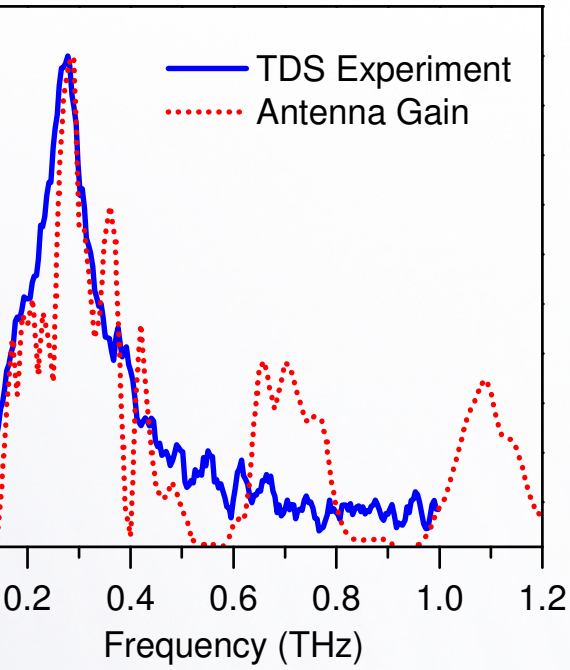
## ana (Slovenia) – Vilnius (Lithuania) cooperation

. at San Diego THz Conference (August 16-17, 2014)







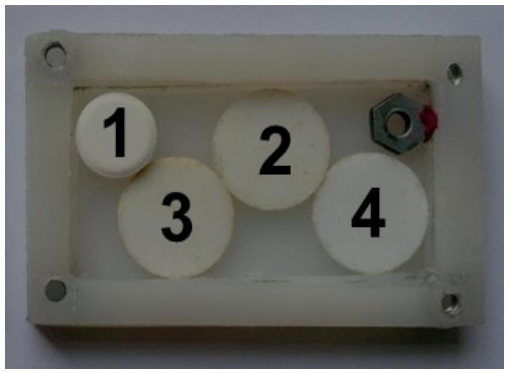
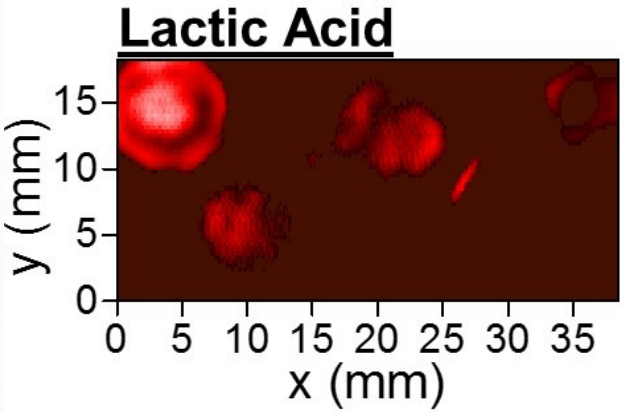
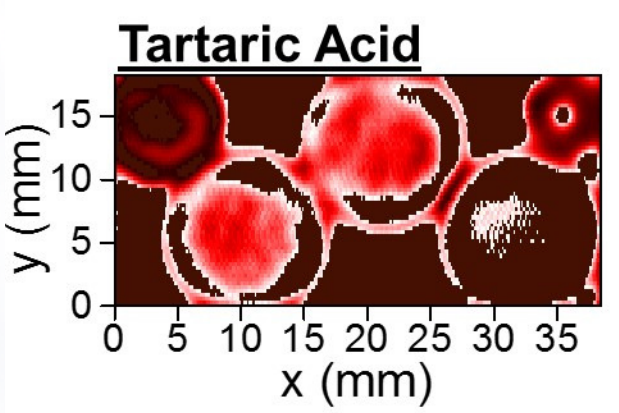
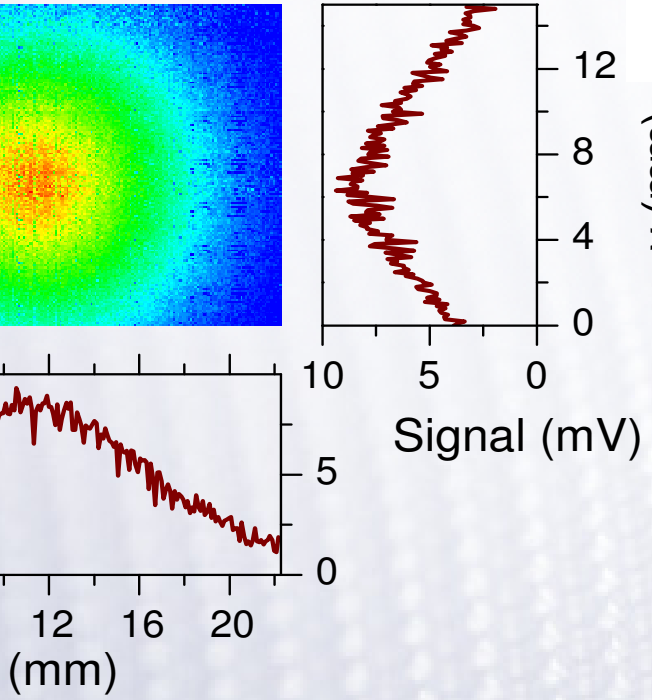
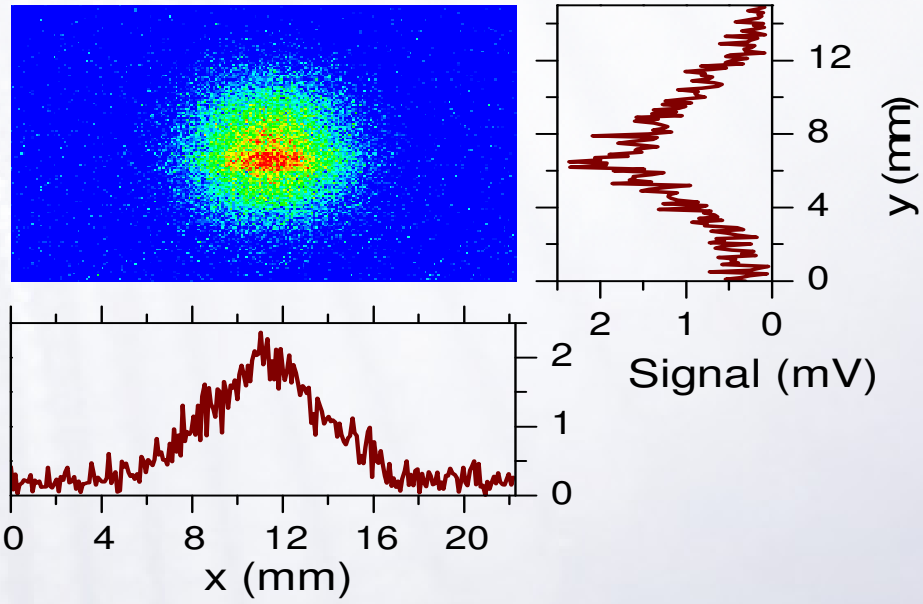




