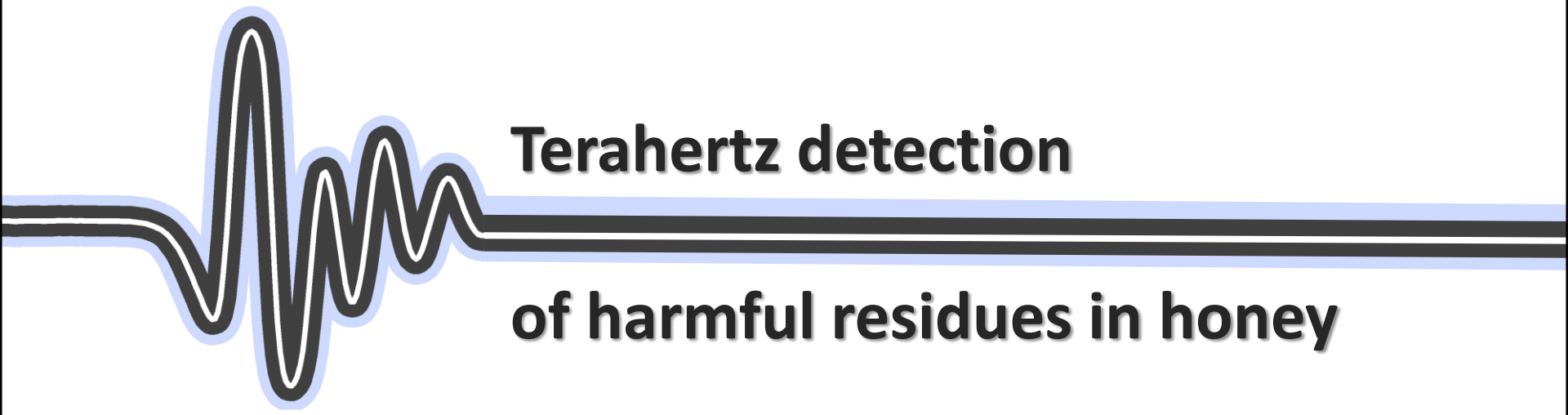
Foundation for Research and Technology-Hellas (FORTH)
Institute of Electronic structure and Laser (IESL)

National Technical University of Athens
School of Applied Mathematical and Physical sciences



Terahertz detection of harmful residues in honey

Dr. M. Massaouti

cost TD1102

PHOTOTECH: BIOSENSORS & BIOCHIPS
21st-25th October 2013 , Athens , Greece

THz radiation and Food industry

Motivation

Food quality and safety control as a tool for regulatory enforcement, protection of consumer's life, health and safety.

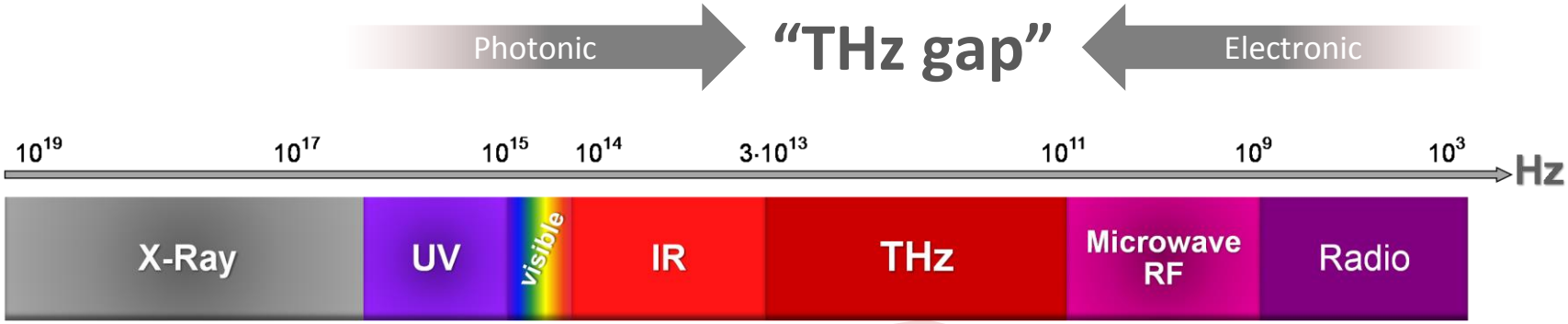
Current analytical methods (few of them…)

- High-performance liquid chromatography (HPLC)
- Gas chromatography (GC)
- mass spectrometry (MS)
- nuclear magnetic resonance (NMR)
- infrared spectroscopy (IR)
- Fluorescence spectroscopy
- Electrochemical (including also biosensors here), and so forth.

New methods for food analysis and inspection:

- ❑ rapid
- ❑ portable (increase of testing capacity)
- ❑ non-destructive
- ❑ with no need of food pre-treatment
- ❑ real-time testing on the production line

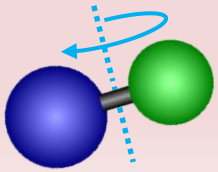
Terahertz radiation



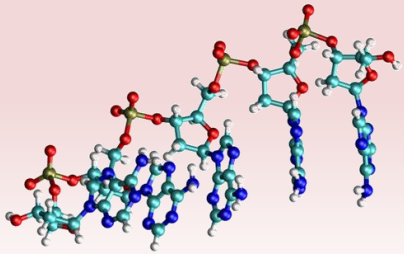
$\lambda \sim 10\mu m - 3mm$

$h\nu \sim 120 - 0.413\ meV$

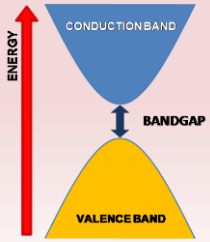
Molecular rotations



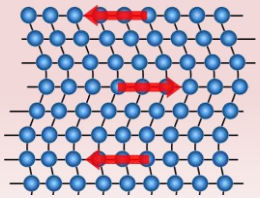
Hydrogen Bonds, Torsions, collective vibrational modes



Superconductivity gap



Lattice phonons



Imaging

National Technical University of Athens

Terahertz radiation

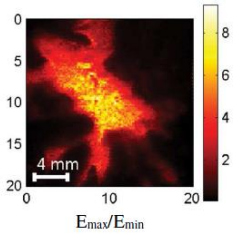
- **Non–ionizing/invasive radiation**
- **Transparent to non-conducting materials** (paper, wood, plastic, etc.)
- **High sensitivity to water**
- **Fingerprint spectrum:** low-frequency torsional and vibrational motion of molecules

