

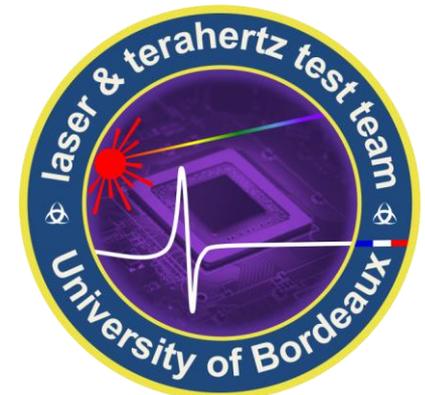
Interaction THz / matière biologique : état des lieux

Présenté par Jean-Paul GUILLET

université
de BORDEAUX



ims





Equipe laser et THz IMS Bordeaux

université
de BORDEAUX



5 permanents
5 non permanents

Contrôle non destructif
Test de circuits intégrés

lt3.fr

Plateforme ATLAS

Laser femtoseconde et continu
Systèmes Terahertz impulsions
Systemes THZ continu

Laser Sources

- [1064 picosecond](#)
- [400 nm to 2,6 \$\mu\$ m femtosecond](#)
- [800 nm - 900 \$\mu\$ J - 90 fs](#)
- [800 nm picosecond](#)
- [CW and others](#)
- [Mai-Tai ; 690 to 1040 nm 100 fs](#)

Terahertz Systems

- [Air plasma intense THz pulse](#)
- [Custom TDS setups](#)
- [Emission microscope](#)
- [FMCW Radar imaging](#)
- [MC2 Millicam](#)
- [Millimeter wave systems](#)
- [Teraview TeraPulse 4000](#)
- [Teraview TPS 3000](#)

Plan de la présentation

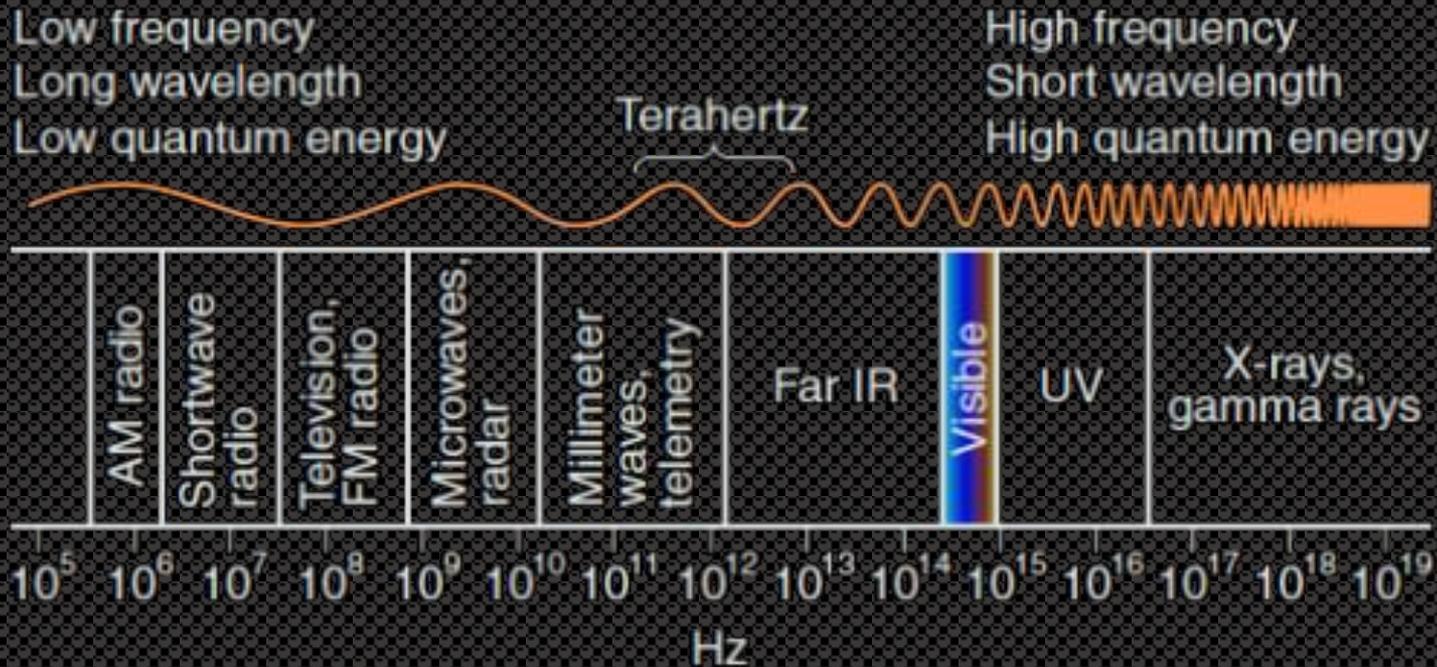
Ondes terahertz

Interactions avec les tissus biologiques

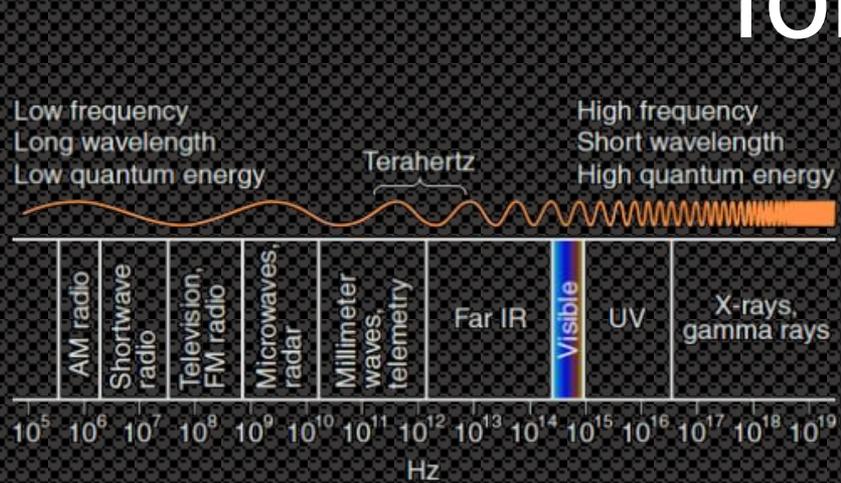
La question des normes

Conclusion

Bande de fréquence terahertz



Le terahertz c'est à la fois



Wavelength (μm)

De l'optique

Miroirs

Beamsplitter

Lentilles

Lasers

Optique

Hyperfréquences

Traitement du signal

Des micro-ondes

Antennes

Semiconducteurs

Guides

Propriétés des ondes THz



$$\lambda = \frac{c}{f}$$



Fréquence entre 100 GHz et 10 THz

Longueur d'onde de 3 mm à 30 μm

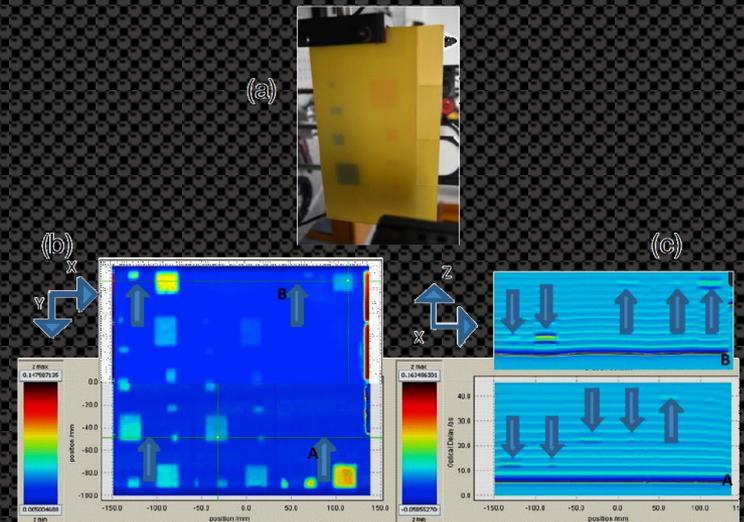
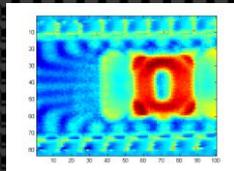
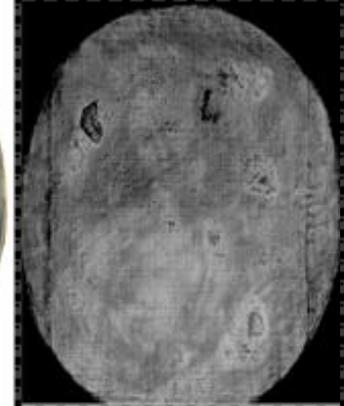
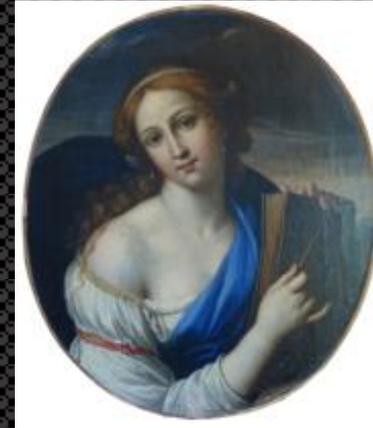
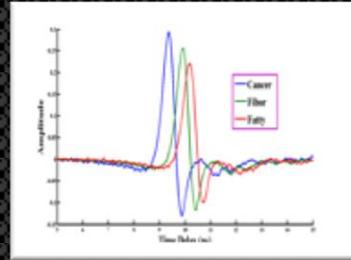
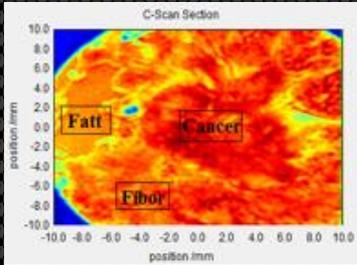
Traverse la plupart des diélectriques