Photo of test pellets packed inside plastic
1 - Lactic Acid, 2- Tartaric Acid, 3 – Mixtur
Tartaric Acid and Sucrose, 4 – Reference
row) Lactic Acid and Tartaric Acid compon
distribution along package (pellets) obtain
using spectroscopic THz imaging techniq

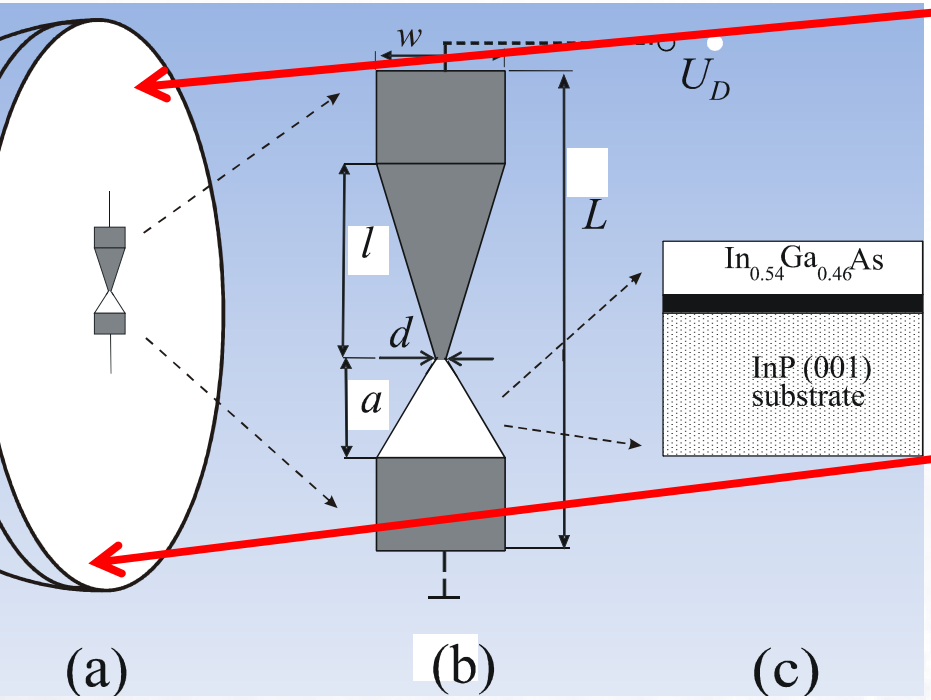


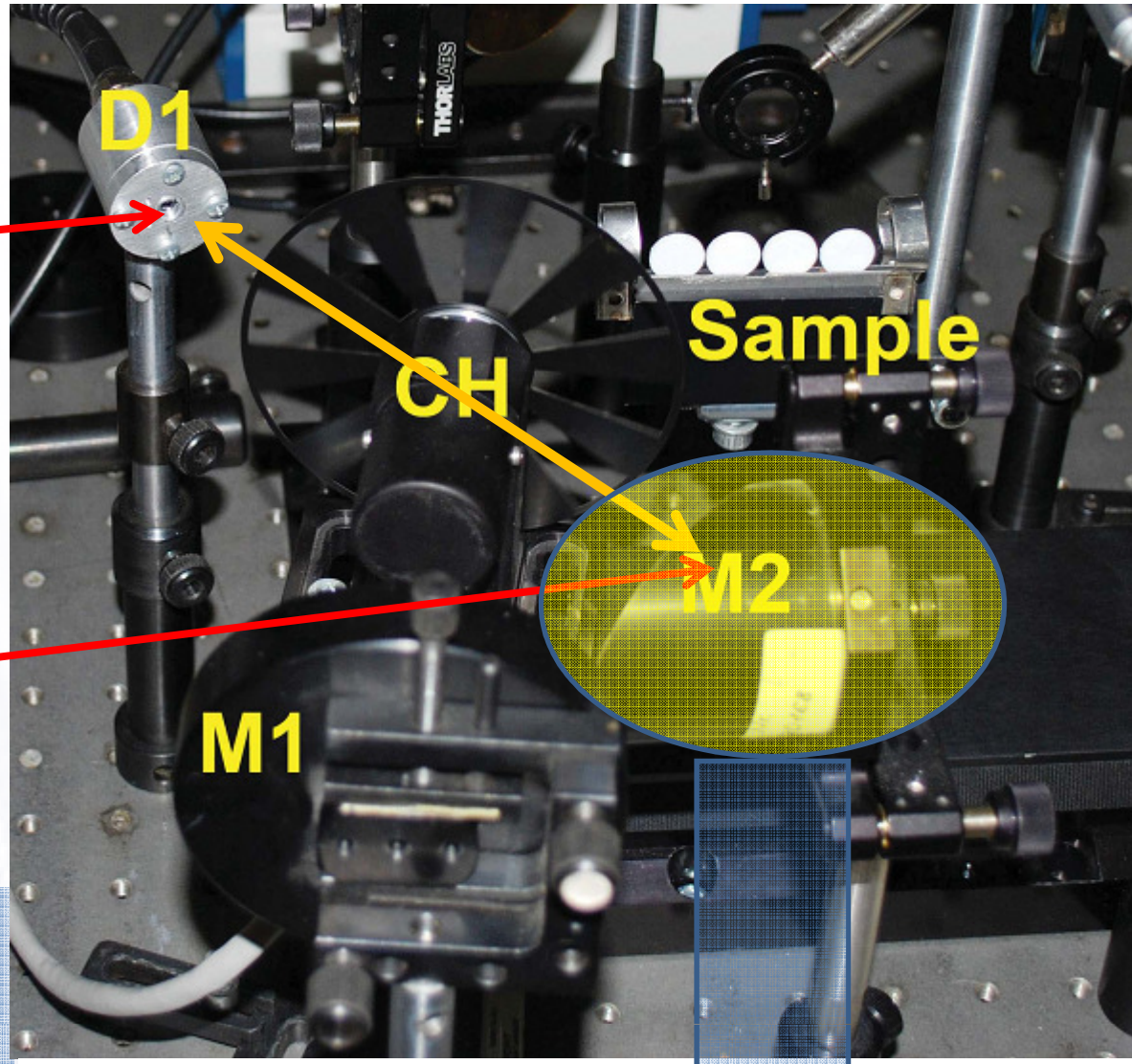




n profile of the THz TDS source measured with linear micro-bolometers array




ta, I. Kašalynas, V. Tamošiūnas,
kauskas, Z. Martūnas, S. Ašmontas,
šis, A. Lisauskas, H.G. Roskos, and