Imaging

Security

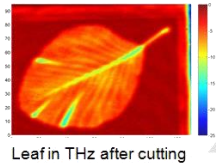
Drugs and explosives

Medical- Cancer



Plant stress

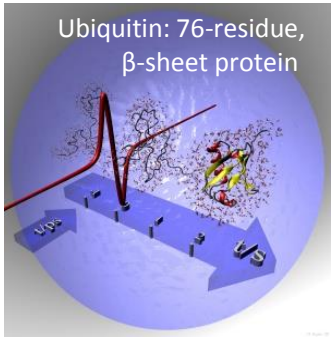
Leaf in visible after cutting



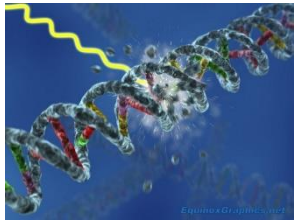
Leaf in THz after cutting

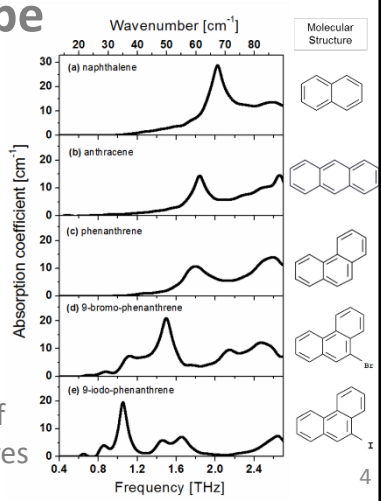
THz pump/probe

Protein folding



DNA damage or repair





Discrimination of molecular structures

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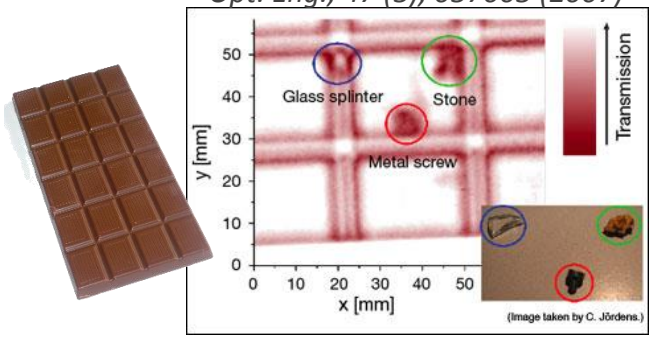
THz radiation and Food industry

- **Non–ionizing/invasive radiation**
- **Transparent to non-conducting materials** (paper, wood, plastic, etc.)
- **High sensitivity to water**
- **Fingerprint spectrum:** low-frequency torsional and vibrational motion of molecules

❖ Detection of foreign bodies in food

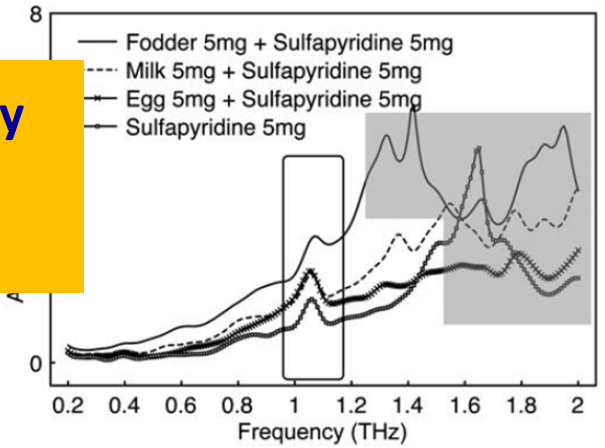
Opt. Eng., 47 (3), 037003 (2007)



❖ Detection of Antibiotics/ pesticides

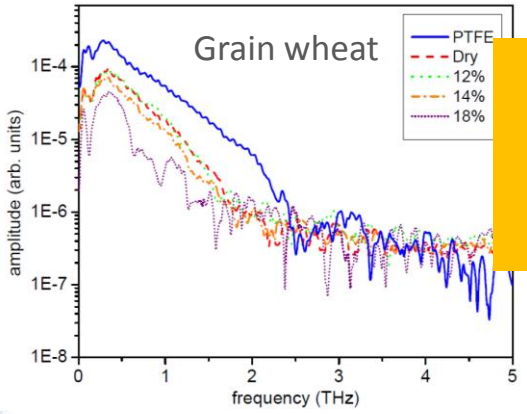
(in milk, egg powders, rice, dried tomato)

Appl. Spectr. Rev.,48, 439 (2013)
Analyst, 136, 1733 (2012)
IEEE Trans., 58, 7, 2064 (2010)



❖ Moisture detection

J Infrar. Milli. Terahz. Waves.33,97 (2012)



THz and Food industry

More to be done!!!

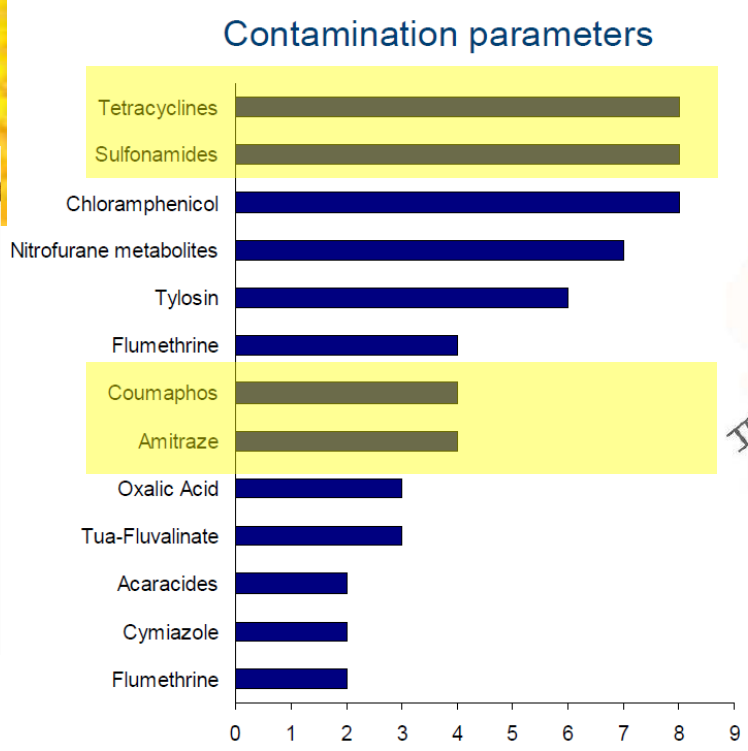
Food industry: Honey

Honey: Natural and healthy product…….

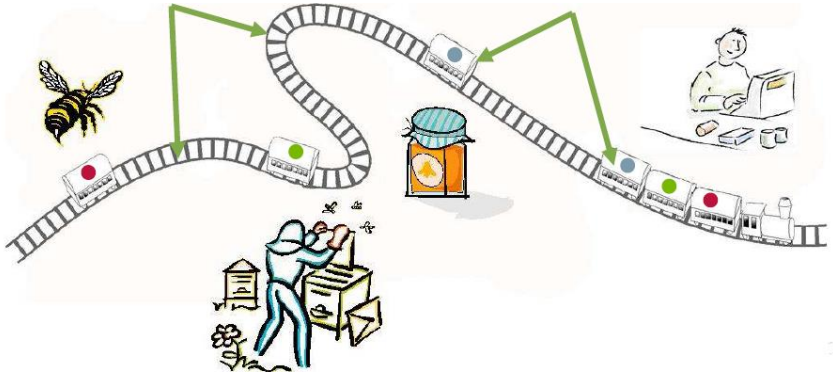
…..Polluted via different sources of contamination

(mainly to improper use of beekeeping practices)

Need: novel detection technologies rapid, non-destructive able to determine the presence of multi-residues in honey.