Fortement absorbé par eau & molécules polaires

Réflexion totale sur le métal

Non ionisant

Spectre large d'applications

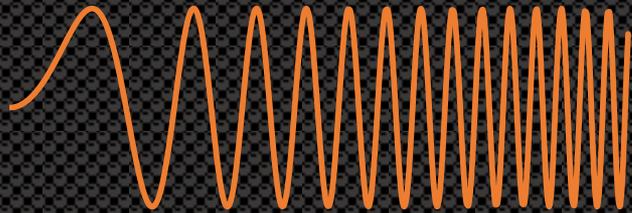


Types de rayonnements



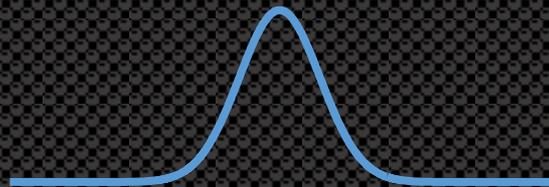
Continu

Imageurs



Modulé

Radar FMCW

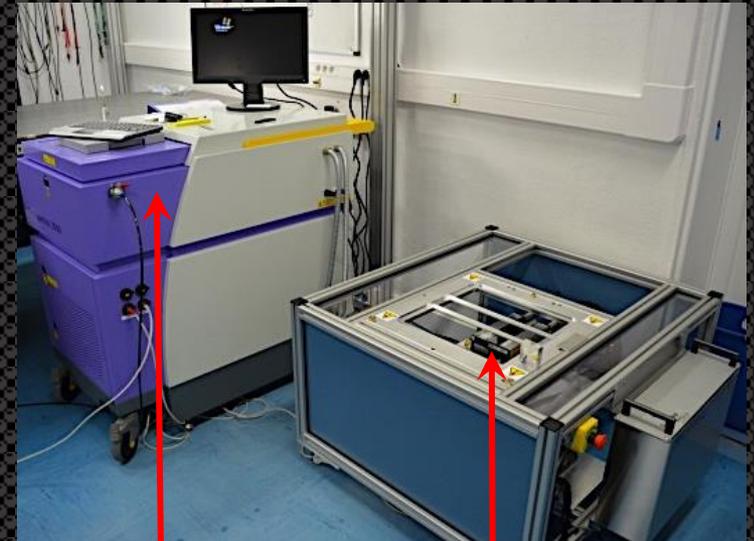
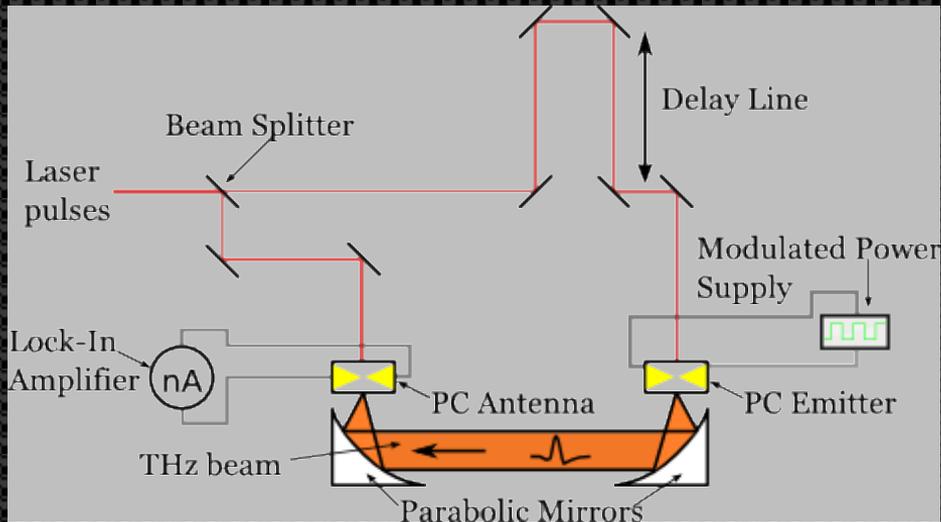


Impulsionnel

Imagerie 2,5D

Spectroscopie

Systeme de mesure



Systeme en
transmission

Systeme en
reflexion

Imaging by millimeter 2D and 3D imaging

Passive

Millicam-MC2



- 8 receiver array
- Frequency: 90 Ghz
- Mechanical scanning
- Scan time: few sec
- Image size: 2x1 m² at 2.5 m distance



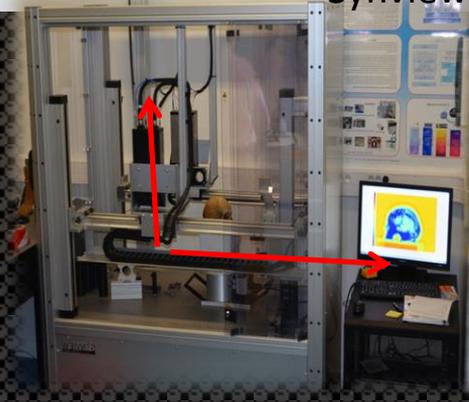
Continuous Wave (CW)



- Sources: Gunn diode
84 GHz, 50 mW
287 GHz, 14 mW
- Detectors: Schottky diode
- Lock-in detection
- Transmission
- Module
- (X, Y, Θ)

Frequency modulated CW

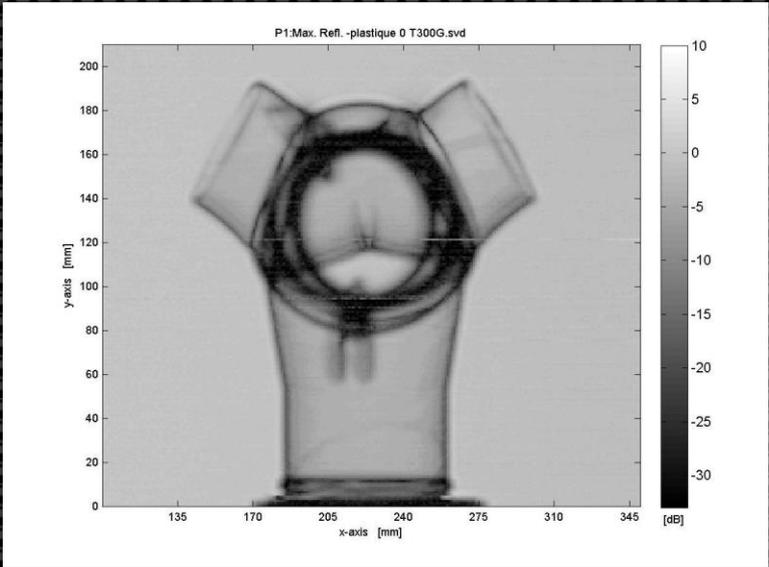
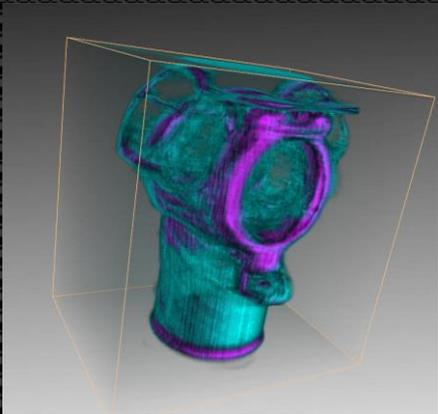
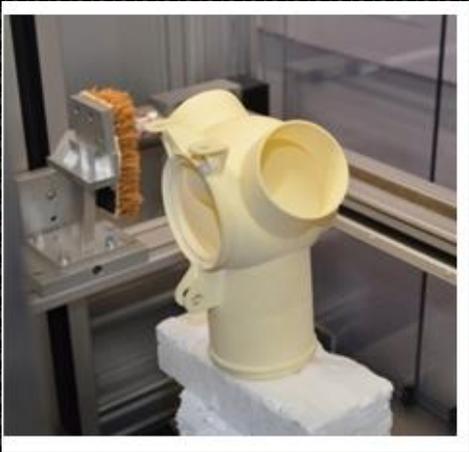
Synview



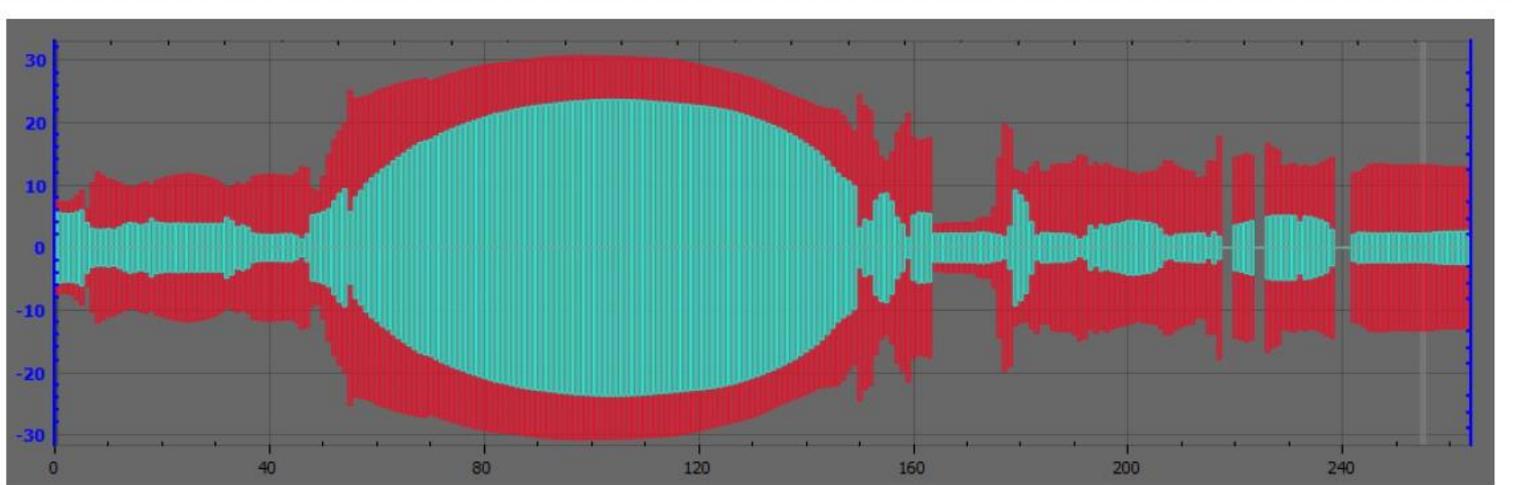
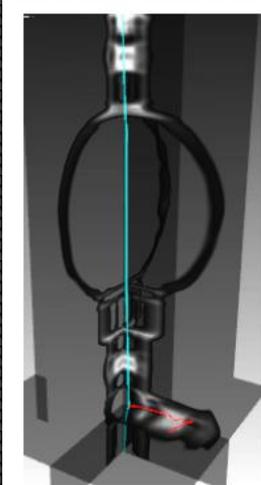
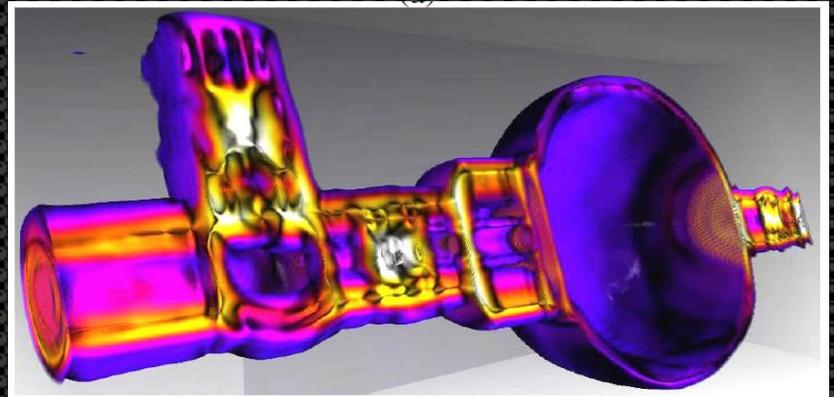
- Frequency range
Head 100: [60 - 110] GHz
Head 300: [230 - 320] GHz
- Transmission & reflection
- Module & phase
- (X, Y, Θ)

Cavity analysis

The sample made by Polyamide12 AM. The role of this multi valve is a piece that is mounted on on civilian aircraft air circuit to regulate the temperature in the cockpit. The AM allows the fabrication of the rolling during the process.