er, *Silicon lens-coupled bow-tie*
*-based broad band terahertz sensor*
*ng at room temperature*, Electron. Lett.
(2006).




50 IEEE SENSORS JOURNAL, VOL. 13, NO. 1, JANUARY

Continuous Wave Spectroscopic Terahertz Imaging With InGaAs Bow-Tie Diodes at Room Temperature

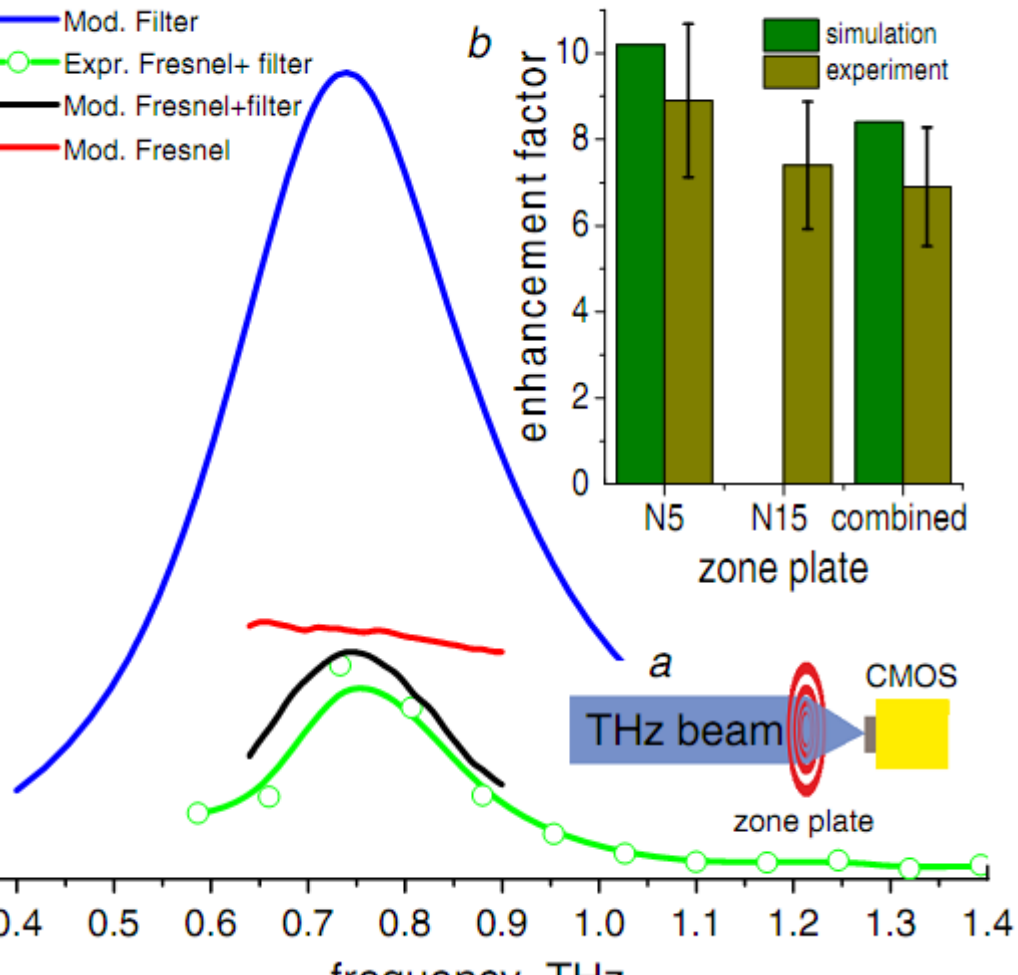
Irmantas Kašalynas, *Member, IEEE*, Rimvydas Venckevičius, and Gintaras Valušis

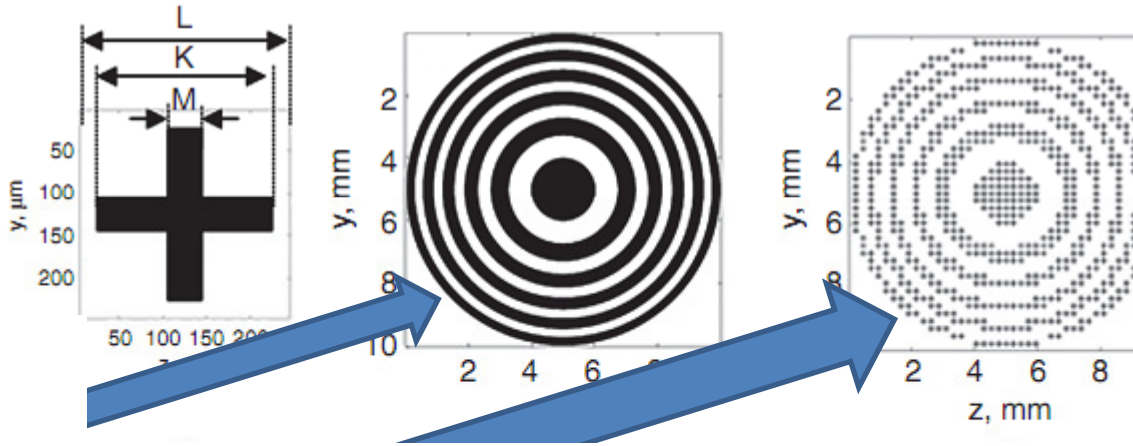
# ertz zone plates with integrated laser-
# d bandpass filters

