Sonia Zappia

THz pulsed imaging and sensing for non-destructive inspection

Tutor: Prof. Giuseppe Ruello

co-Tutor: Dr. Lorenzo Crocco

Cycle: XXXV

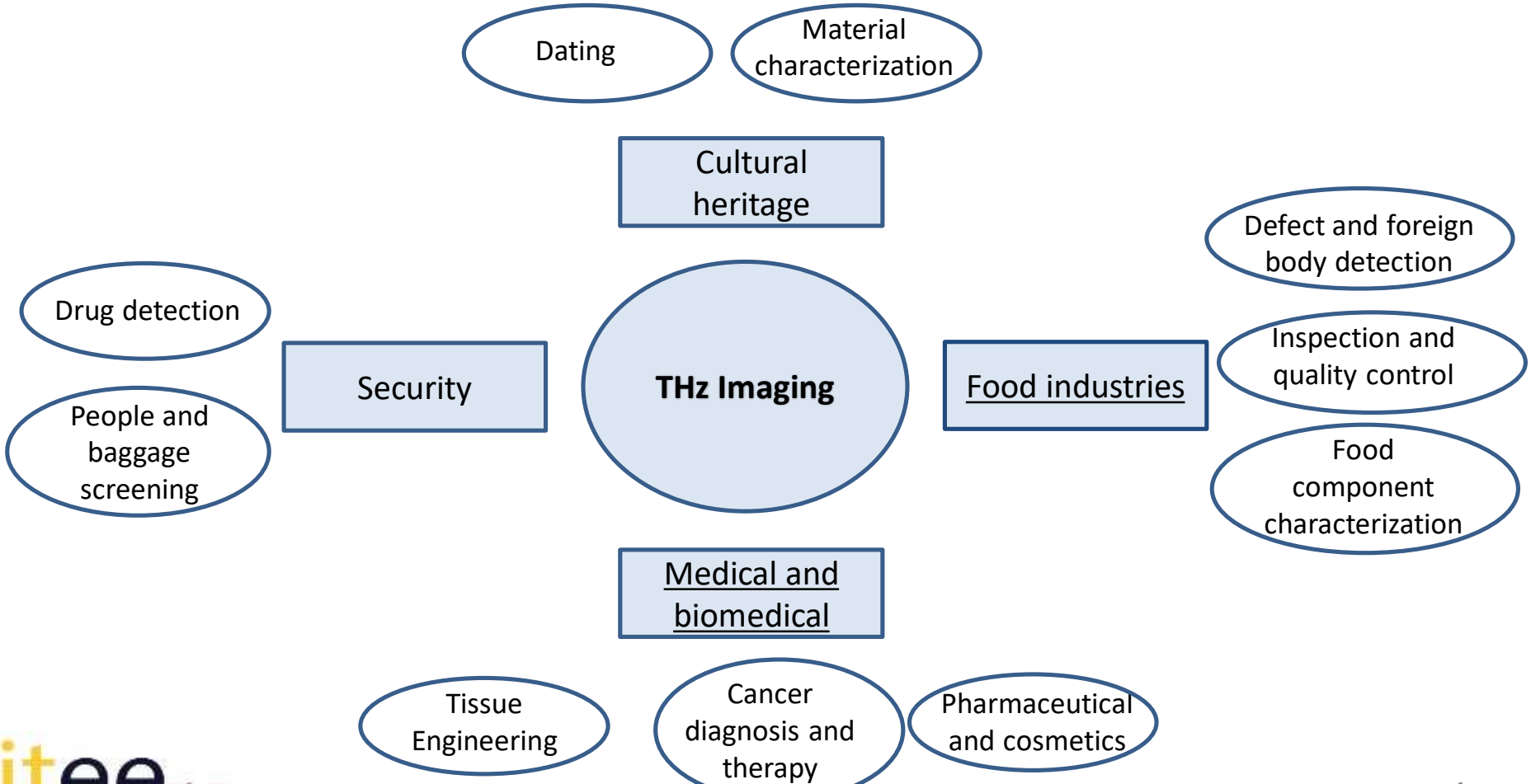
Year: Second

My background

- MSc degree : Biomedical Engineering
- Research group/laboratory: DIETI and IREA-CNR
- PhD start date : Academic Year 2019/2020
- Scholarship type: No scholarship

Research field of interest

Terahertz Imaging is the newest among non-invasive sensing technologies and currently huge attention is pointed towards its use in several applications.



Research activity 1: Overview

- ## THz imaging for food quality inspection

Contamination by foreign bodies and packaging failures are among the main sources of customer complaints against manufacturing companies. The currently adopted technologies show some limitations and the occurrence of incidents remains significant.

- ## Objective

Demonstrate the effectiveness of THz imaging to solve many shortcomings of most approaches discussed in literature, i.e. 1) detection of low density contaminants 2) non-destructive inspection which not compromise the integrity of the product.