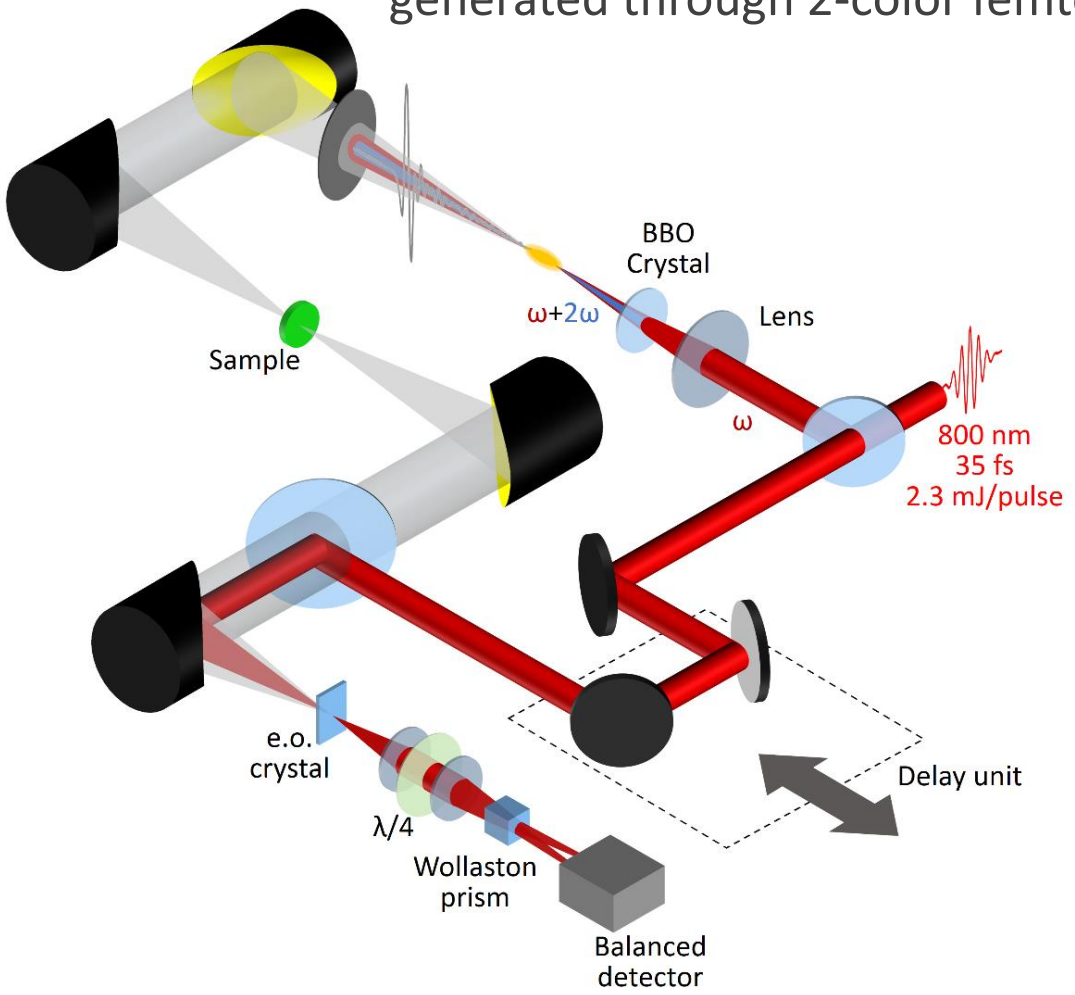


Real-time detection

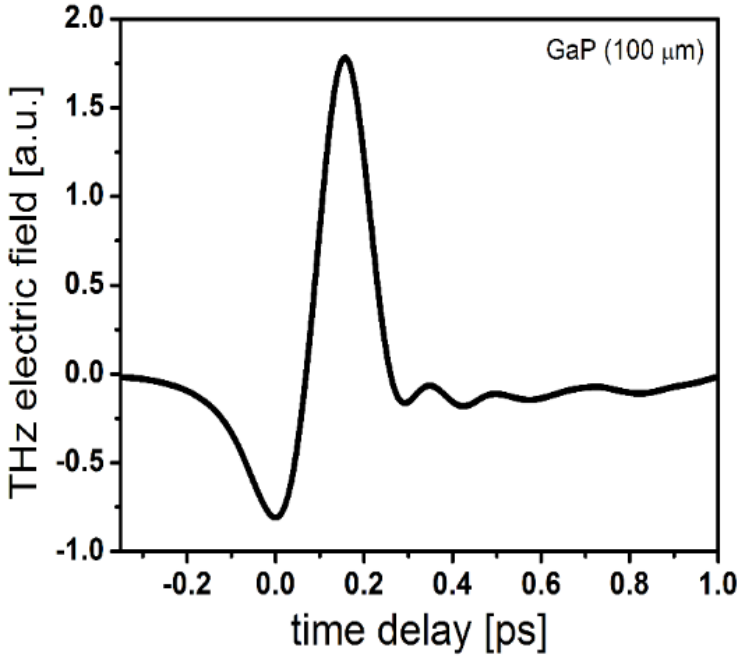


Terahertz source

THz source: Broadband (~0.1-35 THz), intense THz pulses (200 kV/cm) generated through 2-color femtosecond laser filaments in air.



Coherent detection in time domain of the THz electric field.



Terahertz source

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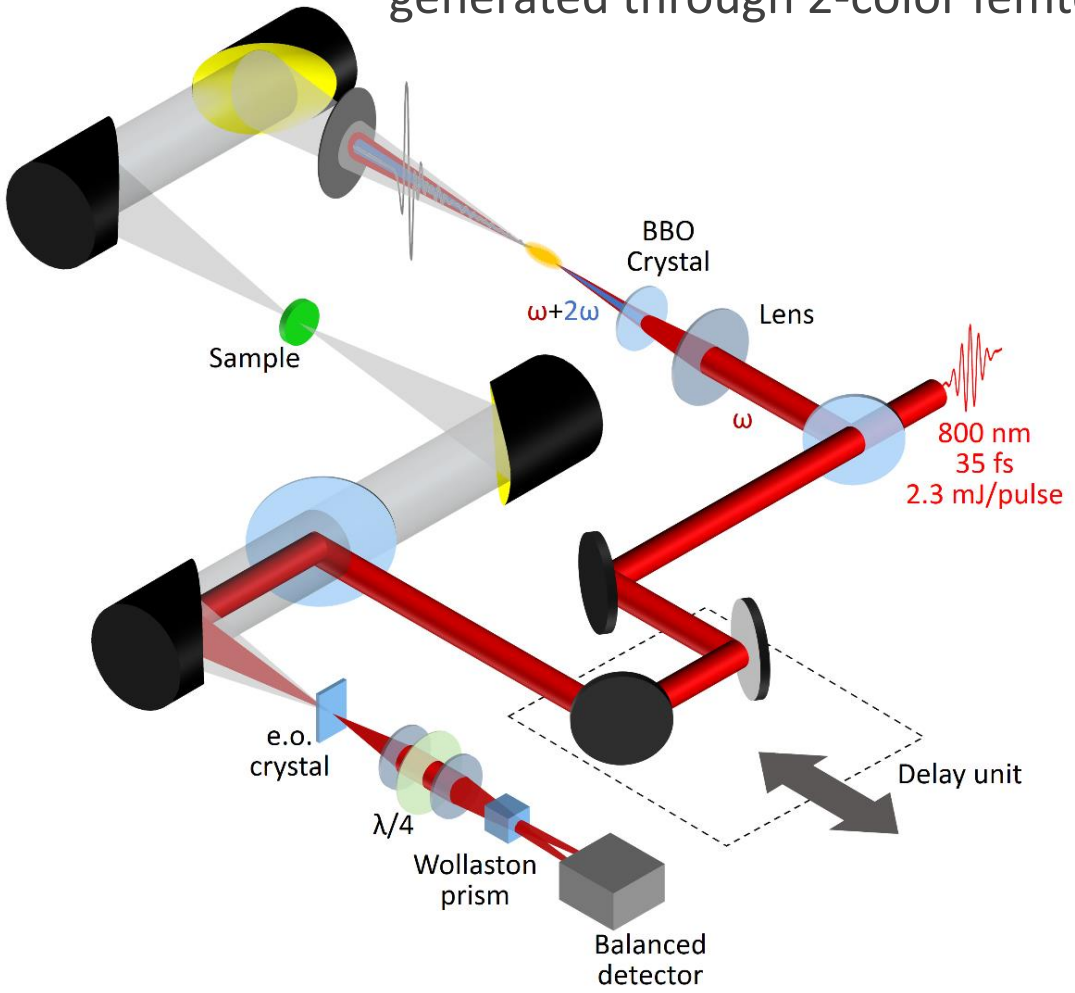
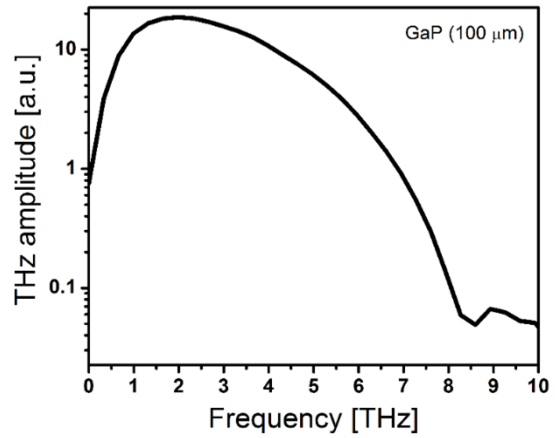
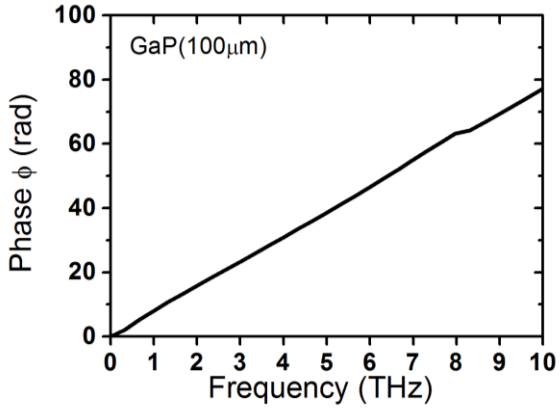


