Università degli Studi di Napoli Federico II
PhD program in
Information Technology and Electrical Engineering

PhD Student: Sonia Zappia

Cycle: XXXV

Training and Research Activities Report

Academic year: 2020-21 - PhD Year: Second

student signature:

Tutor: Prof. Giuseppe Ruello

Co-Tutor: Dr. Lorenzo Crocco

Date: October 21, 2021

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PhD student: Sonia Zappia **Cycle: XXXV**

1. Information:

- **PhD student: Sonia Zappia** **PhD Cycle: XXXV**
- **DR number: 994203**
- **Date of birth: 10/05/1989**
- **Master Science degree: Biomedical Engineering University: University of Naples "Federico II "**
- **Scholarship type: *no scholarship***
- **Tutor: Prof. Giuseppe Ruello**
- **Co-tutor: Dr. Lorenzo Crocco**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Professional skills in clinical environment for biomedical engineering	Course	8	2	12/10/2020 19/10/2020 26/10/2020 2/10/2020	Prof. M.Cesarelli , Prof. P. Bifulco - DIETI	Y
Telemedicina in Italia: casi di successo	Seminar	3	0.6	17/11/2020	Prof. Giovanni D'Addio (DIETI)	Y
Digital Project Management: Practices, process, techniques, tools and scientific approach	Seminar	1	0.2	18/11/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
L'esperienza del progetto di teleriabilitazione NEUROREAB	Seminar	3	0.6	24/11/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
Andràtuttobene : Images, texts, Emojis & Geodata in a sentiment Analysis Pipeline"	Seminar	1.5	0.3	25/11/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
Telemedicina, e-health e mobile health si può davvero usare il digitale nel percorso assistenziale?	Seminar	3	0.6	26/11/2020	Prof. Giovanni D'Addio (DIETI)	Y
Stroke and its imaging	Seminar	1	0.2	01/12/2020	Politecnico	N

in the acute phase: a neurological point of view					di Torino, Instituto de Biofísica e Engenharia Biomédica, FCiências	
Neuroradiologic tools for acquiring images of the brain and its diseases.	Seminar	1	0.2	1/12/2020	Politecnico di Torino, Instituto de Biofísica e Engenharia Biomédica, FCiências	N
At the Nexus of Big Data, Machine Intelligence and Human Cognition	Seminar	1	0.2	2/12/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
Force and visual Control for Safe Human – Robot Interaction	Seminar	1	0.2	2/12/2020	PRISMA Lab DIETI	N
Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics	Seminar	1	0.2	9/12/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
GDPR basics for computer scientists	Seminar	1.5	0.3	10/12/2020	Prof. P. Bonatti, DIETI	N
Synthetic MRI: physical principles and applications	Seminar	1	0.2	16/12/2020	Prof. Giuseppe Ruello, Prof.ssa Rita Massa (DIETI)	Y
Static magnetic field exposure monitoring of MRI workers: methods and practical implementations	Seminar	1	0.2	16/12/2020	Prof. Giuseppe Ruello, Prof.ssa Rita Massa (DIETI)	Y
Data Driven Transformation in WINDTRE through Managers voice	Seminar	1	0.2	16/12/2020	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y

Laboratory activity: THz measurement of Multifunctional Magneto-Responsive Scaffolds Dip Coated with Magnetic Nanocubes. Analysis and study of the THz Tomography and Spatial Distribution of the Magnetic Nanocubes into the Scaffolds	Research	176	7.5	From: 1.11.2020 To: 31.12.2020	-	Y
ESoA School – Title: Microwave Imaging and Diagnostics: Theory, Techniques and Applications.	PhD School	33	3	from 1/02/2021 to 5/02/2021	Dr Lorenzo Crocco – IREA CNR	Y
Salute e sicurezza nei luoghi di lavoro – Formazione Generale Settore Ateco: 207: M72: - Tipologia del rischio: B	Course	4	0	19/02/2021	Unità Prevenzioe e Protezione Consiglio Nazionale delle Ricerche.	Y
Advances in Machine Learning for Modelling and Understanding in Earth Sciences	Seminar	1	0.2	27/01/2021	IEEE Geoscience and Remote Sensing	N
Designing a Socially Assistive Robot for adaptive and personalized assistance to patients with dementia	Seminar	1	0.2	17/02/2021	Prof.ssa S. Rossi, PRISCA Lab. – DIETI	Y
Writing activities: •Report • Chapter Study activities: •Generation and Detection of Broadband Terahertz Pulses; •Continuous-Wave Terahertz Sources and Detectors; • THz cameras and	Research	176	6.6	From: 1.01.2021 To: 28.02.2021	-	Y