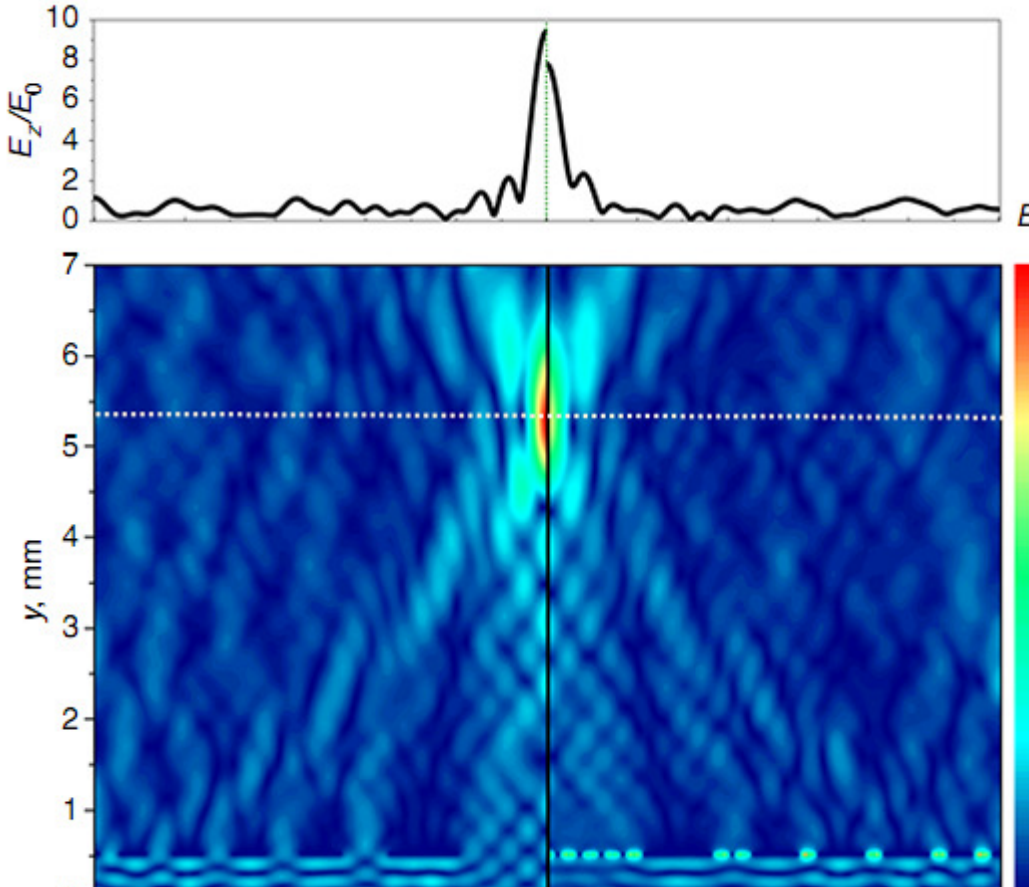
direct laser write techniq

evičius, B. Voisiat, A. Mekys, R. V
nas, D. Seliuta, G. Valušis, G. Rad
šiūnas

etron. Lett. 49, 49 (2013)