Cavity analysis



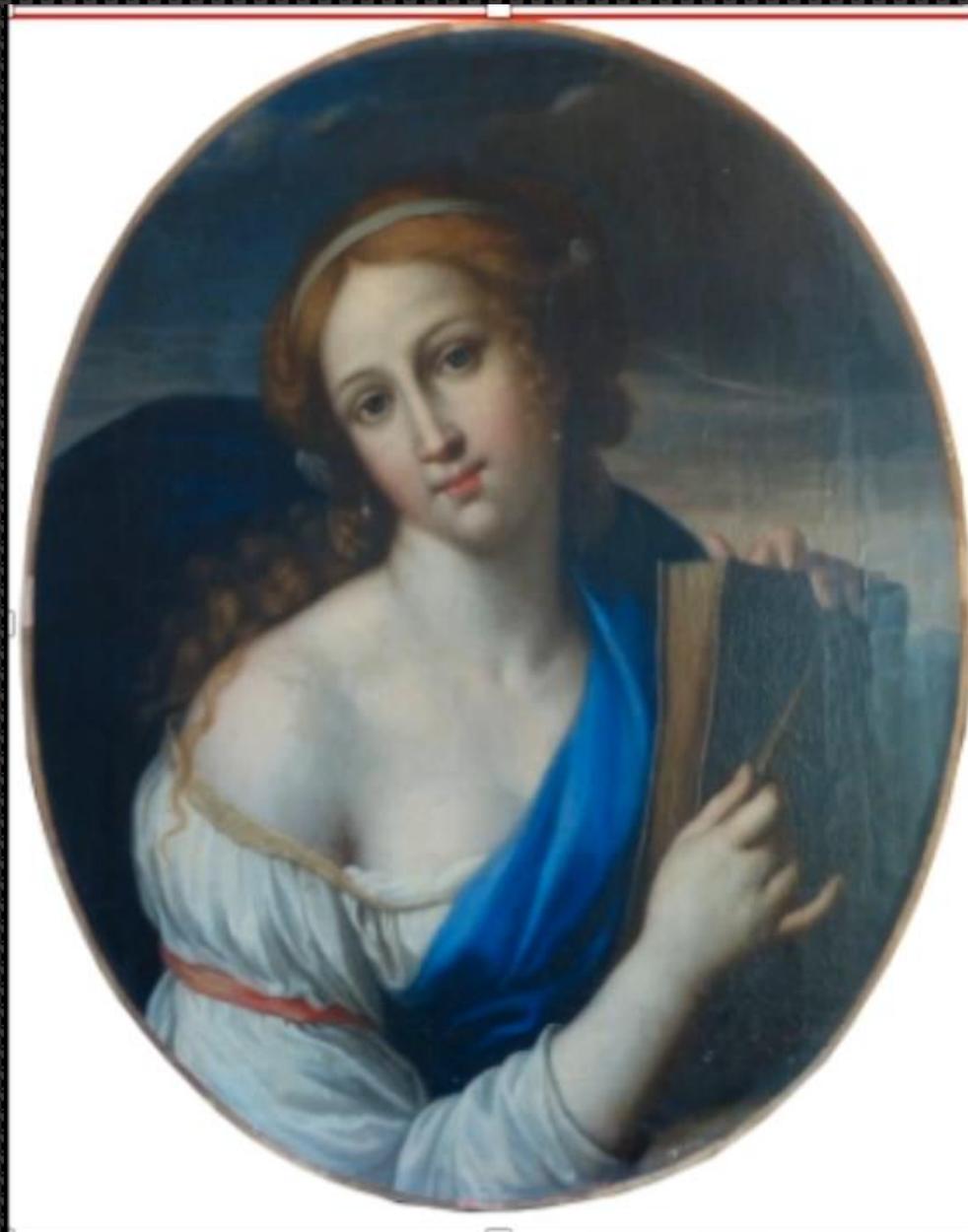
3D Visualization

Longitudinal resolution



Oil painting
78cm by 62cm

Alleged dating of the
work : XVII century

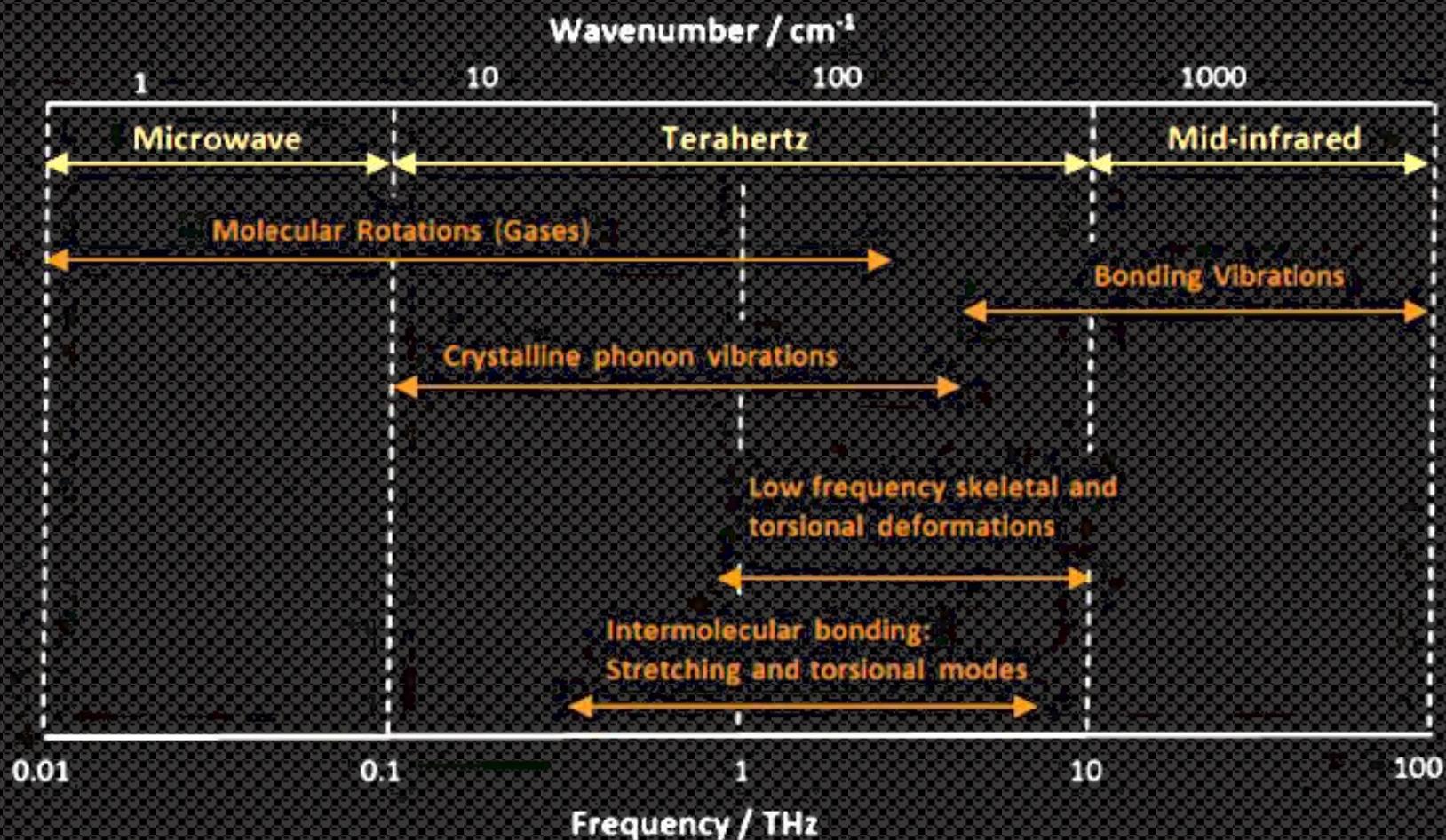


No visible signature
Inscription on the
chassis :

*“Hortense Mancini,
nièce du Cardinal
Mazarin par Pierre
Mignard”*

Analysis before
restoration

Spectroscopie



Spectroscopie

Caractérisation de polymères

Détection d'humidité

Caractérisation de semi-conducteur

Analyse de gaz

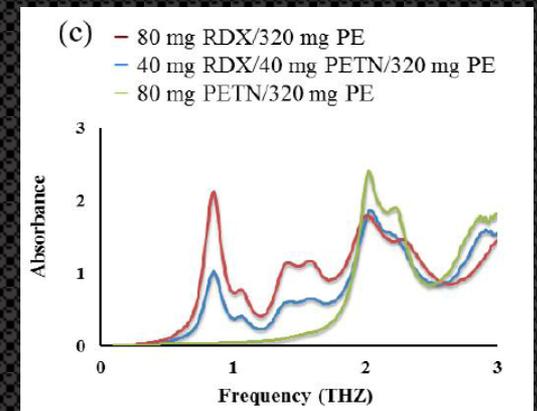
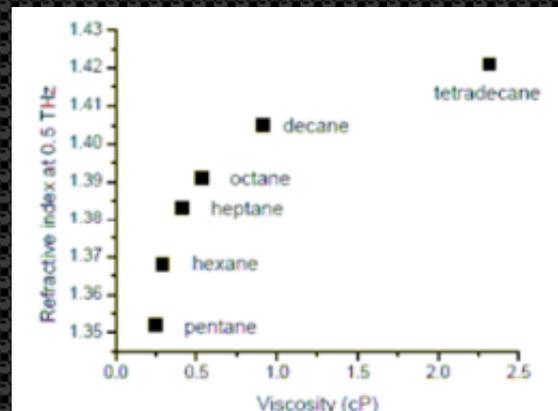
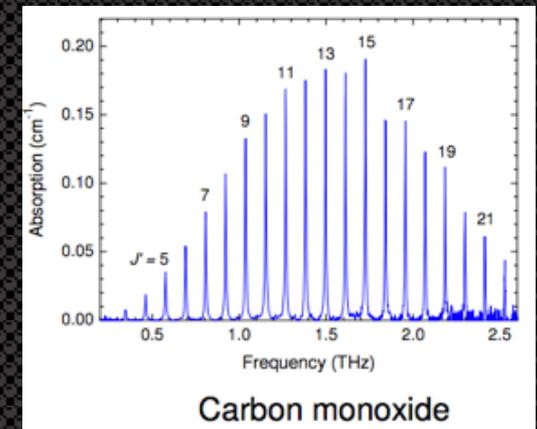
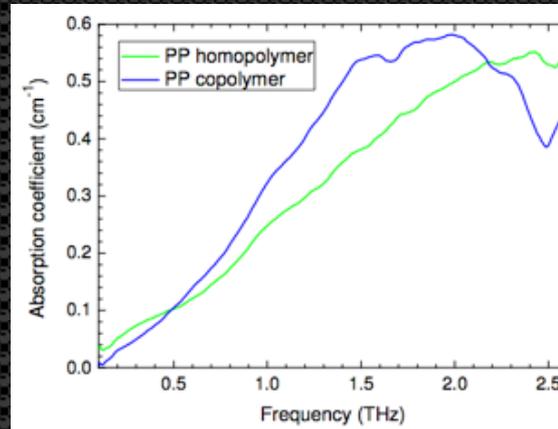
Détection d'explosifs