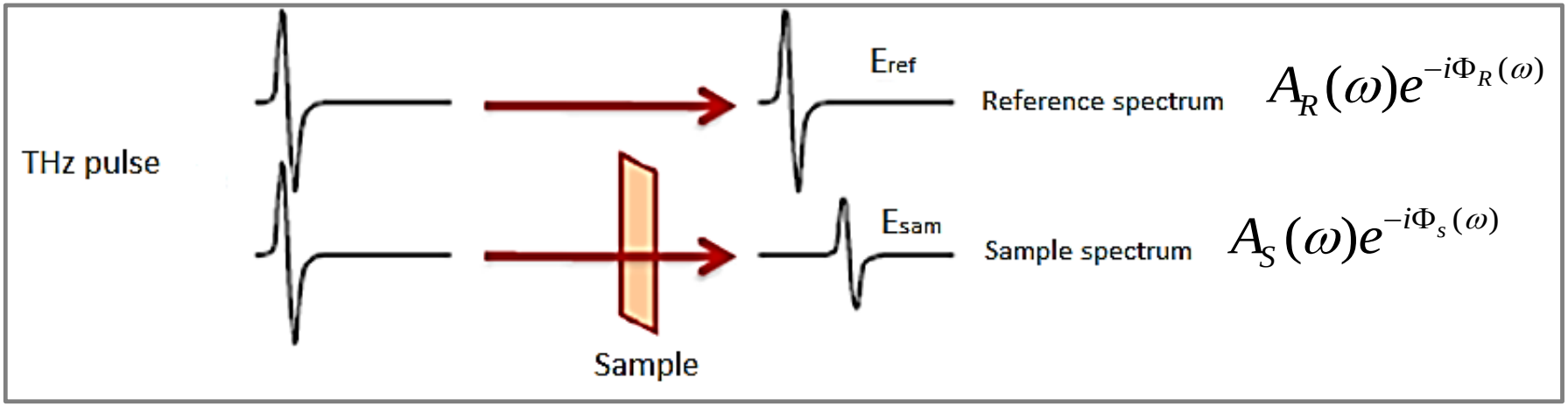
Fourier transform the time signal

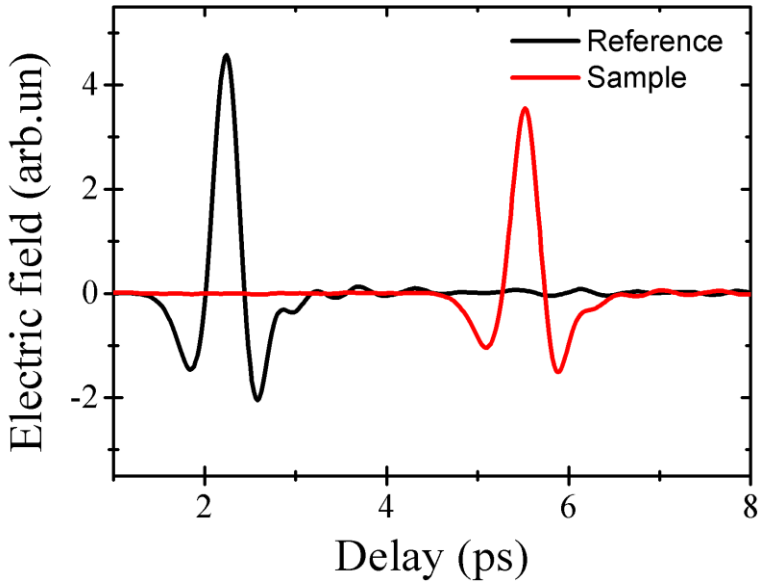
$$\tilde{E}(\omega) \equiv A(\omega)e^{-i\Phi(\omega)} = \int dtE(t)e^{-i\omega t}$$





THz time-domain spectroscopy (THz-TDS)





Refractive index $n = 1 + \dfrac{[\Phi_s(\omega) - \Phi_R(\omega)]c}{\omega d}$

Absorption coefficient: $a = -\dfrac{2}{d}\ln\left(\dfrac{A_S(\omega)}{A_R(\omega)} \cdot T\right)$

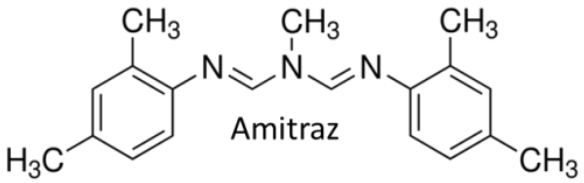
$$T = \frac{(n(\omega)+1)^2}{4n(\omega)}$$

THz spectra: Antibiotics & Acaricides

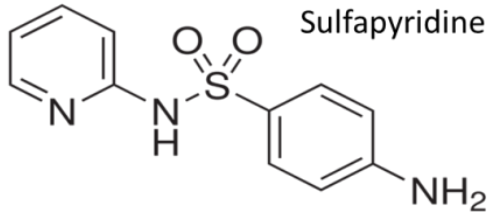
PELLETS: mixture of HDPE powder + chemical compound

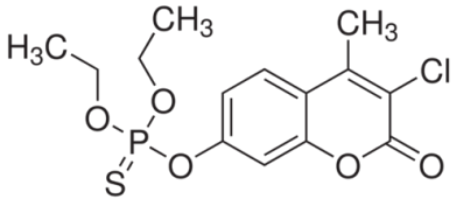
- Concentration 20% w/w
- Thickness ~1 mm
- Diameter 7 mm
- Weight 40 mg