their application in food industry.						
Electromagnetism	Course	24	4	From: 11/01/2021 To: 19/02/2021	Scuola Superiore Meridionale	Y
9th International THz-Bio Workshop	Workshop	25	-	From: 19/04/2021 To: 23/04/2021	ENEA, IREA-CNR and EISBem.	Y
Visual Interaction and Communication in Data Science	Seminar	2	0.4	3/03/2021	Dipartimento di Fisica "Ettore Pacini" and DIETI	Y
Robo Ludens: A game design taxonomy for human – robot interaction	Seminar	1	0.2	5/03/2021	Prof.ssa S. Rossi, PRISCA Lab. – DIETI	Y
Emotions in Reinforcement Learning Agents.	Seminar	1	0.2	17/03/2021	Prof.ssa S. Rossi, PRISCA Lab. – DIETI	N
Research Activity: •Presentation of the poster "THz imaging activities at IREA – CNR" to the 9th International THz-Bio Workshop Writing Activity: •Revision of a chapter paper •Preparation of a paper	Research	200	7	From: 1.03.2021 To: 30.04.2021	-	Y
Progettazione in sicurezza elettromagnetica dell'ambiente ospedaliero.	Course	72	9	II semester aa 2020/2021	Prof. Giuseppe Ruello	Y
L'avvincente storia degli acceleratori	Seminar	1.5	0.3	14/05/2021	Prof. Giuseppe Ruello, Prof.ssa Rita Massa (DIETI)	
End-to-End	Seminar	2	0.4	15/06/2021	5G	N

Optimization of Augmented Experience Services over Cloud-Integrated 5G Networks					Academy – Prof. Tulino (DIETI)	
Studying activity: •X-Ray Diffraction - Transmission Electron Microscopy (TEM) – Scanning Electron Microscope (SEM) - Differential scanning calorimetry (DSC). Writing Activity: •Preparation of a paper	Research	175	6	From: 1.05.2021 To: 30.06.2021	-	Y
Metodologie scalari e Vettoriali di misura dell'esposizione e tecniche di estrapolazione	Seminar	2	0.4	16/07/2021	Prof. Nicola Pasquino (DIETI, UNINA)	N
Writing Activity: •Publication of a preeprint • Preparation of a paper Studying activity: •Studies on the propagation of THz wave in a stratified medium.	Research	90	9.6	From: 1.07.2021 To: 31.08.2021		
Compressive Sensing as Applied to Electromagnetics Theory, Techniques, and EM Applications.	PhD School (ESOA Course)	33	3	From: 25.10.2021 To: 29.10.2021	ELEDIA Research Center, Trento	N
SAR Polarimetry: Theory, Machine Learning & Applications.	Seminar	2	0.4	19/10/2021	Prof. A. Iodice, DIETI – Unina	Y
Writing Activity: •Revision of a paper •Preparation of a paper Studying activity: •Study on the exploitation of THz technologies for the non destructive inspection of composite material focused on polymeric	Research	180	7	From: 1.09.2021 To: 31.10.2021	-	Y

matrixes loaded with magnetic nanoparticles (MNPs) that are widely used in tissue engineering and regenerative medicine.						

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	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**	

3. Research activity:

In the second year of my Ph.D I have continued the research activity started in the first year and I focused my study on Terahertz (THz) pulse imaging and its application for non-destructive inspection.

THz imaging is the newest among non-invasive sensing technologies and currently huge attention is pointed towards its use in several applications [1].

THz are electromagnetic waves ranging from 0.1 to 10 THz (wavelength from 3 mm to 30 μm), which are currently attracts considerable interest due to their unique properties [2].

THz radiation can penetrate a wide range of non-conducting materials, including plastic, polymers, ceramics, wood, and glass [3] [4]. In addition, THz waves are non-ionizing radiations thus they allow a non-destructive inspection of the materials and a safe analysis without requiring specific security protocols.

Various applications of THz waves have been reported in many fields, including medical diagnosis [5], pharmaceutical analysis [6], security enhancement [7] and artwork [8], just to name a few.

Among possible applications, food inspection represents one of the most prominent cases, due to the possible dangerous impact on human safety [1]. Hence, significant efforts are currently addressed towards the exploitation of THz imaging as a tool to improve the effectiveness of food quality surveys.

My activity deals with the exploitation of THz imaging technology for food quality control and assessment. In particular, my studies have aimed at reviewing the latest developments regarding THz imaging, both in terms of measurement systems and data processing methodologies and to propose some laboratory designed experiments aiming to demonstrate THz imaging capabilities to detect foreign body, surface defect and packaging failures.
The results of the experiments carried out last year and the data processing techniques developed are reported in the following published papers [9], [10] which represent my research products related to the application of THz technologies for food quality inspection. These works demonstrate the effectiveness of THz technology compared to other available techniques, highlighting its strength and limits.

Another important industrial application on which I focused my attention this year has been the non-destructive evaluation of composite materials [11][12], i.e. a combination of two or more materials, that differ in terms of chemical or physical properties and are merged to create a material with properties unlike the individual elements.
From industrial fields to biomedical applications, polymer-based composite materials have emerged as an interesting alternative, replacing others materials (i.e. metals, plastic and ceramics) in several applications, thanks to their mechanical properties, flexibility and structural integrity.
However, the manufacturing process of composite materials is a complex multivariable process [13], and the demand for ever more sophisticated procedures that allow to check the quality, the absence of defects and, more in general, a characterization of the manufactured material, is increasing.