Drogues

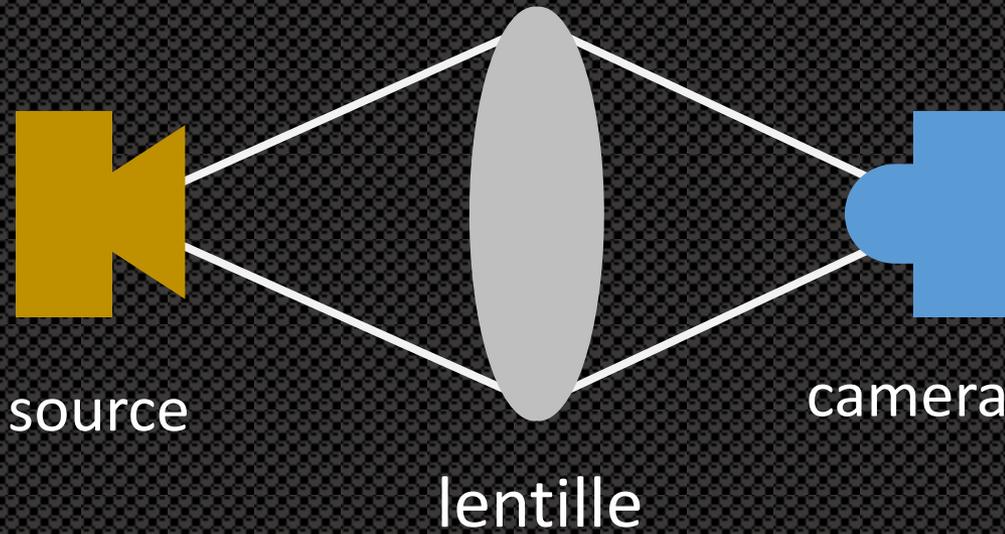
Analyse de peinture

Pharmaceutique

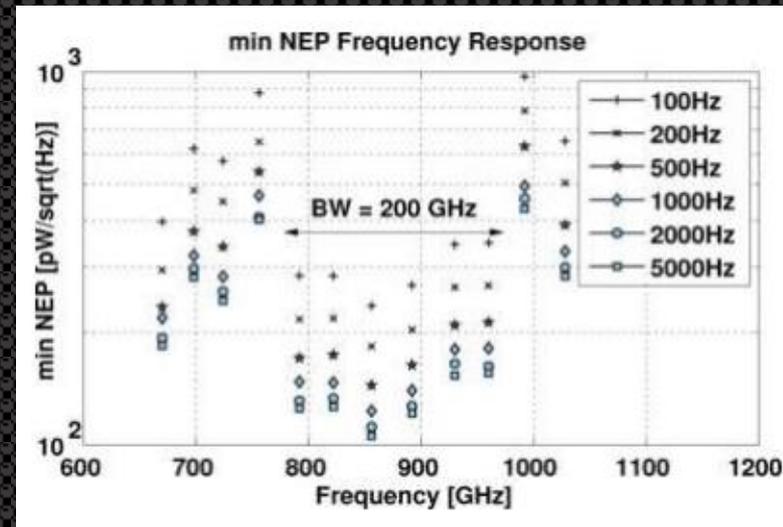
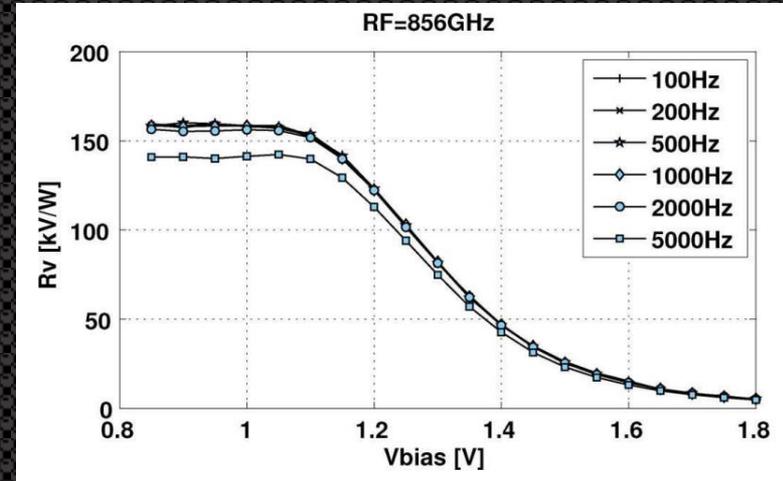
Etc



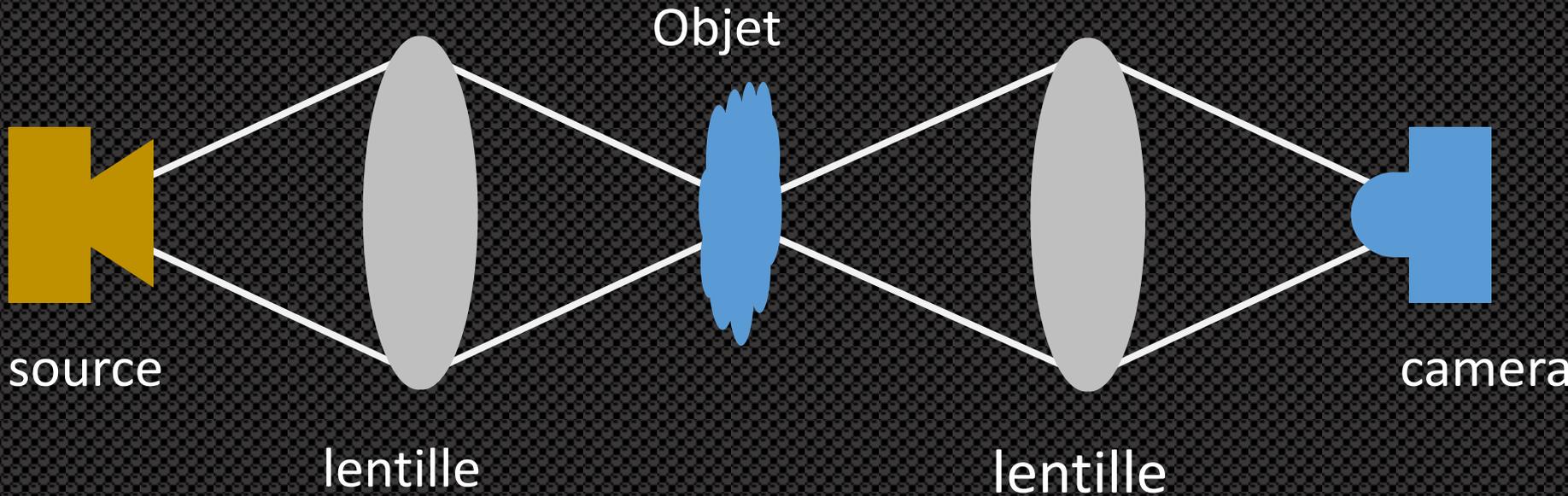
Capteurs intégrés



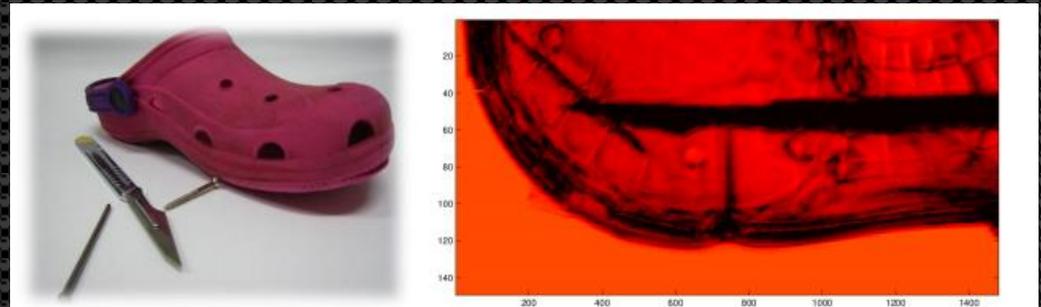
Technologie CMOS qui
fonctionne jusqu'à 1 THz !