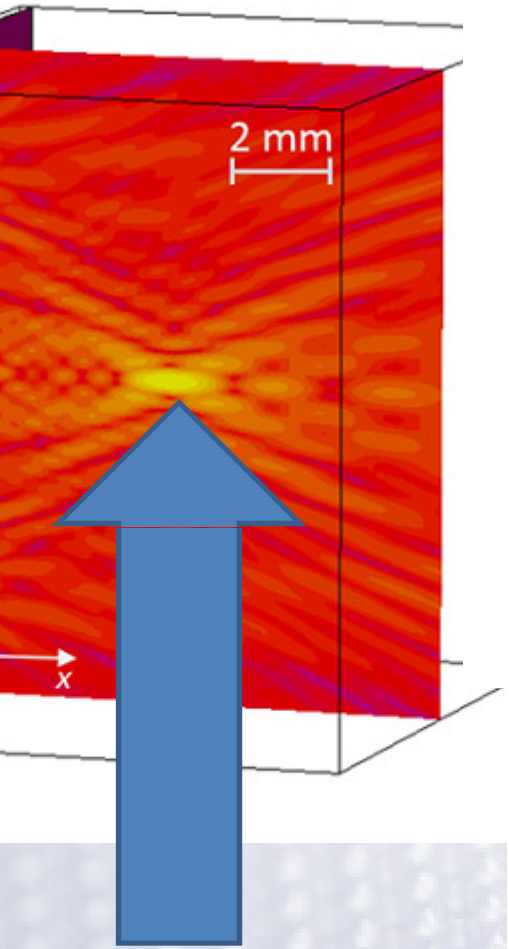



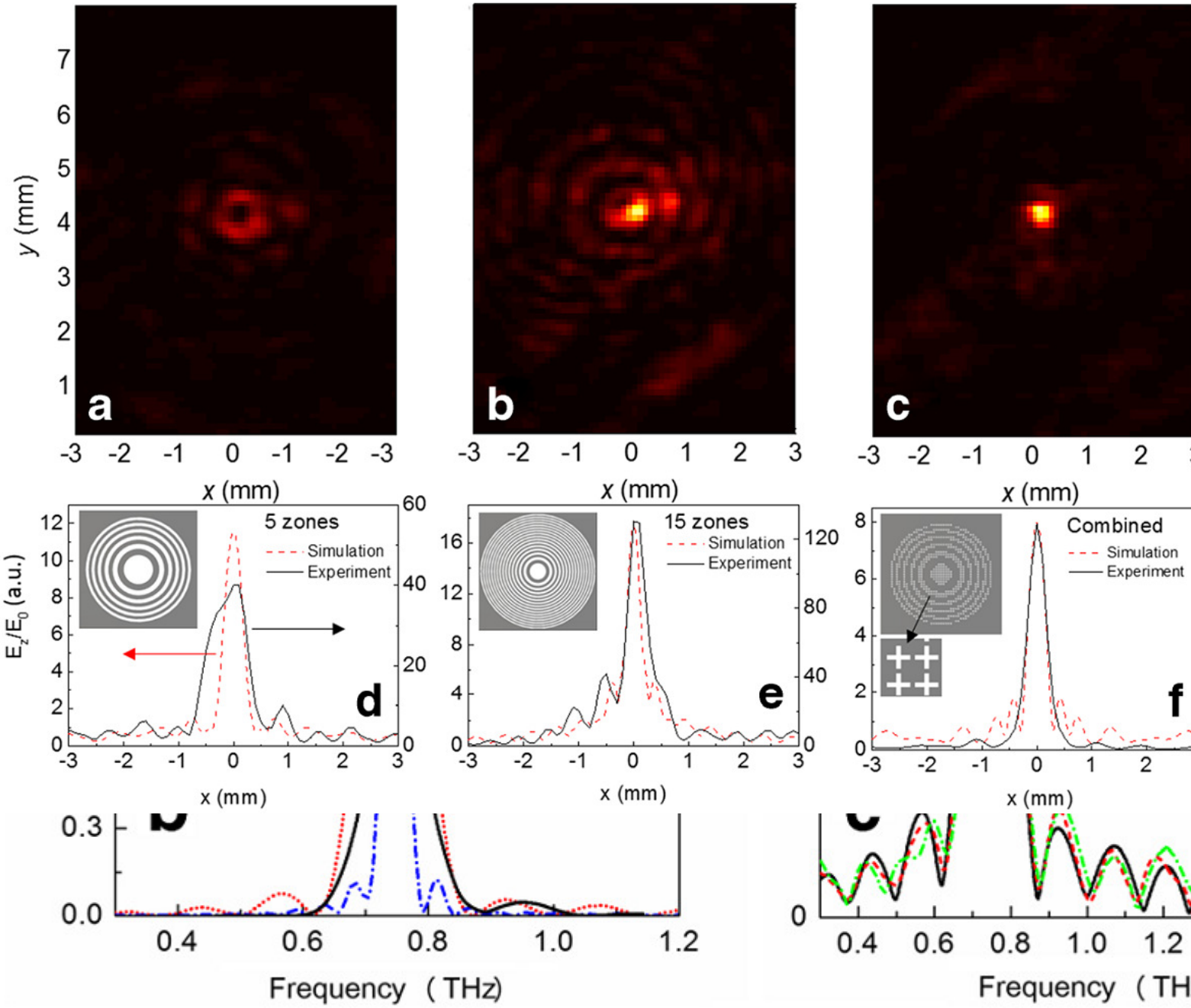



ahz Waves (2014) 35:699–702
2-014-0086-8

# erformance of Terahert
# ated Cross-shape Apert

• K. Madeikis • B. Voisiat • I. Ka
V. Tamošiūnas • G. Valušis

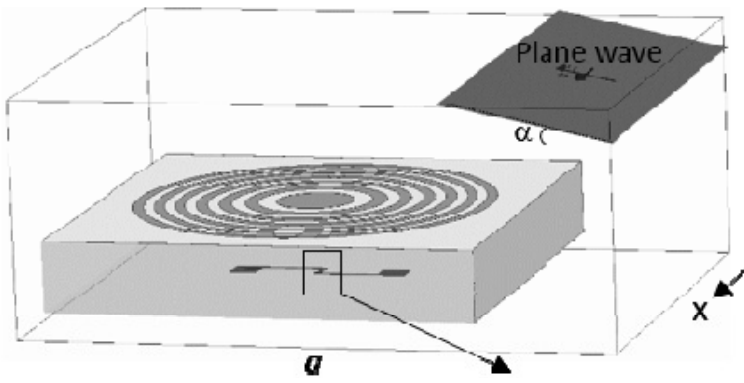


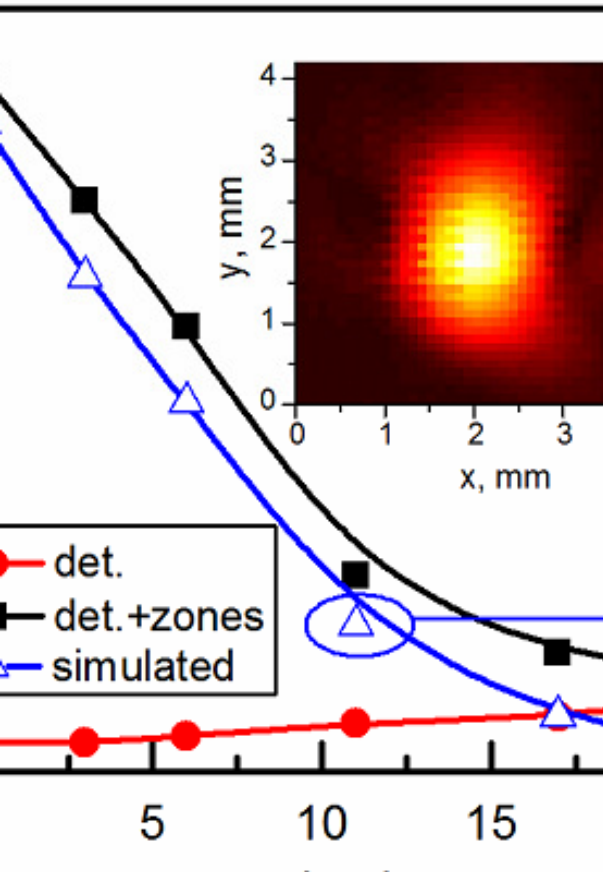



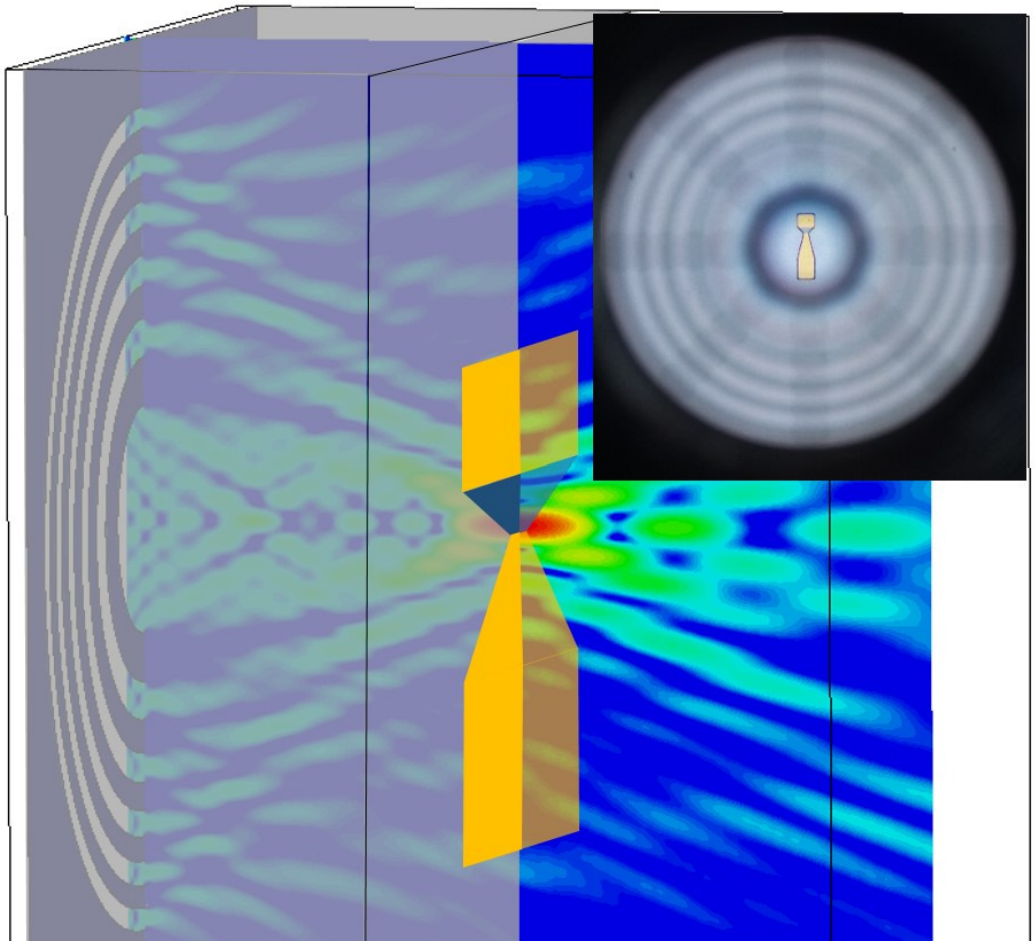