- ## Methodology

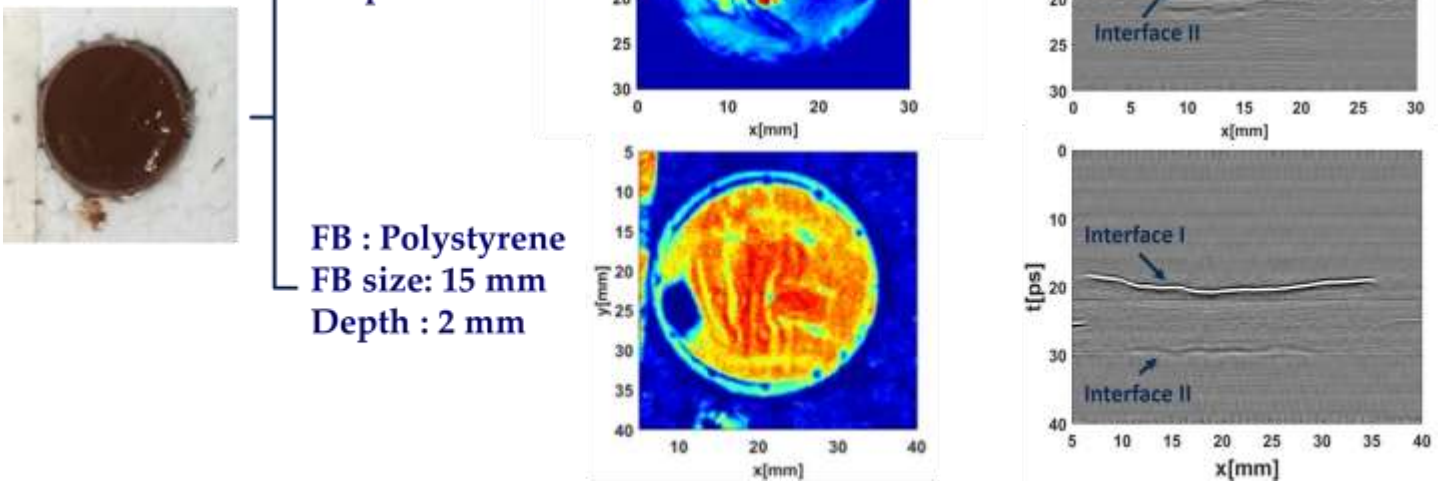
I have carried out some laboratory prepared experiments aiming to demonstrate THz imaging capabilities to detect foreign body, surface defect and packaging failures in food samples. Furthermore, I have developed a signal filtering algorithms that combines the use of a band pass filter followed by a singular value decomposition in order to improve THz imaging quality.

Research activity 1: Overview

- Results

(for brevity only one example has been shown)

THz imaging of a chocolate laboratory prepared samples where foreign bodies (FBs) have been hidden inside the chocolate cream.



False colors images demonstrate THz abilities to detect the presence of FBs inside the sample. This hypothesis is supported by the plot of the THz radargram, which show two different reflections due to the occurrence of different materials.

Research activity 2: Overview

- THz imaging and Spectroscopy for non-destructive inspection of composite materials

From industrial fields to biomedical applications, polymer-based composite materials have emerged as an interesting alternative, replacing other materials (i.e. metals, plastic and ceramics) in several applications, thanks to their mechanical properties, flexibility and structural integrity. However, it is worth to notice that the manufacturing process of composite materials is complex, and the demand for ever more sophisticated quality control procedures is increasing.

- Objective

Demonstrate the effectiveness of THz non-destructive inspection to characterize polymer scaffolds loaded with magnetic nanoparticles (MNPs) used for tissue engineering applications, from a morphological point of view (thickness, shape, size) and to evaluate the presence of damages such as not – impregnated area in the polymeric matrix.

- Methodology

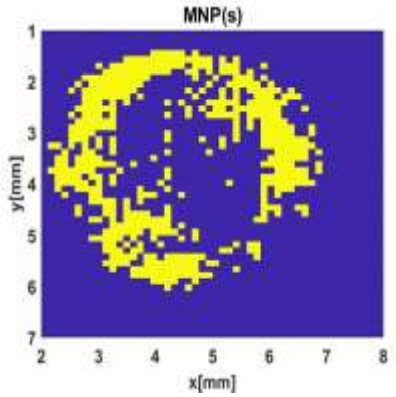
The application of a suitable measurement set up and the developing of a multi-step data processing procedure allows to derive useful information on the structure of the sample under test, such as the thickness, the refractive index and the volumetric distribution of the MNPs in the polymeric matrix.