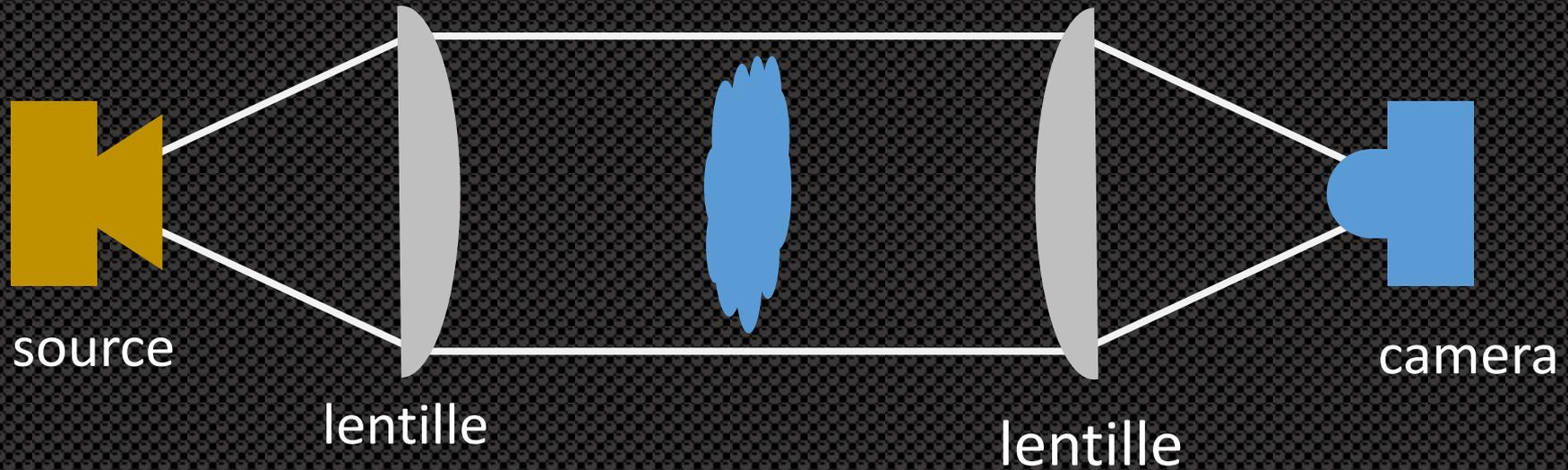
Configuration mono pixel



Efficace, mais ca
reste monopoint



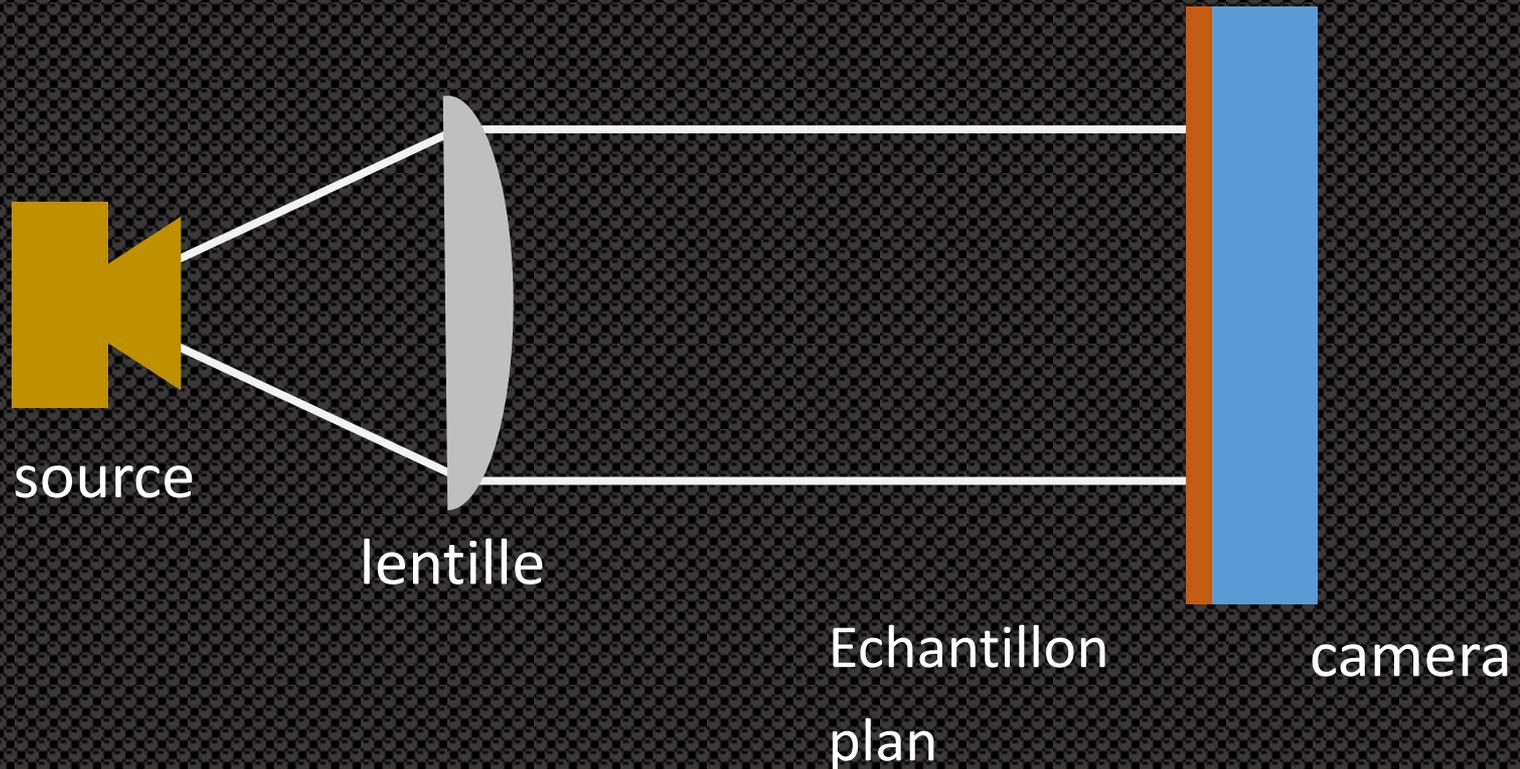
Configuration imagerie



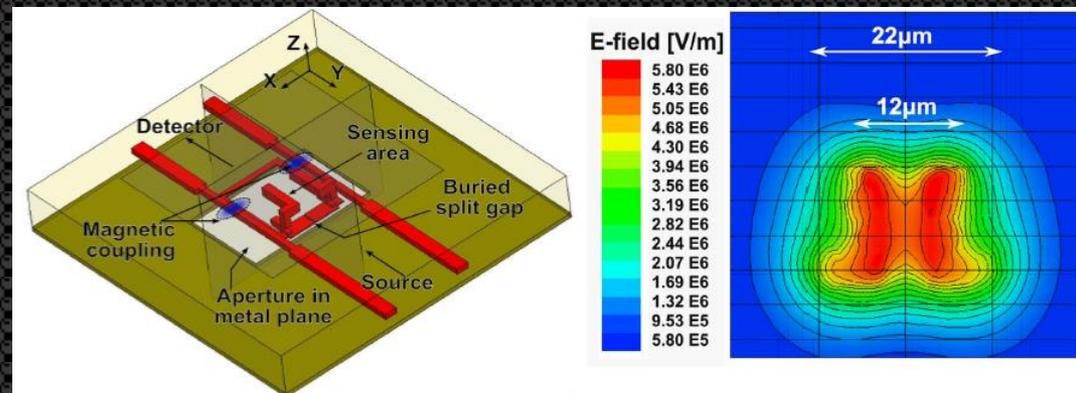
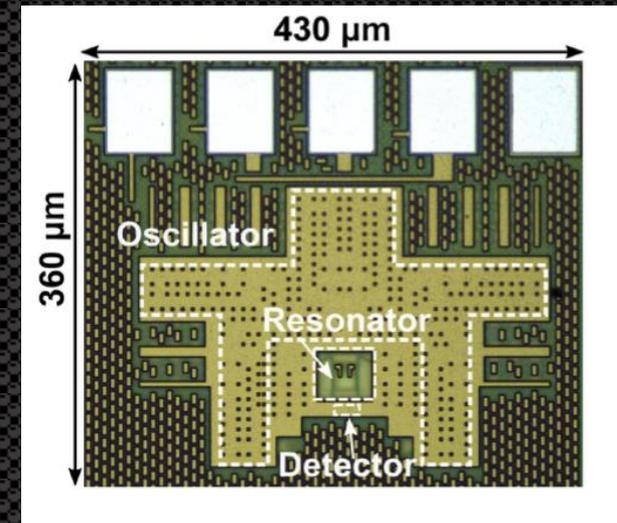
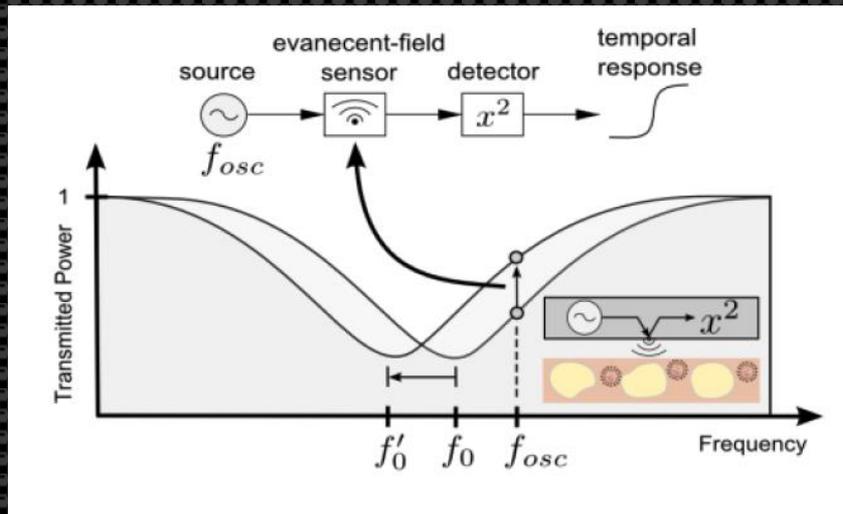
Rapide mais très
peu sensible



Proposition d'integration champ proche



Integration champ proche



Grzyb, J., Heinemann, B., & Pfeiffer, U. R. (2016, January). 25.1 A fully integrated 0.55 THz near-field sensor with a lateral resolution down to 8nm in 0.13nm SiGe BiCMOS. In *2016 IEEE International Solid-State Circuits Conference (ISSCC)* (pp. 424-425). IEEE.

Plan de la présentation

Ondes terahertz

Interactions avec les tissus biologiques

La question des normes

Conclusion

Marges d'exérèse

Diagnostic des marges

Vérifier que toute la tumeur a été retirée

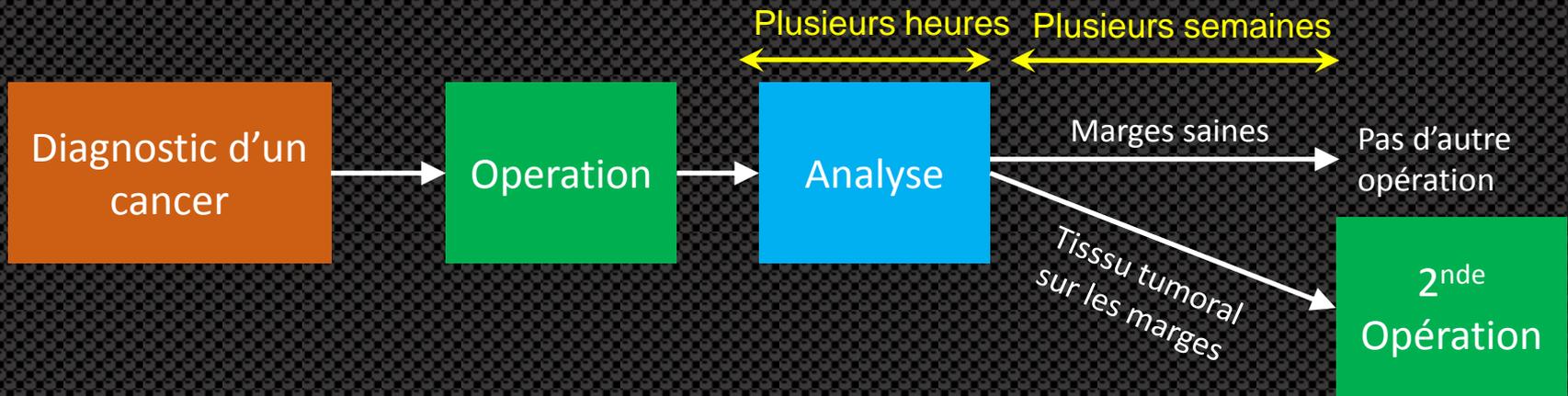
Pour décider une potentielle 2^{ème} opération

Minimiser le taux de récidence

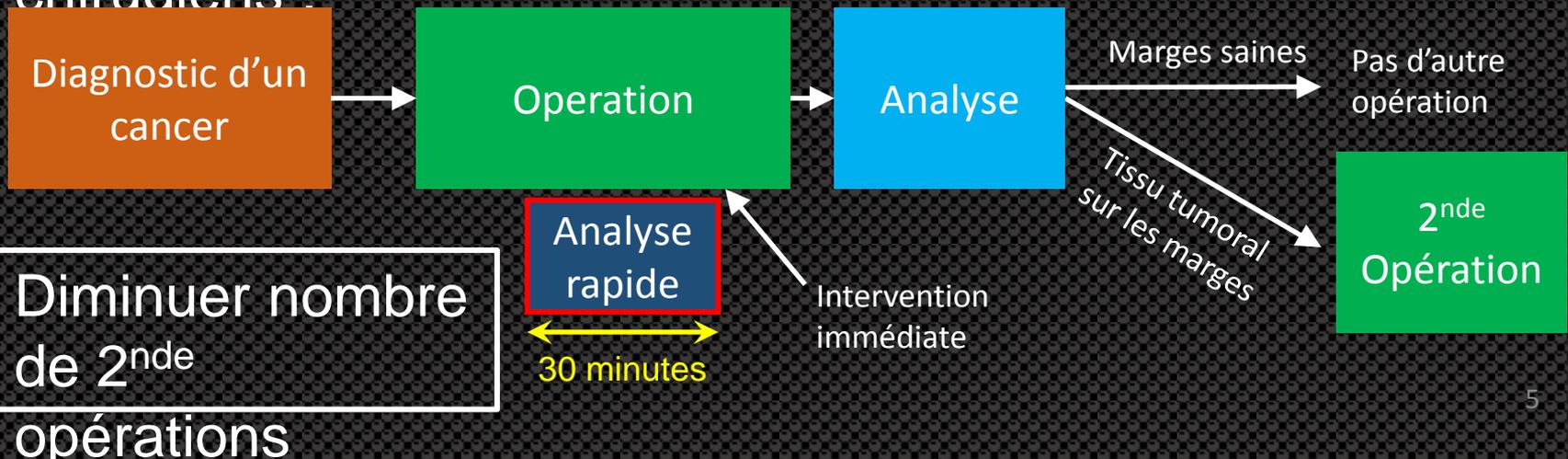
Processus d'analyse à l'aide de marqueurs
Plusieurs heures pour avoir un diagnostic



Processus médical



Besoin identifié par les anapathologistes & chirurgiens :

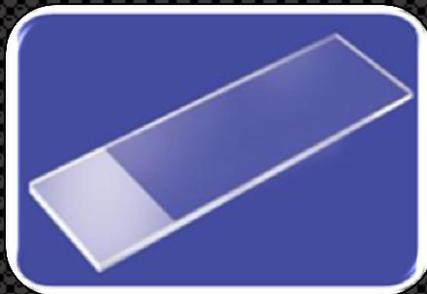


Préparation d'échantillons

1ers échantillons fixés sur paraffine

Découpe avec épaisseur de l'ordre de 30 μm

Déposé sur substrat en saphir ou quartz



Glass Slide



Sapphire Window

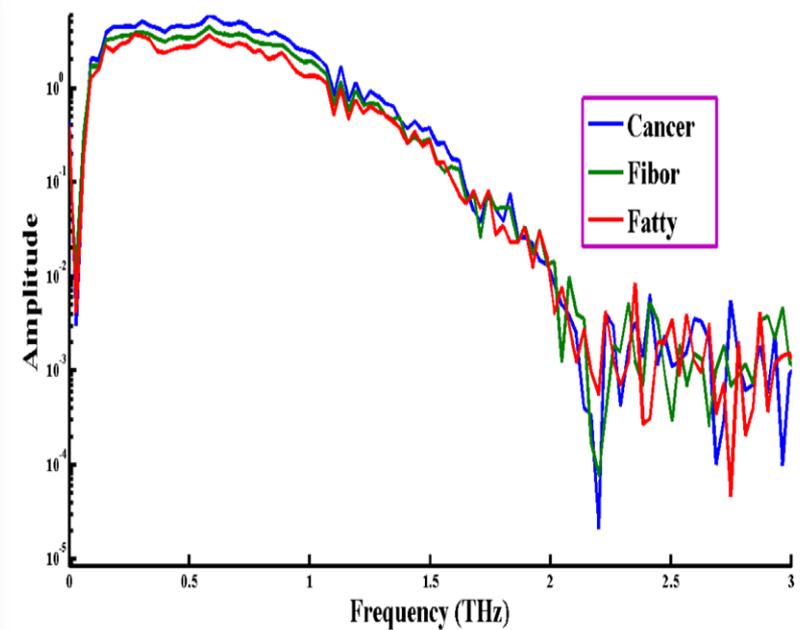
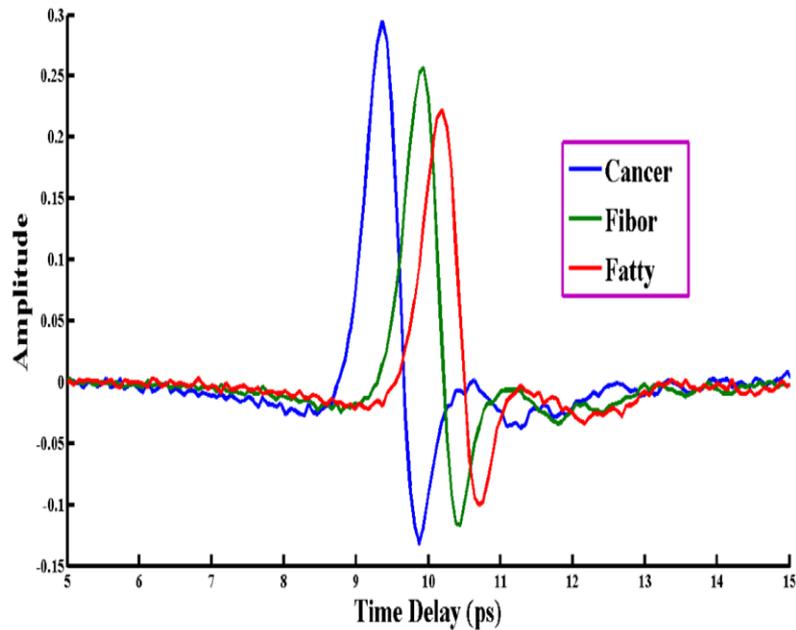