# ip integration of laser-ablated zone for detection enhancement of s bow-tie terahertz detectors

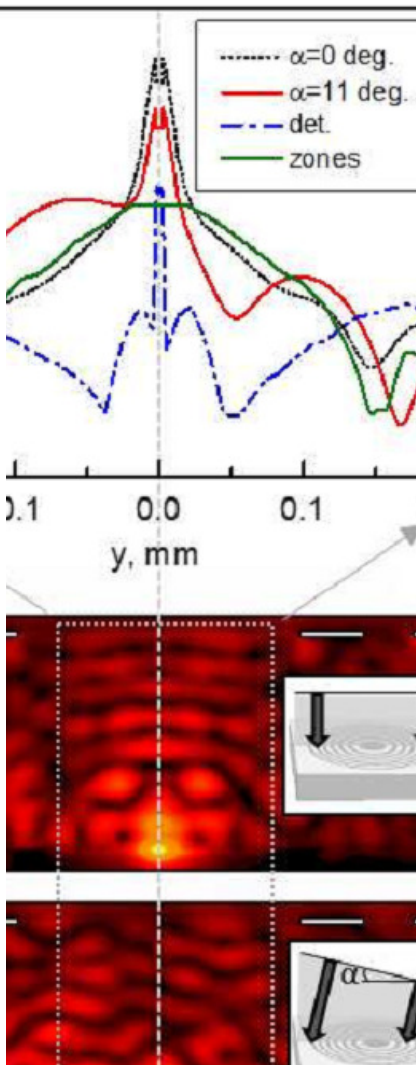
evičius, V. Tamošiūnas, K. Madeikis, B. Voisiat, nas and G. Valušis

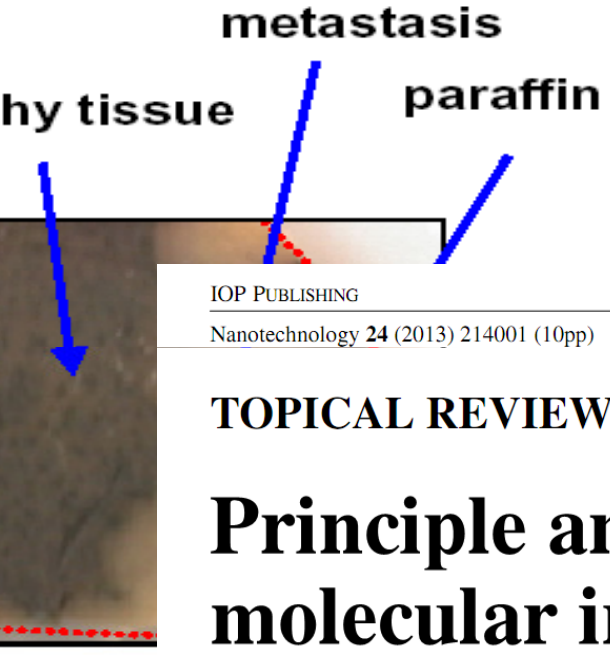
Lett. **50**, featured article, in press (2014)







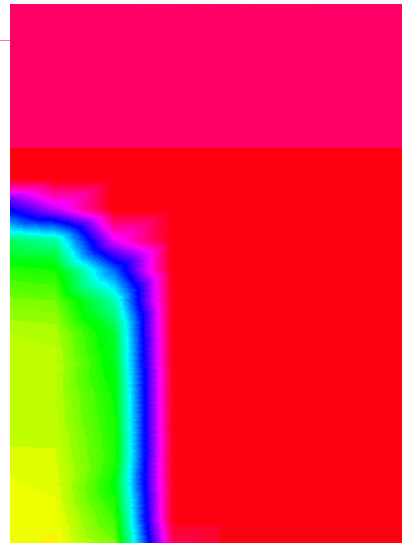

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Nanotechnology **24** (2013) 214001 (10pp) doi:10.1088/0957-4484/24/21/214001