Antibiotics	❑ Sulfapyridine ❑ Sulfathiazole ❑ Tetracycline
Acaricides	❑ Coumaphos ❑ Amitraz

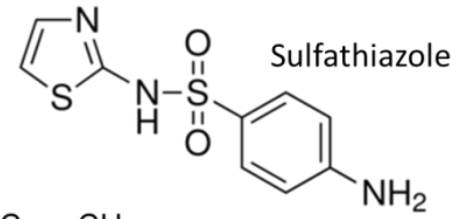


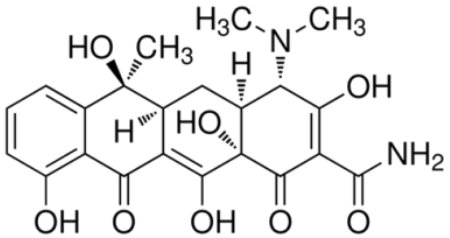
Amitraz





Coumaphos





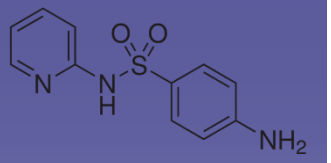
Tetracycline

SAMPLE HOLDER
(pellets)

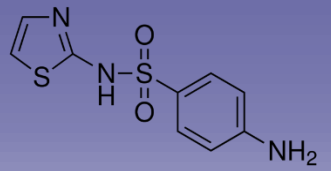
THz spectra : Antibiotics

THz region (0.5-2.6 THz)

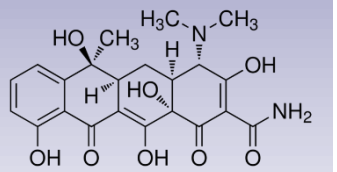
Sulfapyridine

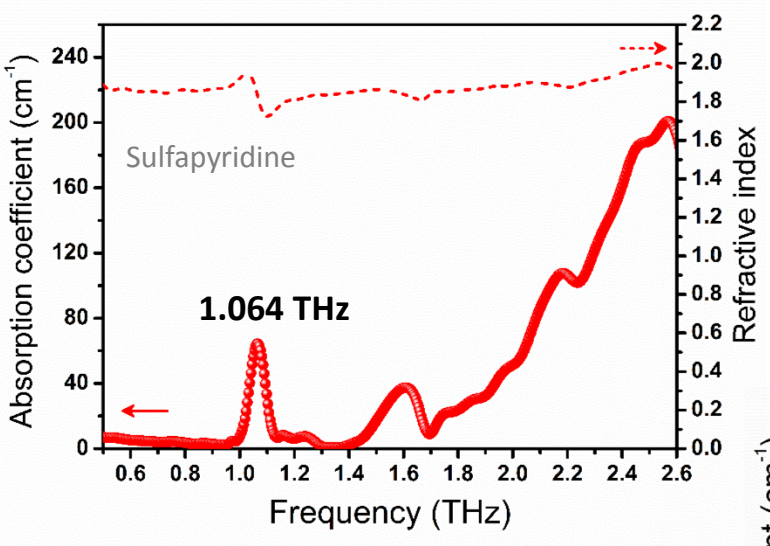


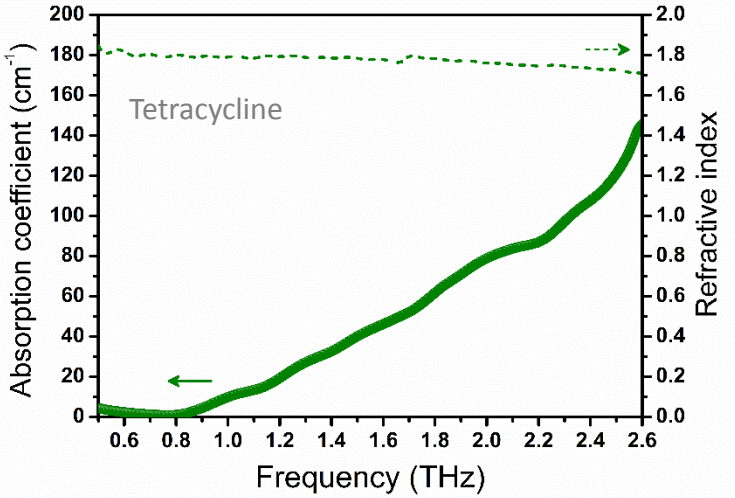
Sulfathiazole



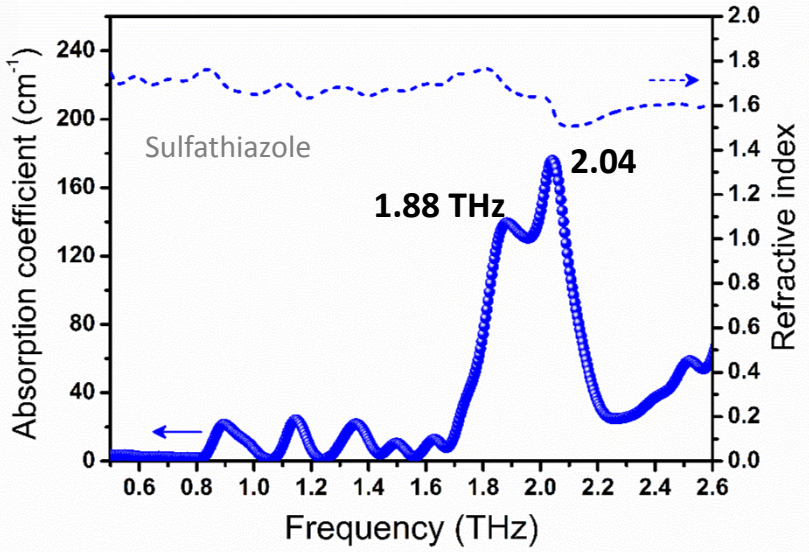
Tetracycline







Distinct resonance peaks in the THz regime

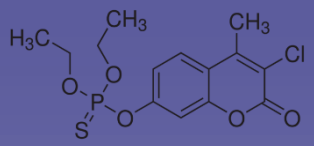


Massaouti et al. J. Appl. Spectr. (2013)

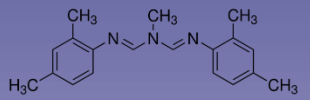
THz spectra : Acaricides

THz region (0.5-2.6 THz)

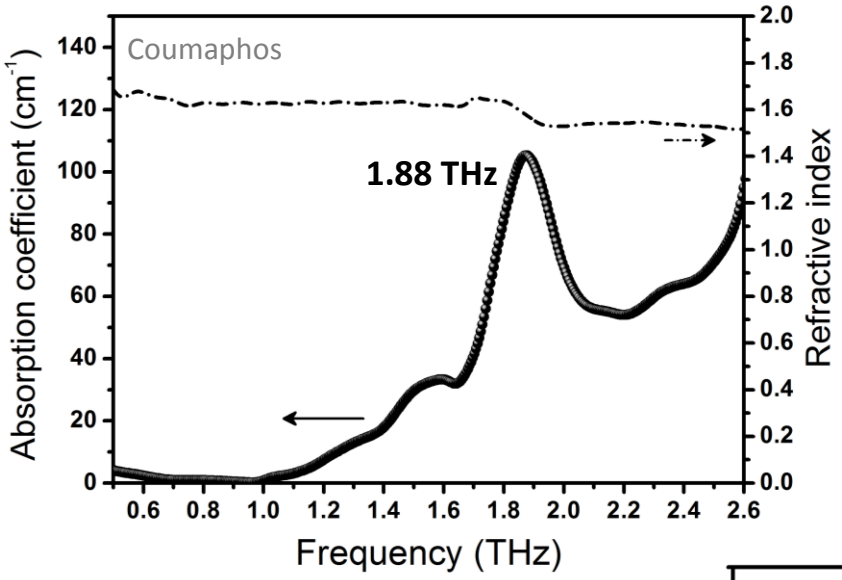
Coumaphos



Amitraz



Massaouti et al. J. Appl. Spectr. (2013)