UVFS Window



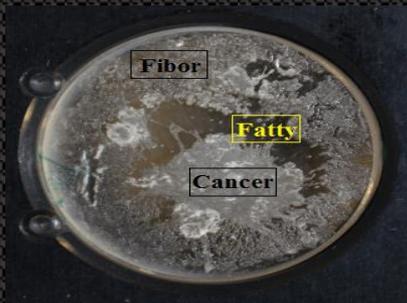
Block

Signaux sur les différentes zones

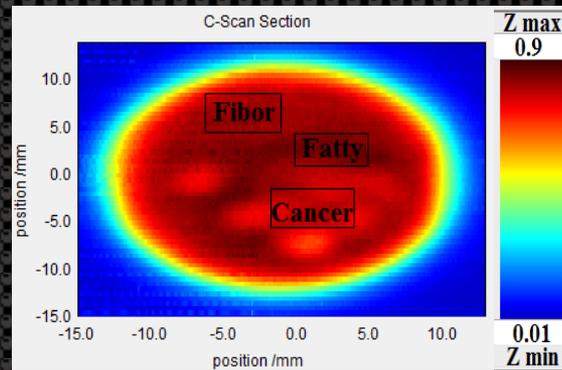


Images en réflexion

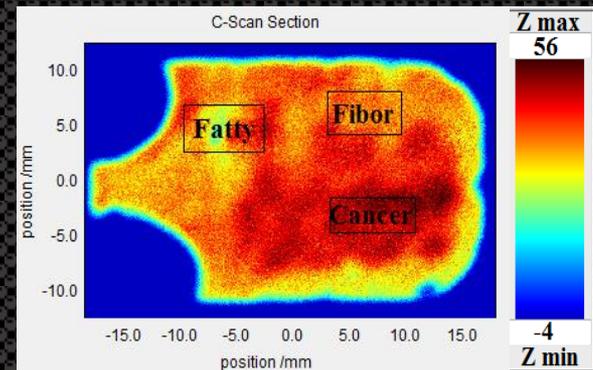
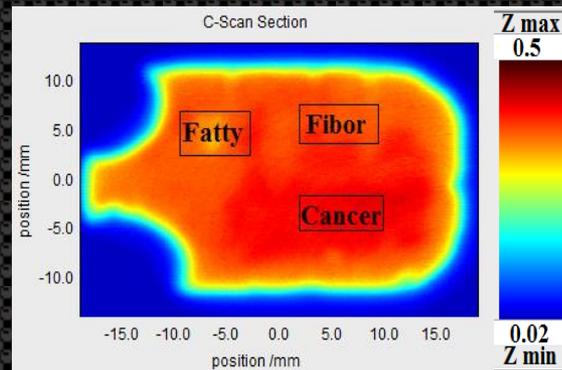
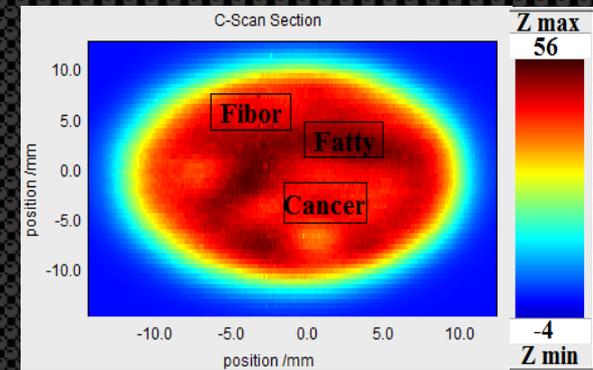
Study Sample



Time-Domain

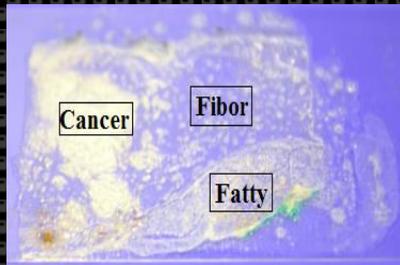


Frequency-Domain

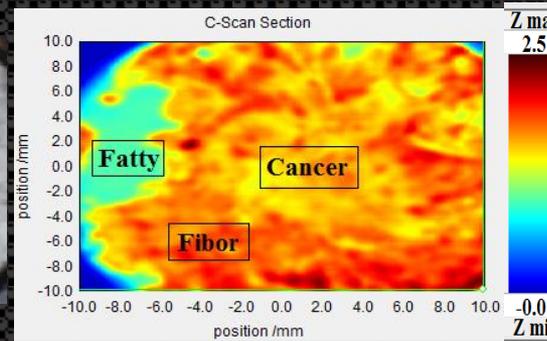
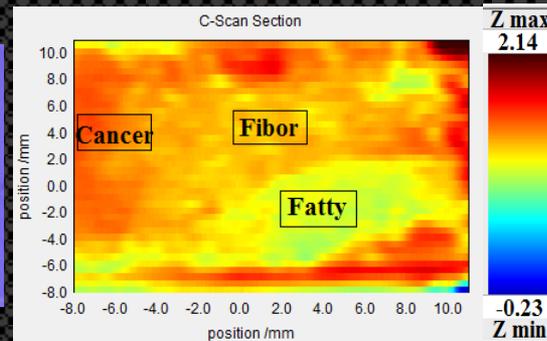


Images en transmission

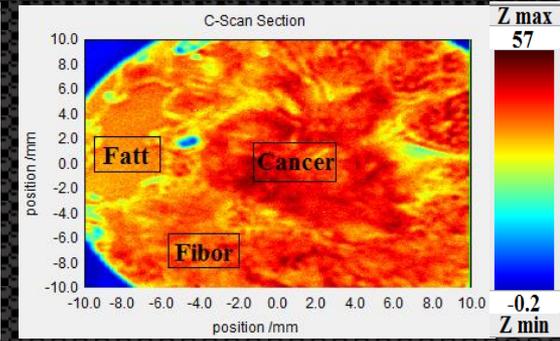
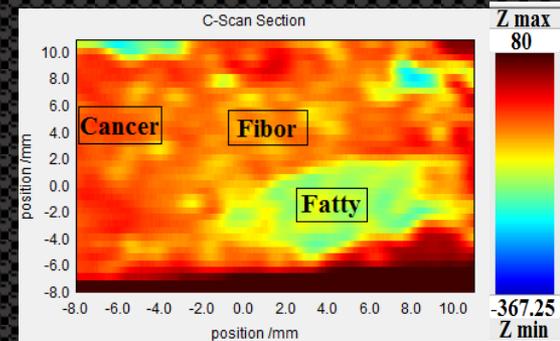
Study Sample



Time-Domain



Frequency-Domain

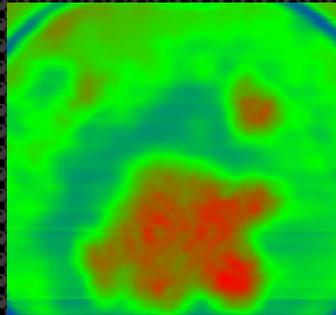


Images en transmission

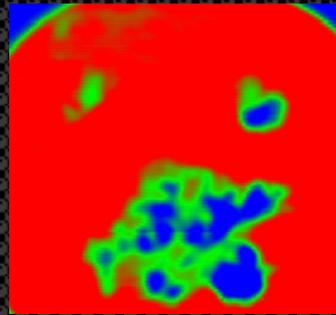


visible

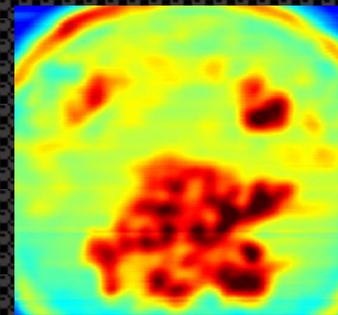
5 ps



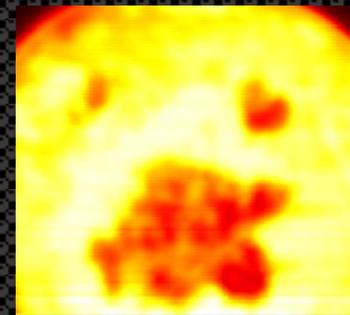
6 ps



10 ps

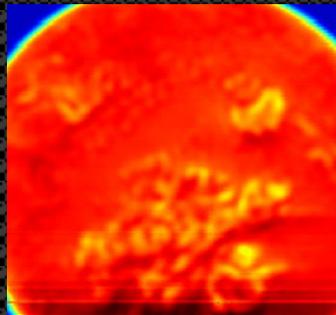


5.8 ps

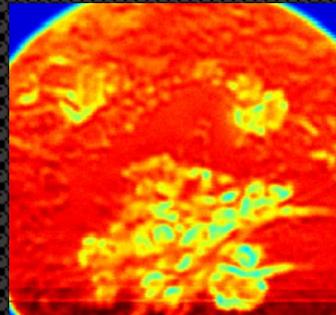


Multiple time domain comparison

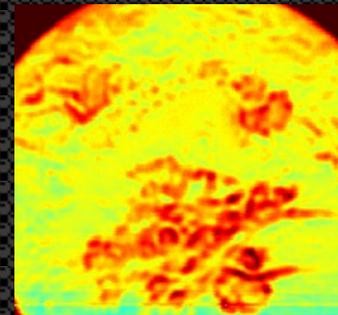
1 THz



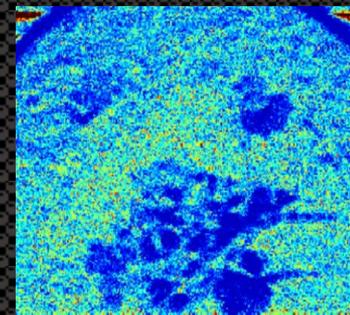
1.5 THz



2 THz



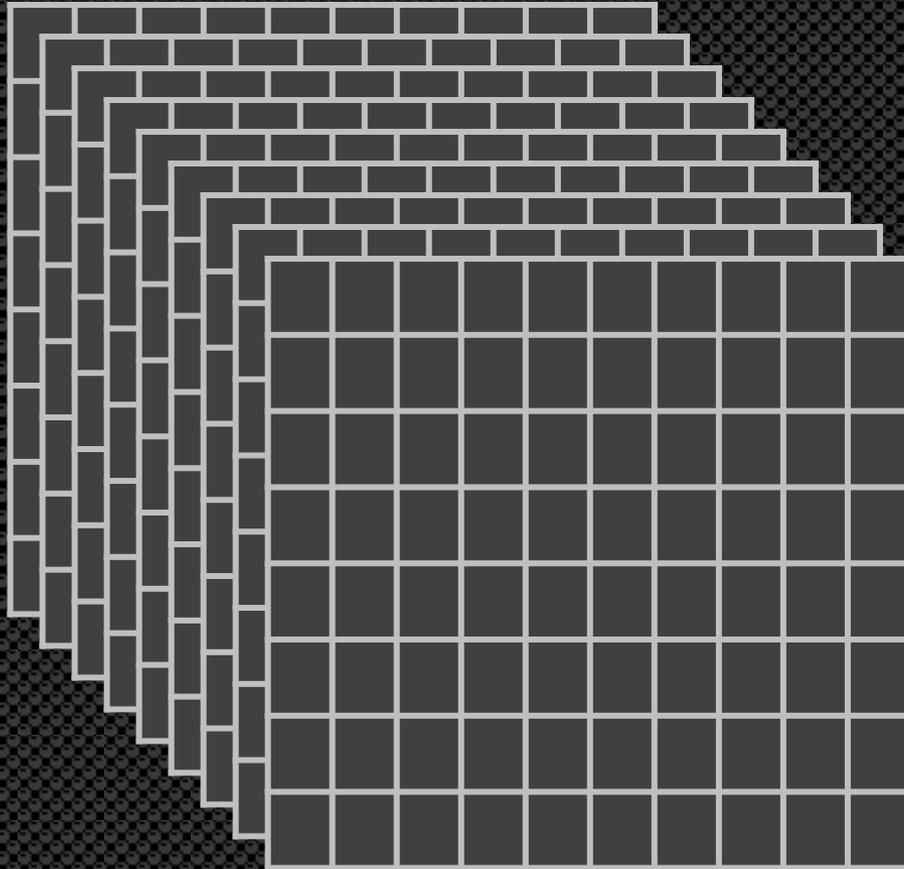
2.3 THz



Paraffin tissue at **30 μm** .
Quartz **5mm** thick.