TOPICAL REVIEW

# Principle and applications of terahertz molecular imaging

**Joo-Hiuk Son**

Department of Physics, University of Seoul, Seoul 130-743, Republic of Korea



aging for m



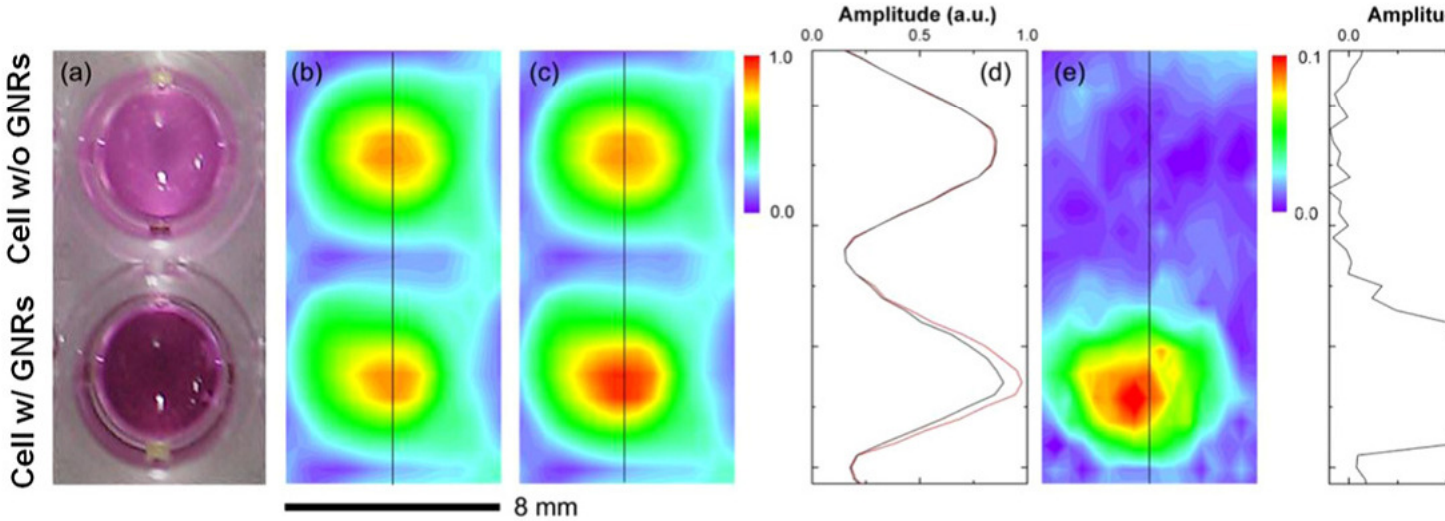


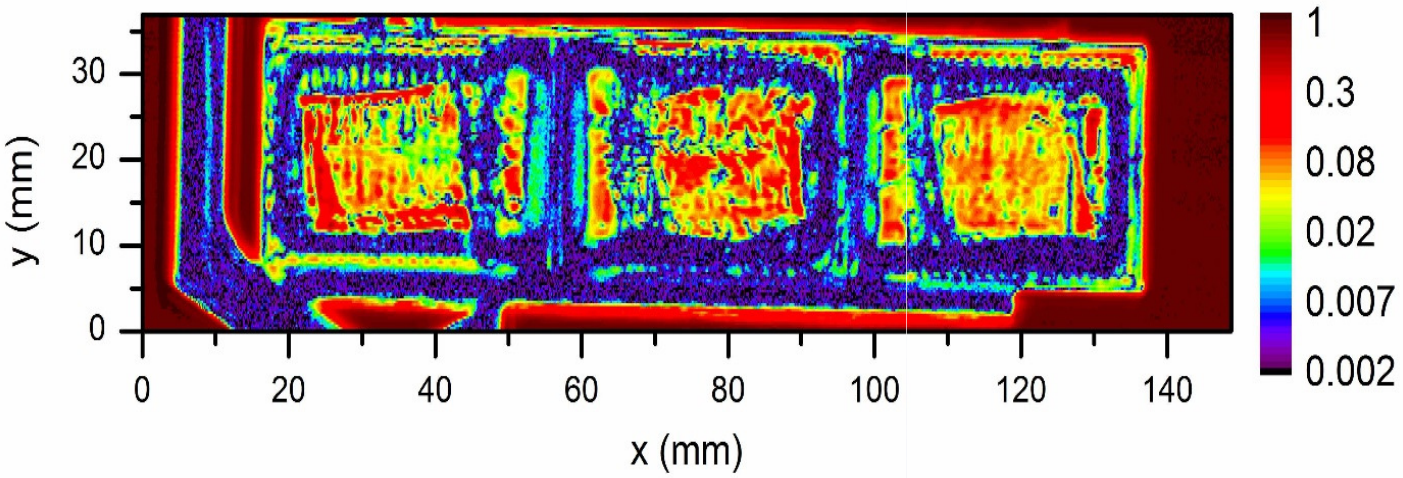

**Figure 5.** Images of A431 cancer cells with and without GNRs. (a) Photograph of the cancer cells; (b) THz image witho

## (Portugal) – Vilnius (Lithuania) cooperation

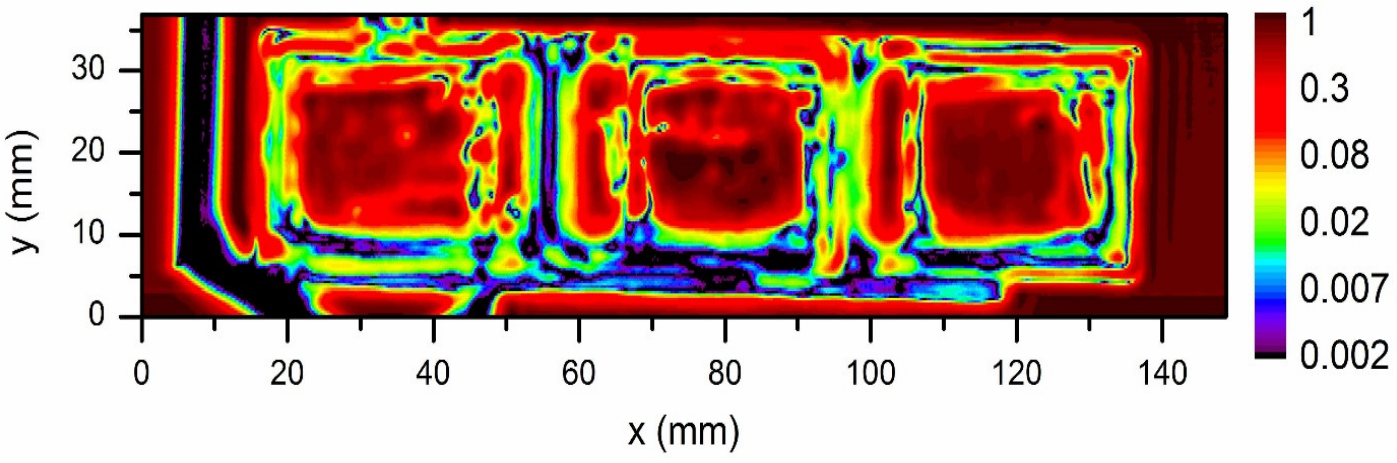
paration for press ( 2014) -- gastric cancer in paraffin