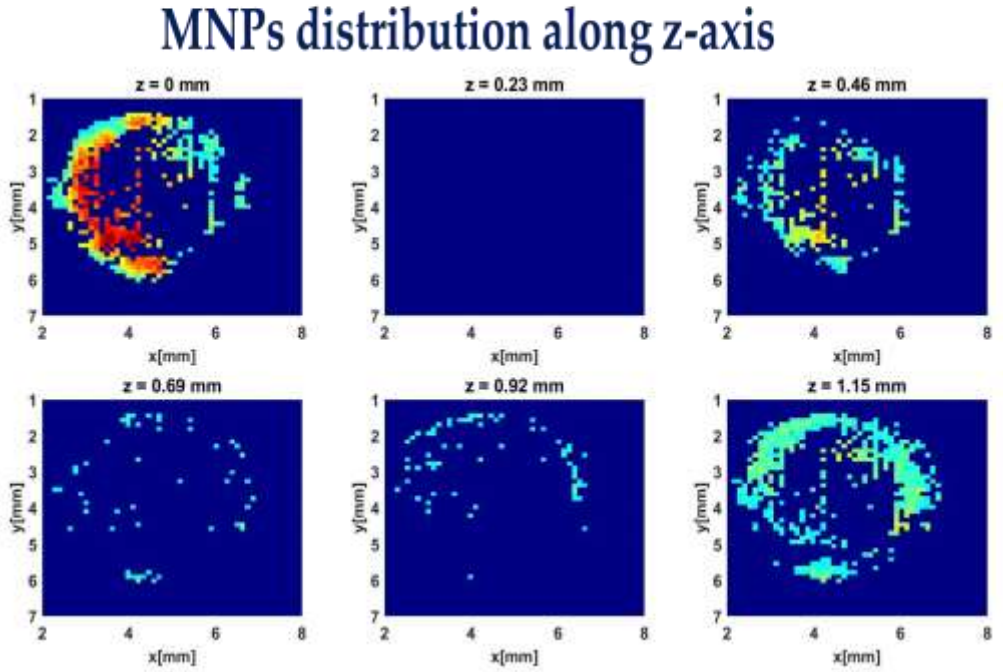
Research activity 2: Overview

- Results

THz analysis is used to derive the spatial distribution of nanoparticles (MNPs) in a polimeryc matrix.

Sample





The use of an appropriate THz imaging algorithms allows us to derive the volume distribution of magnetic nanoparticles.

Products

[P1]	Zappia, Sonia, Lorenzo Crocco, and Ilaria Catapano. "THz Imaging for Food Inspections: A Technology Review and Future Trends." (2021). *Published*: June 21st 2021 DOI: 10.5772/intechopen.97615.
[P2]	Catapano, I., Zappia, S., Ludeno, G., & Soldovieri, F :THz imaging activities at IREA–CNR. In *Workshop Co-chairs* (p. 65). 9th International Workshop THz-Bio 2020. The Technical Digest of the Workshop has been *published* by CNR Edizioni (ISBN: 978 88 8080 454 3).
[P3]	Lodi, M. B., Curreli, N., Zappia, S., Pilia, L., Casula, M. F., Fiorito, S., ... & Fanti, A. (2021). Influence of Magnetic Scaffold Loading Patterns on their Hyperthermic Potential against Bone Tumors. – *Under review* to the IEEE Transactions on Biomedical Engineering (TBME).

Summary of study activities

Ad hoc PhD courses:

- Professional skills in clinical environment for biomedical engineering;
- Electromagnetism.

Courses attended borrowed from MSc curricula:

- Progettazione in sicurezza elettromagnetica dell'ambiente ospedaliero.

Phd School:

- ESoA School – Title: Microwave Imaging and Diagnostics: Theory, Techniques and Applications
- ESoA School – Title: Compressive Sensing as Applied to Electromagnetics Theory, Techniques, and EM Applications.

Workshop:

- 9th International THz-Bio Workshop

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	2	4.2	7.5	-	13.7
Bimonth 2	3	0.4	6.6	-	10
Bimonth 3	4	0.8	7	-	11.8
Bimonth 4	9	0.7	6	-	15.7
Bimonth 5	-	0.4	9.6	-	10
Bimonth 6	3	0.4	7	-	10.4
Total 2nd year	21	6.9	43.7	-	71.6
Total 1st year	22.9	6.8	27.1	-	56.8
Sum 1st and 2nd	43.9	13.7	70.8		
Expected for three years	30 - 70	10 - 30	80 - 140	0 – 4.8	

Next Year:

- *Research activity:*

  ✓ Development of a multilayer model of THz wave propagation;

  ✓ Evaluation of the electromagnetic properties at the frequency [80 GHz – 3 THz] of different case studies (food, contaminant, composite materials).

- *Draft topic of the thesis:*

The thesis will focus on the exploitation of THz technologies for quality control of different materials of industrial interest. The aim is to propose the application of a suitable measurement set up and the developing of a multi-step data processing procedure for non-destructive inspection of food samples and composite materials.

- *Draft structure of thesis:*

  ✓ Review of the latest development regarding THz technologies and its application in various fields. Comparison with other existing diagnostic techniques and description of its strong and weakness;

  ✓ Description of the research activity : 1) the methodologies used to carry out the experiments in the laboratory and 2) the data processing algorithms applied to the collected raw data.

  ✓ Presentation of the results obtained for the case studies analyzed in the last years and demonstration of THz imaging non-destructive inspection capabilities.

  ✓ Conclusions and future trends.

I wish to thank Dr. Ilaria Catapano for her supervision and support in the experimental activities.

THANK YOU FOR YOUR KIND ATTENTION