Measurements
parameters:
Step size:**0.1mm**, **7v**
Area scan:(**12.5*12.5**)mm.
Acquisition time : about **1h**
48min; **averages:2**

Quel paramètre choisir?

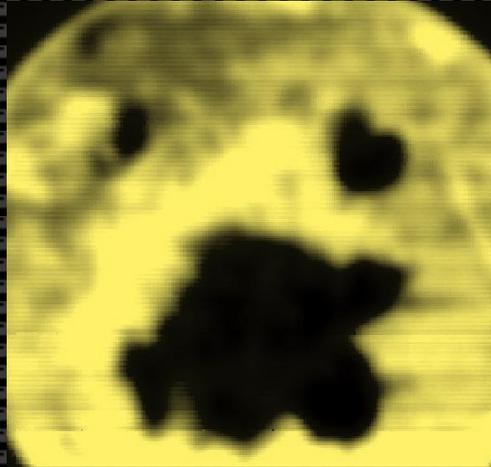


Jusqu'à plusieurs
gigaoctet par image

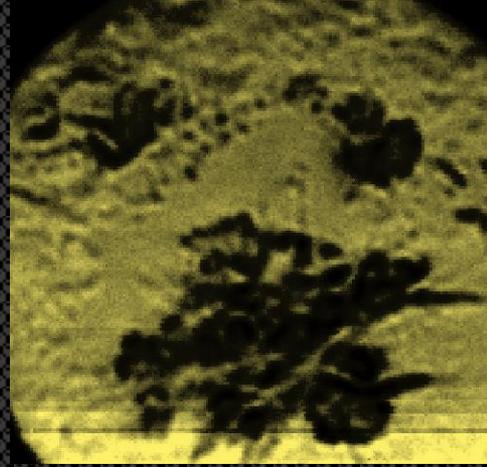
Big Data

Analyse en composante principale

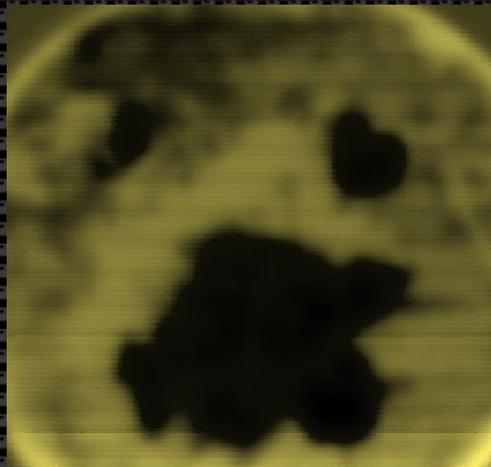
Time Domain



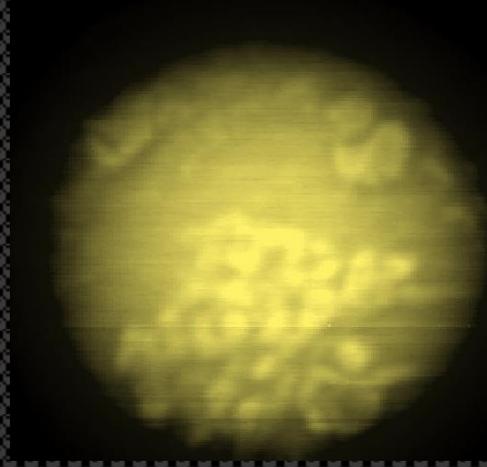
Frequency Domain



PCA

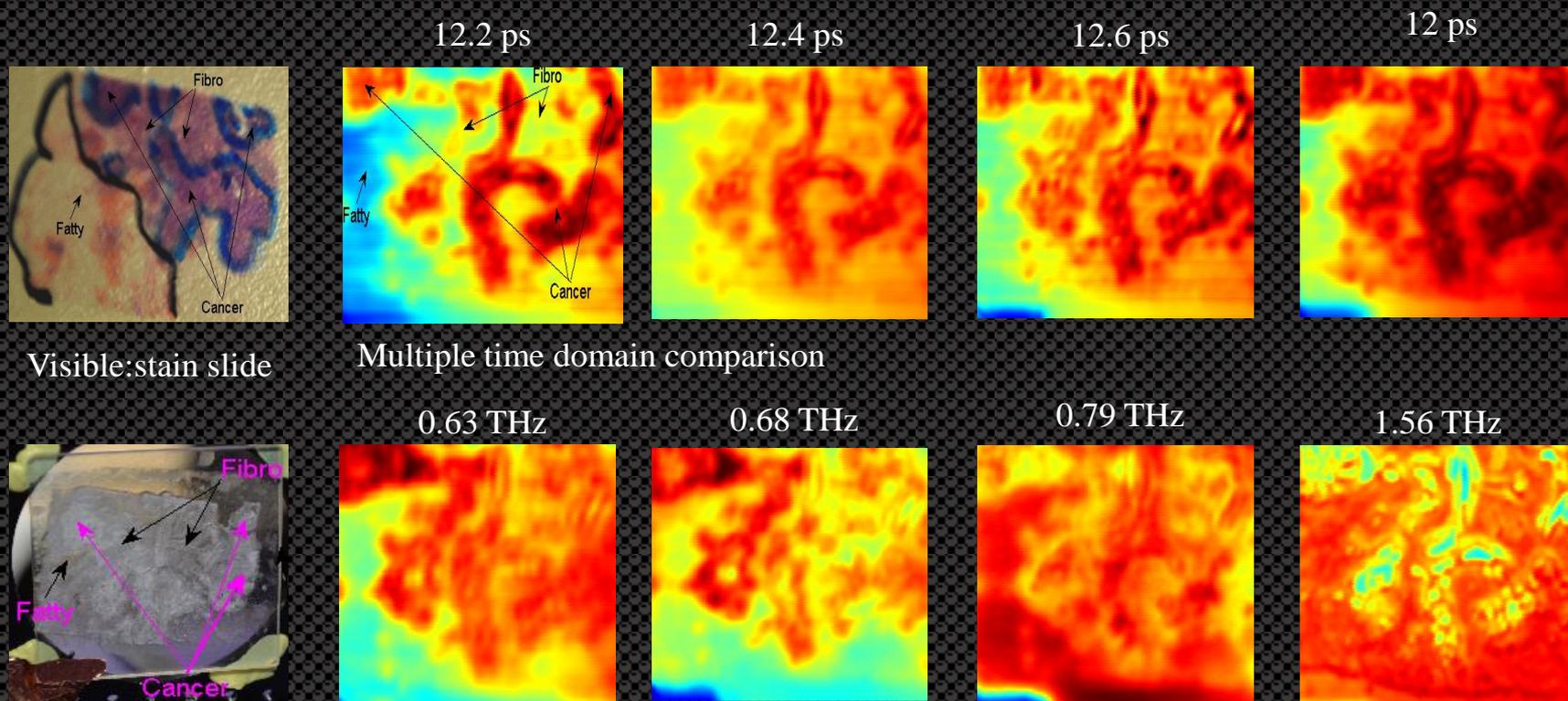


Entropy



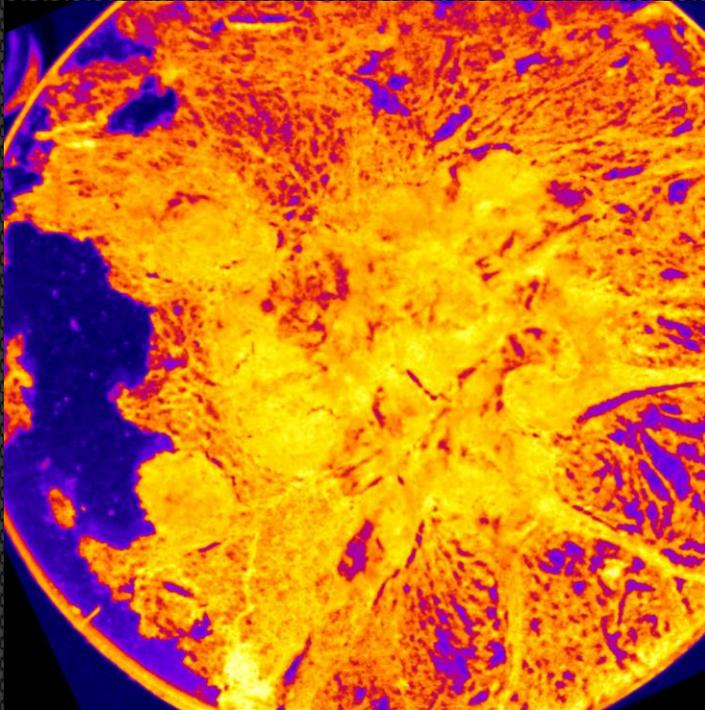
Analyse
statistique
multivariée

Autre échantillon



- Paraffin tissue at **30 μm** ;silica **2mm** thick.
- Measurements parameters:
- Step size:**0.1mm**, **7v**;Area scan:(**20*20**)mm.;Acquisition time : about **1h 40min**;
averages:2