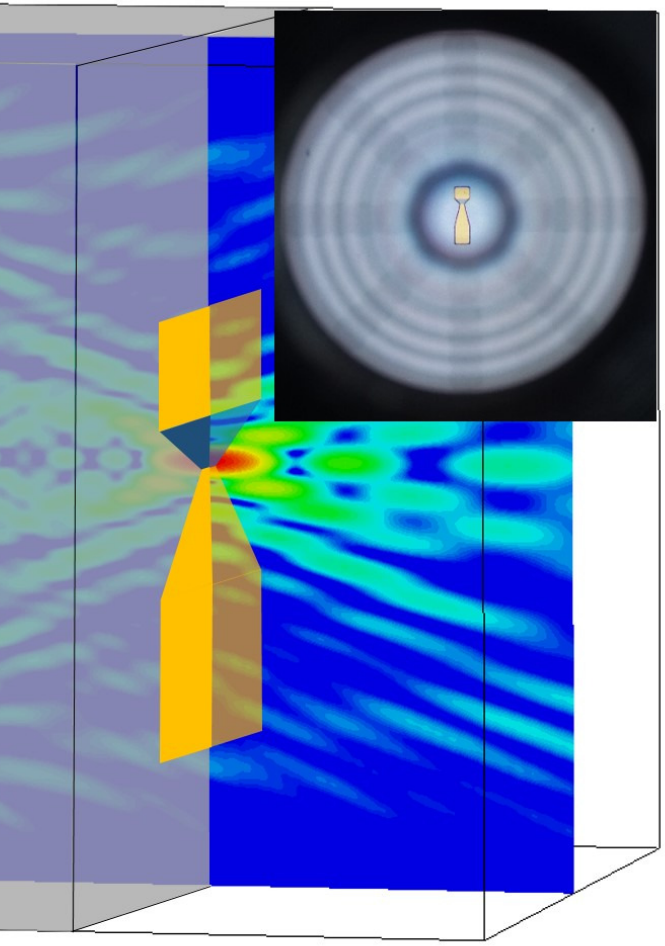
(photo)

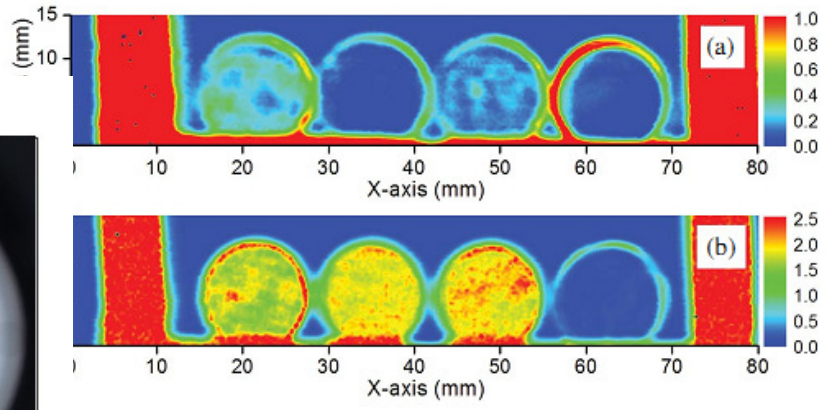


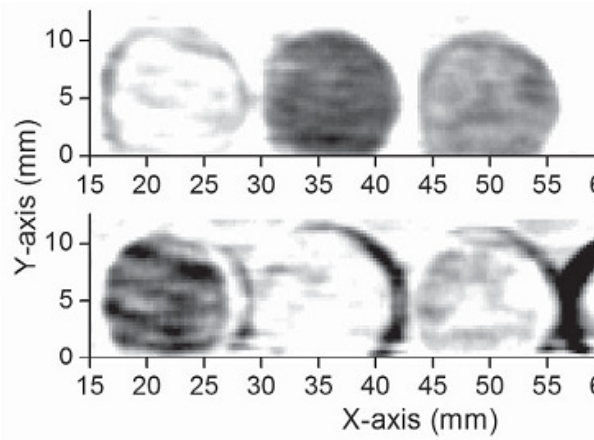

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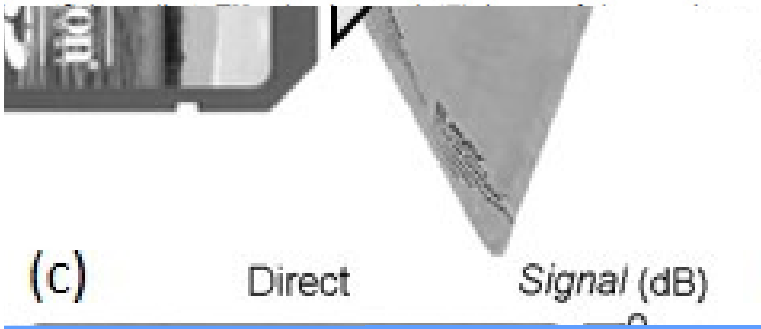


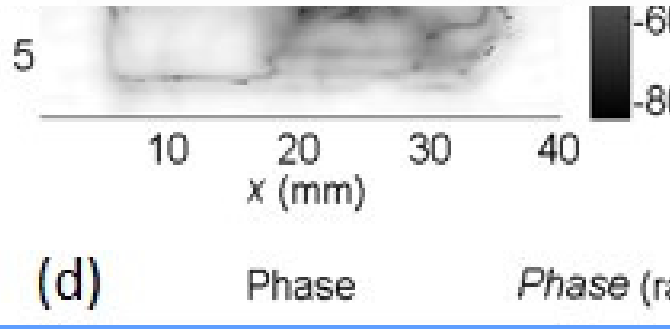

0.194 T






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