The use of THz technology represents a good choice for a non-destructive inspection of these composite materials and allows to characterize them from a morphological point of view (thickness, shape, size) and to evaluate the presence of damages such as non – impregnated area in polymer composite materials.

In this frame, I have investigated THz imaging and spectroscopy capabilities to characterize poly-caprolactone scaffolds loaded with magnetic nanoparticles (MNPs) used in several medical application such as cancer therapy, tissue engineering and bone regeneration [14].

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.

The method used is partially described in a work submitted to the IEEE Transactions on Biomedical Engineering (a pre-print version is available [15]) and is the subject of a new paper in progress.

Ref.

[1] Ok, Gyeongsik, et al. "High-performance sub-terahertz transmission imaging system for food inspection." *Biomedical optics express* 6.5 (2015): 1929-1941.

[2] Y.-S. Lee, Principles of Terahertz Science and Technology. New York, NY, USA: Springer, 2009.

[3] G. A. Komandin, V. I. Torgashev, A. A. Volkov, O. E. Porodinkov, I. E. Spektor, and A. A. Bush, "Optical properties of ceramics in the frequency range 0.3–30.0 THz," Phys. Solid State, vol. 52, no. 4, pp. 734–743, Apr. 2010.

[4] S. Wietzke et al., "Terahertz spectroscopy on polymers: A review of morphological studies," J. Molecular Structure, vol. 1006, no. 1–3, pp. 41–51, Dec. 2011.

[5] E. Pickwell and V. P. Wallace, "Biomedical applications of terahertz technology," *J. PhysicsD: Appl. Phys.*, vol. 39, no. 17, pp. R301–R310, Sept. 2006.

[6] Y.-C. Shen, "Terahertz pulsed spectroscopy and imaging for pharmaceutical applications: A review," *Int. J. Pharmac.*, vol. 417, no. 1–2, pp. 48–60, Sept. 2011.

[7] Y. Wang, Z. Zhao, Z. Chen, K. Kang, B. Feng, and Y. Zhang, "Terahertz absorbance spectrum fitting method for quantitative detection of concealed contraband," *J. Appl. Phys.*, vol. 102, no. 11, p. 113108, Dec. 2007.

[8] Catapano, I., & Soldovieri, F. (2017). A data processing chain for terahertz imaging and its use in artwork diagnostics. *Journal of Infrared, Millimeter, and Terahertz Waves*, *38*(4), 518-530.

[9] Scapaticci, R., Zappia, S., Catapano, I., Ruello, G., Bellizzi, G., Pasquino, N., ... & Crocco, L. (2021, March). Broadband Electromagnetic Sensing for Food Quality Control: A Preliminary Experimental Study. In *2021 15th European Conference on Antennas and Propagation (EuCAP)* (pp. 1-5). IEEE.

[10] Zappia, S., Crocco, L., & Catapano, I. (2021). THz Imaging for Food Inspections: A Technology Review and Future Trends. DOI: 10.5772/intechopen.97615.

[11] I. Amenabar, F. Lopez, and A. Mendikute, "In introductory review to THz non-destructive testing of composite mater," *J. Infrared, Millim., THz Waves*, vol. 34, no. 2, pp. 152–169, Feb. 2013.

[12] L. Cheng and G. Y. Tian, "Comparison of nondestructive testing methods on detection of delaminations in composites," *J. Sensors*, vol. 2012, p. 408437, Jan. 2012.

[13] B. Qi, J. Raju, T. Kruckenberg, and R. Stanning, "A resin film infusion process for manufacture of advanced composite structures," Composite Structures, vol. 47, no. 1–4, pp. 471–476, 1999.

[14] Y. Li, G. Huang, X. Zhang, B. Li, Y. Chen, T. Lu, T. J. Lu, and F. Xu, "Magnetic hydrogels and their potential biomedical applications," *Adv. Funct. Mat.*, vol. 23, no. 6, pp. 660–672, 2013.

[15] 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.

4. Research products

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.

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).

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).

5. Conferences and seminars attended

9th International Workshop THz-Bio 2020 (online) 19-24/04/2021 organized by ENEA, IREA CNR, EISBem. Poster session on April, 21, 2021.

6. Periods abroad and/or in international research institutions

-

7. Tutorship

-

8. Plan for year three

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) with the exploitation of THz non-destructive inspection technique;
- Carry out measurements of appropriately laboratory designed samples.

Draft topic of the thesis:

The thesis will focus on the exploitation of THz imaging for the non-destructive inspection of different materials.
The first chapters of the thesis will aim to review the latest developments regarding THz technology and its applications in various fields (i.e. medical diagnosis, pharmaceutical analysis, security enhancement, artwork, food industry, composite materials). THz imaging technique will be described in terms of

measurement systems, sensing principle and data processing methodologies. Furthermore, THz technologies will be compared with other existing diagnostic techniques and its strong and weakness will be described.
The following chapters will aim to show 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.
Finally, the last chapters have the purpose to presents the results obtained for the case studies analyzed in the last years and to demonstrate THz imaging non-destructive inspection capabilities.