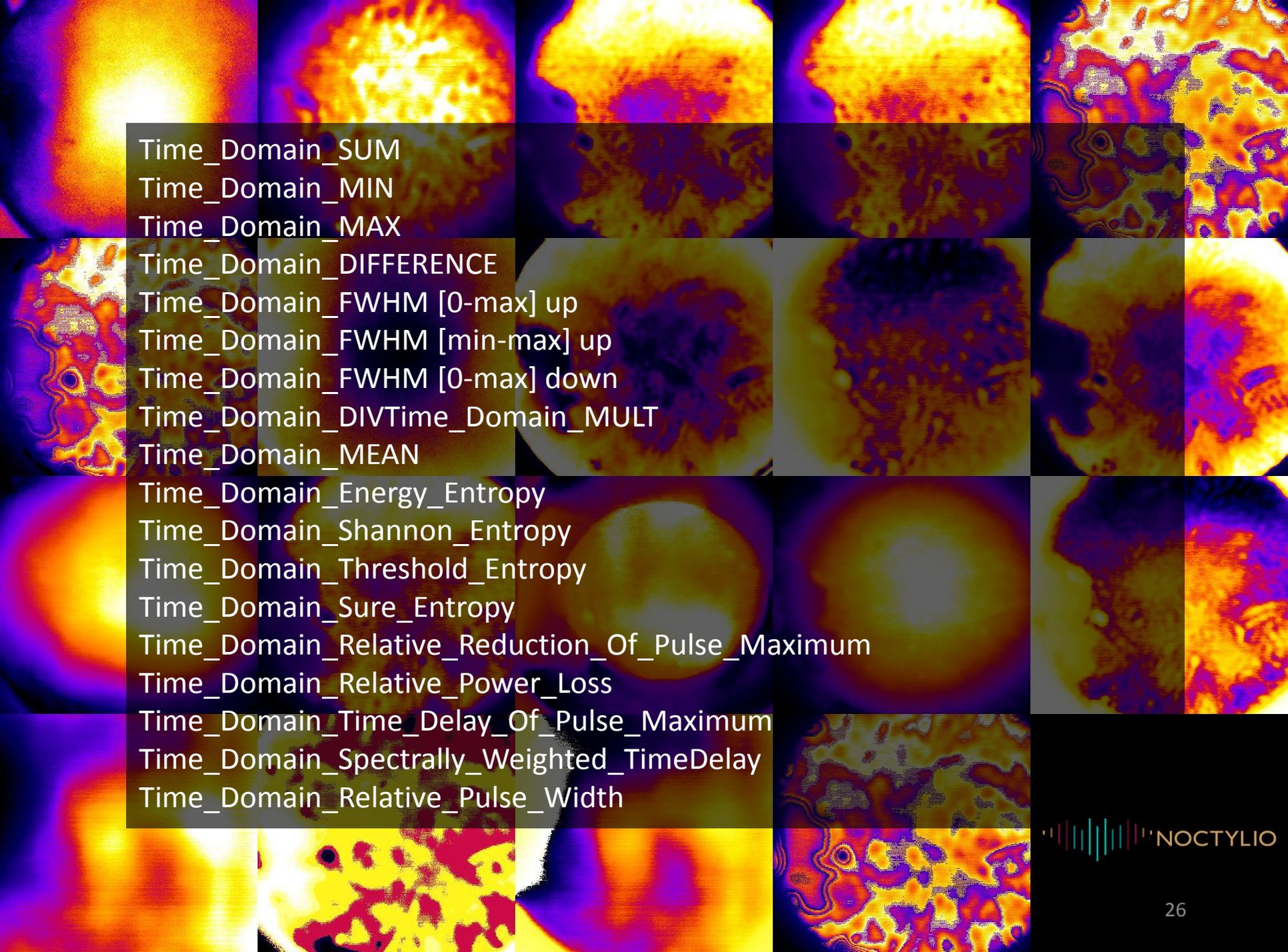
Image visible avec marqueurs



Développement numériques en cours:

Système d'imagerie automatique, calibré et répétable

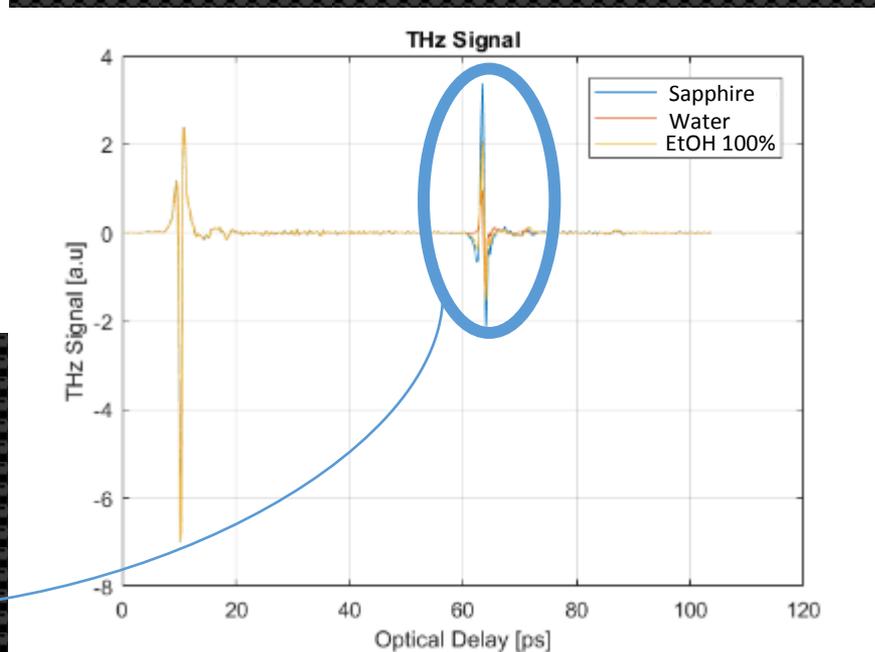
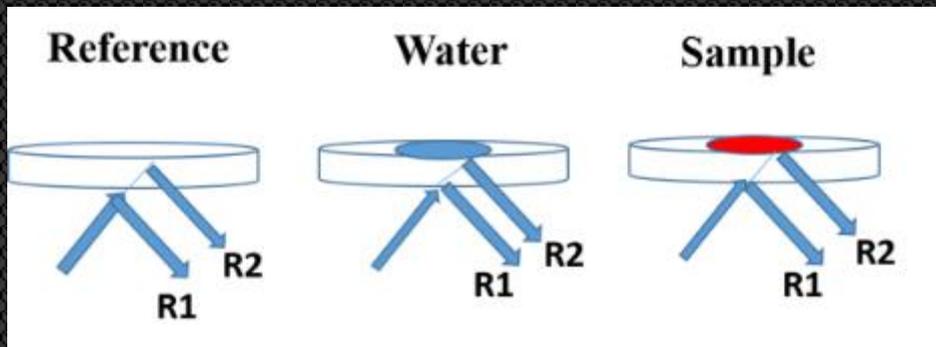
Outils d'analyse intégrés



Time_Domain_SUM
Time_Domain_MIN
Time_Domain_MAX
Time_Domain_DIFFERENCE
Time_Domain_FWHM [0-max] up
Time_Domain_FWHM [min-max] up
Time_Domain_FWHM [0-max] down
Time_Domain_DIVTime_Domain_MULT
Time_Domain_MEAN
Time_Domain_Energy_Entropy
Time_Domain_Shannon_Entropy
Time_Domain_Threshold_Entropy
Time_Domain_Sure_Entropy
Time_Domain_Relative_Reduction_Of_Pulse_Maximum
Time_Domain_Relative_Power_Loss
Time_Domain_Time_Delay_Of_Pulse_Maximum
Time_Domain_Spectrally_Weighted_TimeDelay
Time_Domain_Relative_Pulse_Width

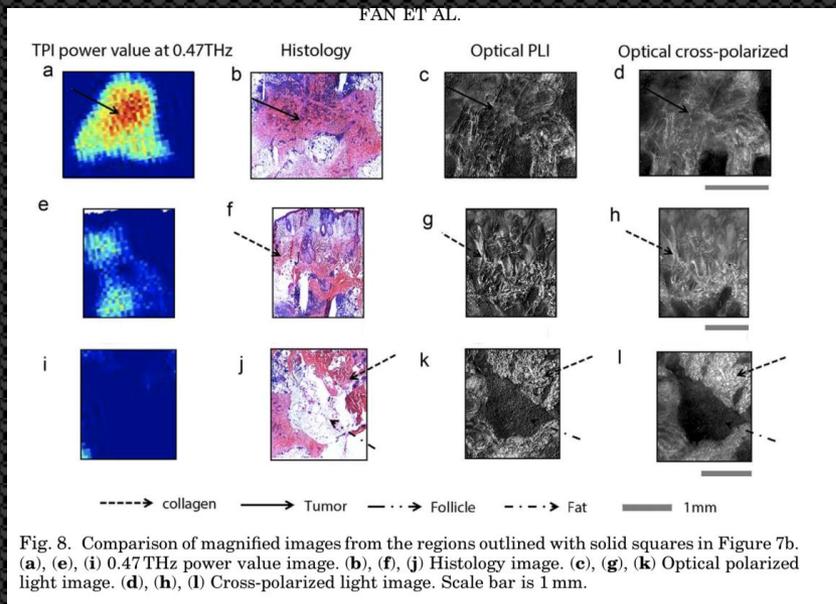
THz Spectroscopy & Imaging for Breast Cancer Detection in the 300 – 500 GHz Range

THz



$$Q = \frac{FFT\{E_2^{Sample}(x, y, t)\}}{FFT\{E_2^{Reference}(x, y, t)\}}$$

Analyse de la peau



Multimodal imaging for nonmelanoma skin cancer margin delineation

[Bo Fan MS](#)

[Victor A. Neel MD, PhD](#)

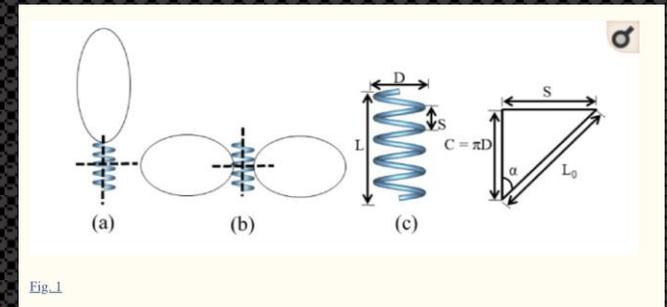
[Anna N. Yaroslavsky](#)

Cause des interactions

- Eau
- Géométrie
- Epaisseur des couches
- Nature des espèces chimique
- **Etc**

Effets potentiels

- Effets potentiels sur les biomembranes, perméabilité ?
- Effet focalisé en raison de la structure?
- Stimulation directe de cellules de la peau?



human sweat duct

[Kodo Kawase](#)

Enjeux de ces études

- Effets possibles sur des fréquences précises

→ Bandes de fréquences larges

- Nature variable des sources

→ CW, FMCW, Pulse

Trop peu d'études sur le sujet

Plan de la présentation

Ondes terahertz

Interactions avec les tissus biologiques

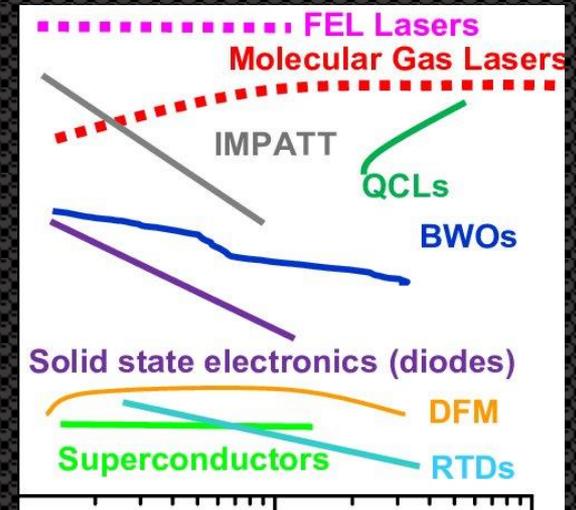
La question des normes d'exposition

Conclusion

Généralités sur l'exposition

Sources commerciales globalement peu puissantes, mais:

- Faisceaux très directifs
- Densité de puissance qui peut être élevée en bout de guide



Sources confinés au secteur de la recherche, mais:

- Arrivée des bandes millimétriques commerciales
- Technologie CMOS qui arrive dans le THz
- Systèmes de contrôle non destructif qui vont se développer dans l'industrie

Normes :

Bien défini jusqu'à 300 GHz
→ 2013/35 EC

Bien défini pour l'infrarouge

Fréquences	Intensité du champ électrique (V/m)
>1 – 50 Hz	5 000
50 Hz – 3 kHz	250/f
3 kHz – 1 MHz	87
1 - 10 MHz	$87/f^{1/2}$
10 - 400 MHz	28
400 - 2000 MHz	$1,375 \times f^{1/2}$
2 – 300 GHz	61

Pour une station de base

Courbes de limites au delà avec peu de communication sur ces niveaux entre 300 GHz et l'infra rouge

Plan de la présentation

Ondes terahertz

Interactions avec les tissus biologiques

La question des normes

Conclusion

Conclusion

THz : Technologie qui sort désormais des labos

Santé : Applications pour le cancer, la peau, etc

Puissances faibles, donc question des normes peu prise en compte dans la communauté des utilisateurs

Normes à clairement définir sur toute la

Merci pour votre attention.