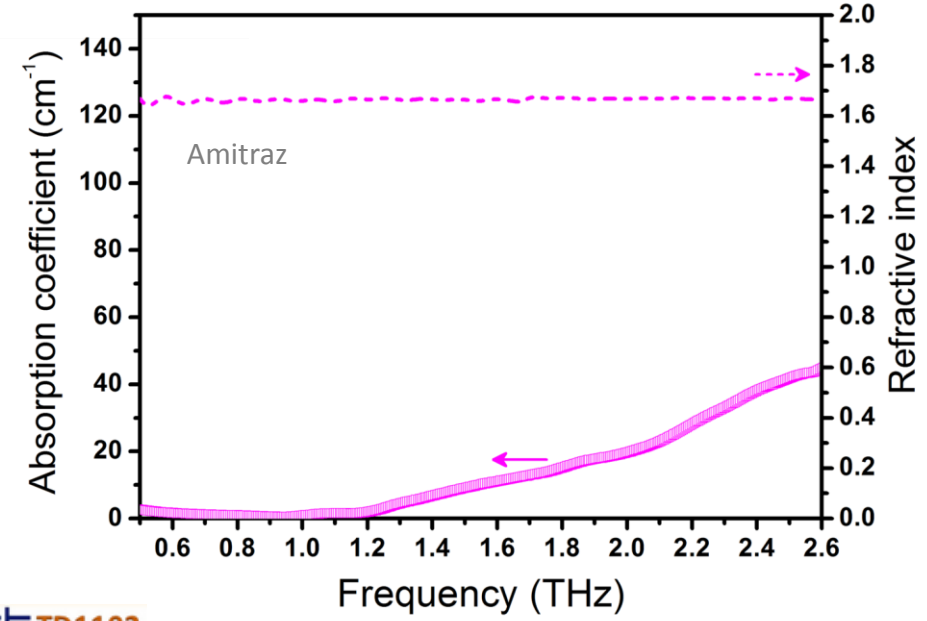


Distinct resonance peaks (0.5-2.6 THz)

↓

Discrimination of:

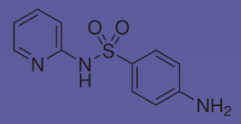
- ❑ **Sulfapyridine**
- ❑ **Sulfathiazole**
- ❑ **Coumaphos**



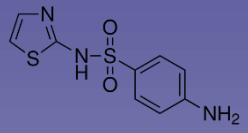
THz spectra : Antibiotics

THz region (0.5-6.0 THz)

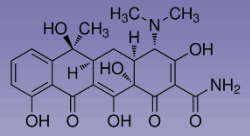
Sulfapyridine



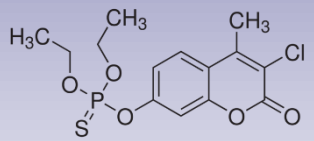
Sulfathiazole



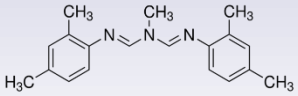
Tetracycline

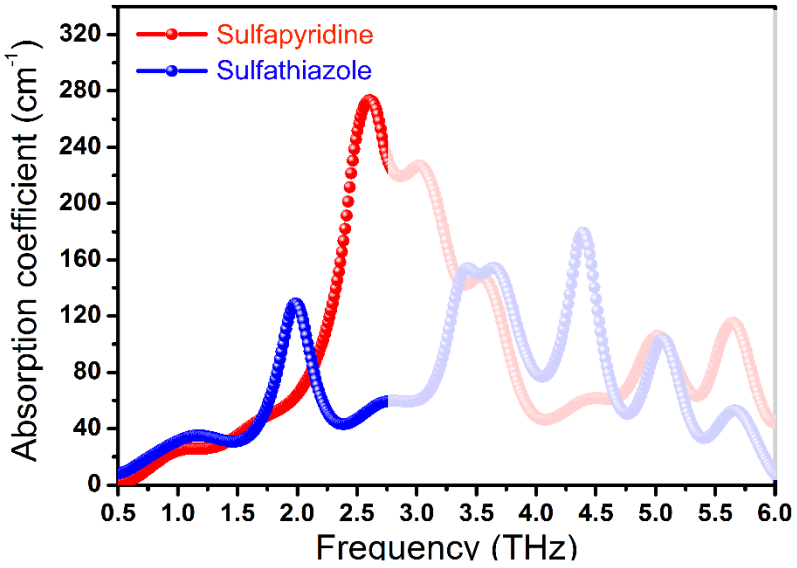


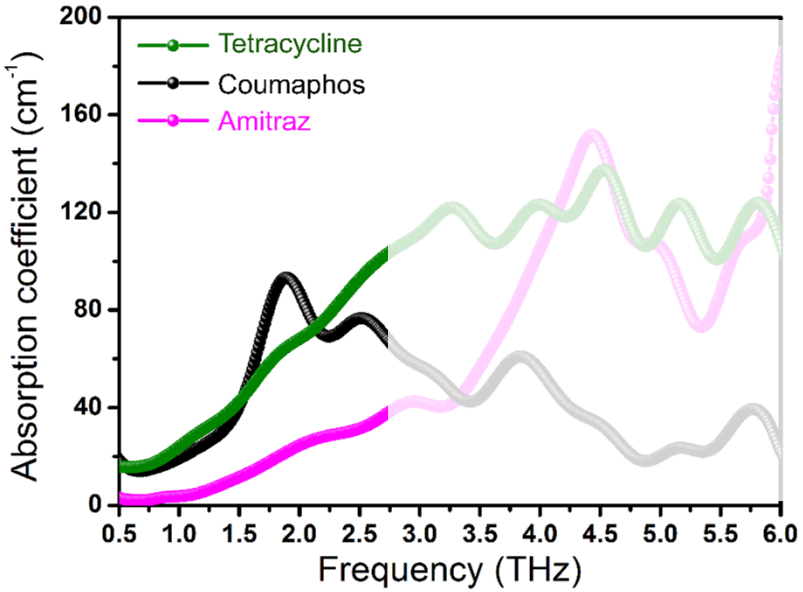
Coumaphos



Amitraz







Detection in a wider THz region
0.5-6.0 THz
↓
Additional resonance peaks
↓
Discrimination of:

- ❑ **Sulfapyridine**
- ❑ **Sulfathiazole**
- ❑ **Coumaphos**
- ❑ **Amitraz**

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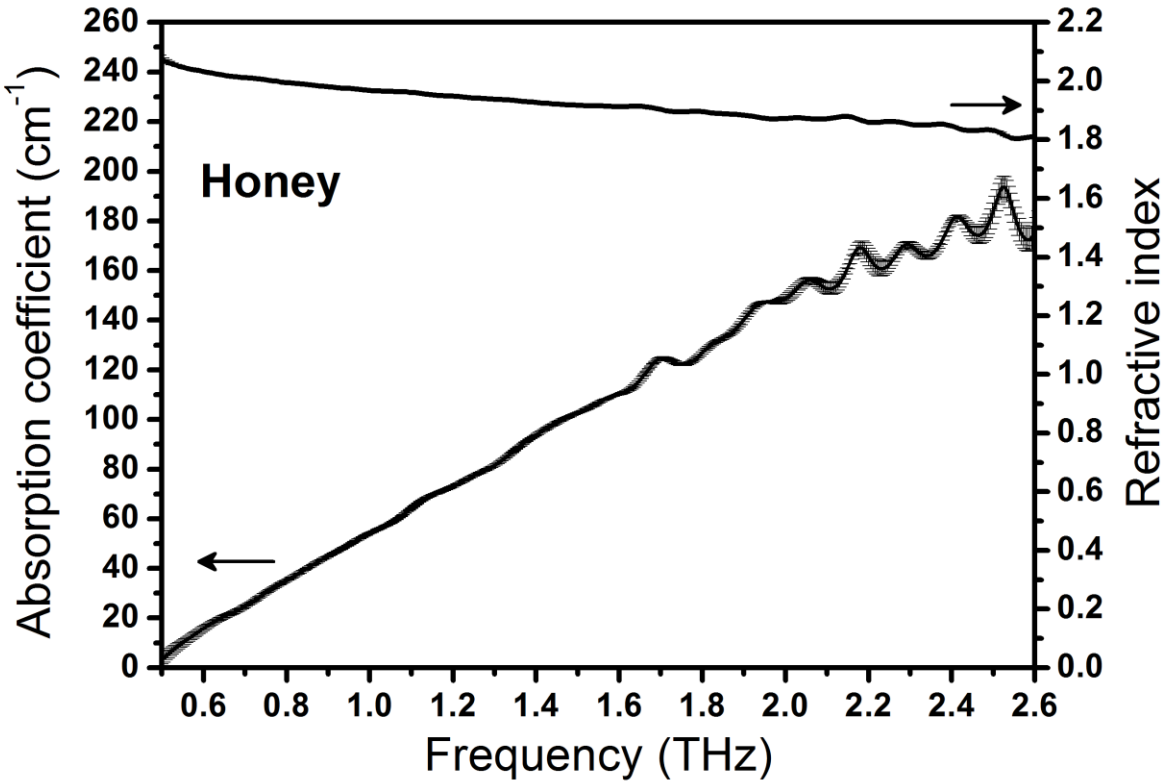
THz spectrum of honey

Massaouti et al. J. Appl. Spectr. (2013)

SAMPLE HOLDER

(liquids)



Highly absorptive: α = 50 cm^{-1} (1 THz)

Refractive index: n = **1.8**

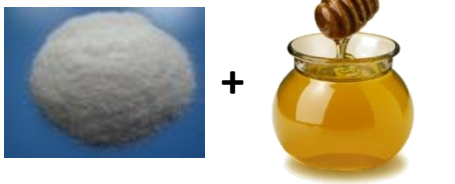
Sulfapyridine in honey

SAMPLE HOLDER
(liquids)

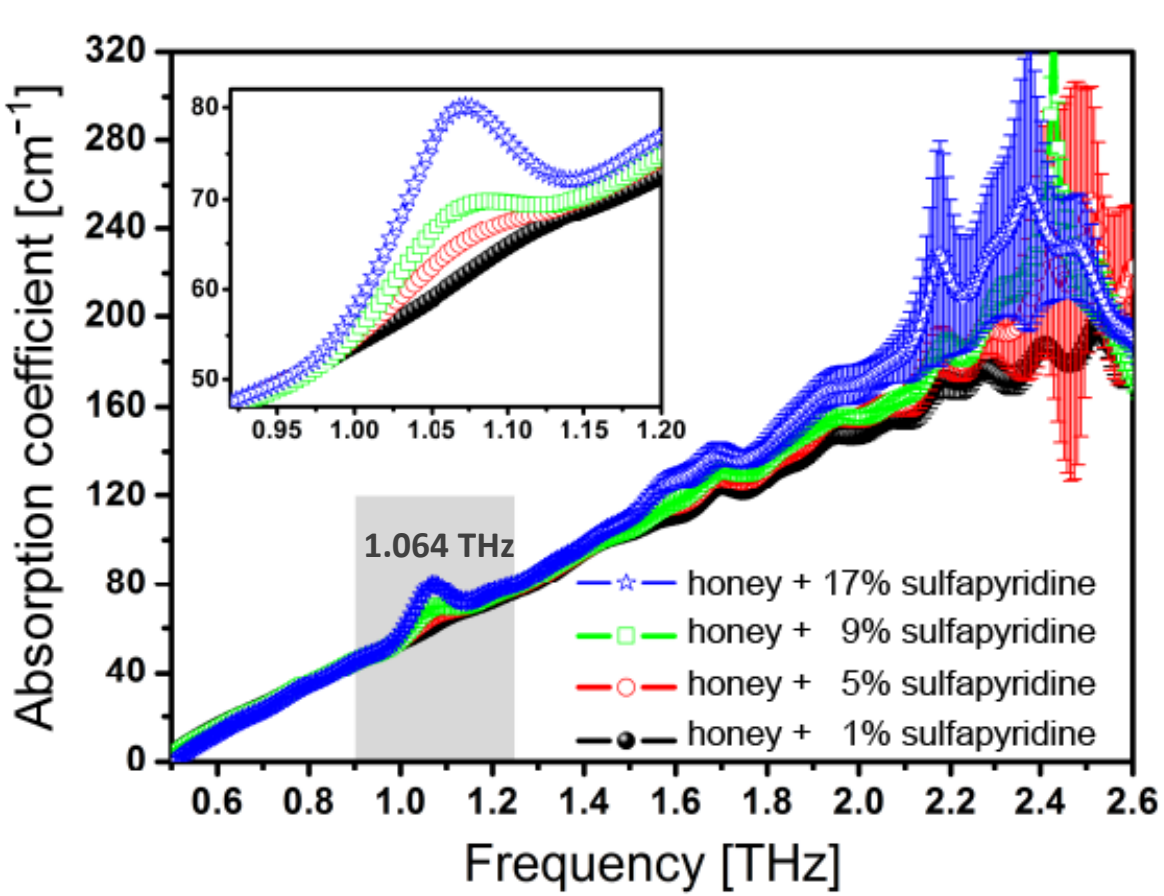
Spacer 620 μm

Mixture:

Sulfapyridine + Honey



different concentrations (w/w)



$$\alpha_{mixture} \propto \frac{A_{mixture=honey+sylfapyridine}}{A_{THz\ ref.}}$$

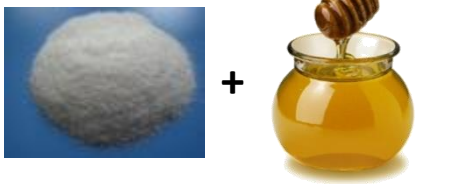
Massaouti et al. J. Appl. Spectr. (2013)

Sulfapyridine in honey

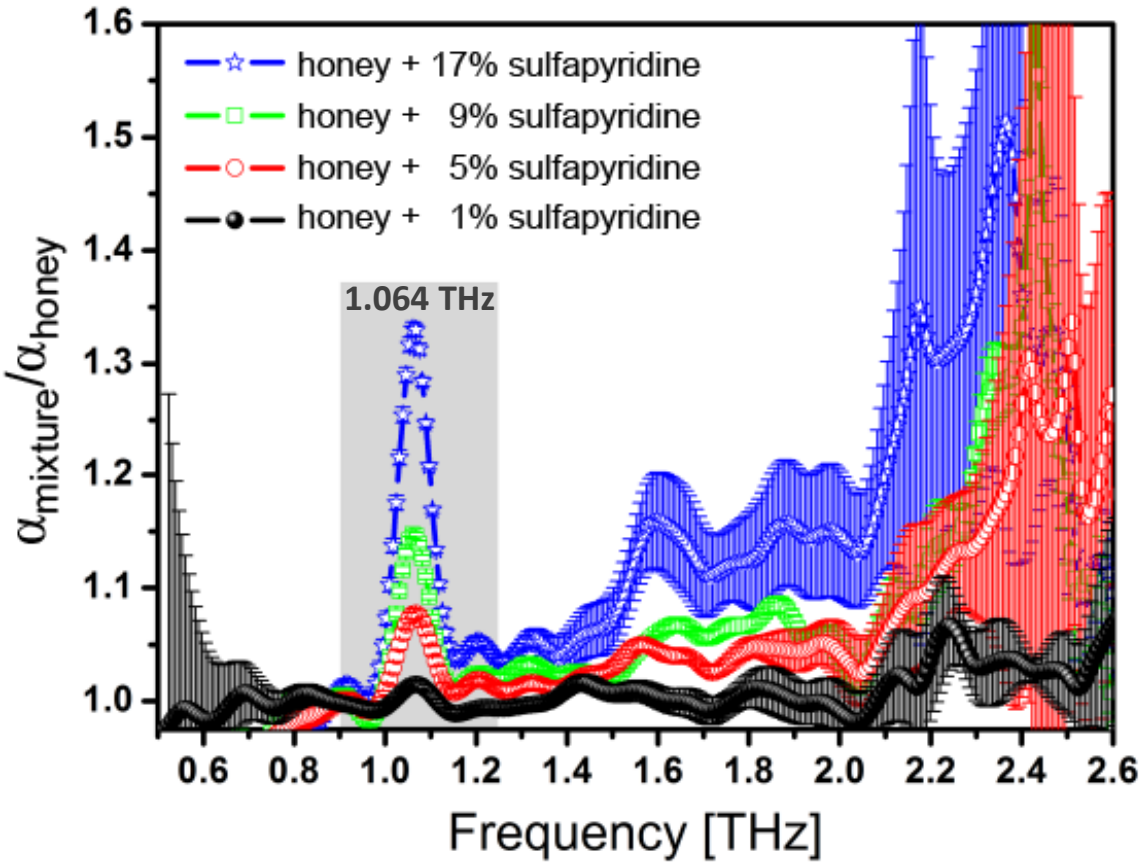
SAMPLE HOLDER
(liquids)

Mixture:

Sulfapyridine + Honey



different concentrations (w/w)



Detection of Sulfapyridine in honey at relatively low concentrations (1% w/w)

Sulfapyridine & Sulfathiazole in honey

Massaouti et al. J. Appl. Spectr. (2013)

Multiple residues in honey

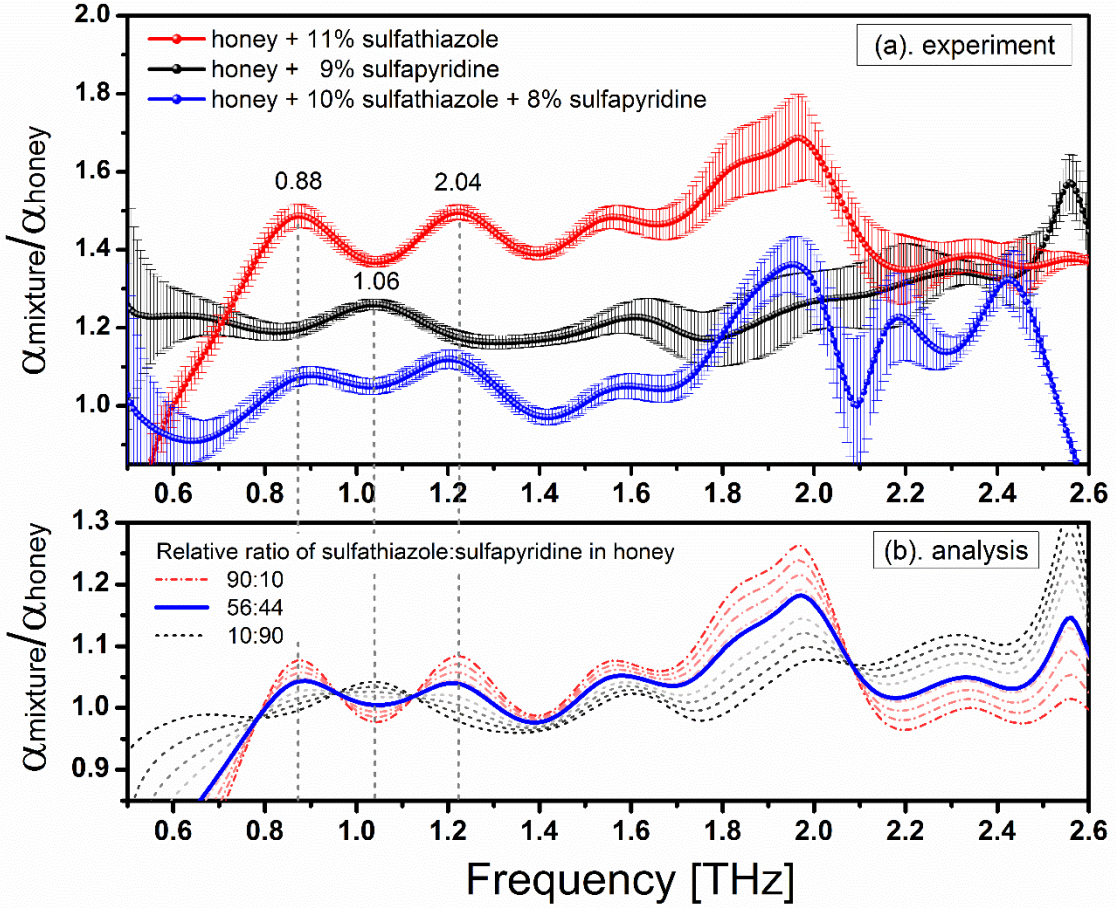
Mixture:

Sulfapyridine (9%) and Sulfathiazole (11%) +

Honey

$$\alpha_{\text{binary mixture}} / \alpha_{\text{honey}} = \sum_i B_i \cdot \alpha_i / \alpha_{\text{honey}}$$

$$i = sulfapyridine, sulfathiazole$$



Potential of THz-TDS to be used in the near future as a fast, real-time technique for detecting and discriminating multi-residues strictly related to food safety issues.

National Technical University of Athens

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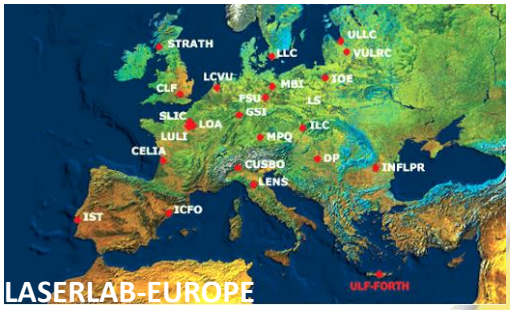
UNIS Ultrashort Nonlinear Interactions and Sources Lab



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