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

PhD Student: BARBARA ROSSI

Cycle: XXXVIII

Training and Research Activities Report

Year: FIRST

Barbara Rossi

Tutor: prof. Antonello Cutolo

A. Cutolo

Date: October 16, 2023

1. Information:

- **PhD student: Barbara Rossi**
- **DR number: DR996628**
- **Date of birth: 03/10/1996**
- **Master Science degree: Biomedical Engineering**
- **University: Federico II**
- **Doctoral Cycle: XXXVIII**
- **Scholarship type: UNINA**
- **Tutor: Antonello Cutolo**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Entangled relativity (SSM Scientific Colloquia)	Seminar	1	0.2	15/12/2022	Prof. Olivier Nlinazzali	Y
Cascading risk assessment in the energy and chemical industry: a longlasting issue in the new framework of climate change (SSM Scientific Colloquia)	Seminar	1	0.2	12/01/23	Valerio Cozzani	Y
Open Digital framework-crash (SSM Scientific Colloquia)	Seminar	3	0.6	17/01/23	Valeria Crimaldi	Y
Scientific programming and visualization in Pyhton	Course	10	2	21-23/02/23	Prof. A. Botta	Y
Industry 4.0 Fundamentals in Bosch Applications	Seminar	10	2	23-26/01/23	Eng. Martino Bruni,Prof. Ing. Mariagrazia Dotoli, National Doctoral program in	Y

					Autonomous Systems, in collaboration with Bosch – Centro Studi Componenti per Veicoli and the Decision and Control Laboratory of Politecnico di Bari.	
PRINCIPI ARCHITETTURALI-TOGAF I (5G Academy seminar)	Seminar	3	0.6	30/01/23	Prof A.Curcio, Ing. P.Boscolo	Y
PRINCIPI ARCHITETTURALI-TOGAF II (5G Academy seminar)	Seminar	3	0.6	9/02/23	Prof A.Curcio, Ing. P.Boscolo	Y
TBA (SSM Scientific Colloquia)	Seminar	1	0.2	9/02/23	Prof. Felix Otto	N
Blockchain and 5G in business (5G Academy seminar)	Seminar	3	0.6	13/02/23	Dr.Conforto Luca, Dr. Mutarelli Gabriele	Y
Multi-robot control of heterogeneous herds (SSM Scientific Colloquia)	Seminar	1	0.2	16/02/23	Dr Eduardo Montijano	N
How to boost your PhD	Course	20	4	19/04/23	Prof.ssa Antigone Marino	Y
Componenti e Circuiti Ottici	Course	45	9	20/06/23	Prof.A.Capozzoli (DIETI)	Y
Ottica e Iperfrequenze	Course	45	9	20/06/23	Prof.A.Capozzoli (DIETI)	Y

CI-LAM 2023	Summer School	26	5.2	17-21/07/23	Prof. G. Breglio,Prof. G. D'urso	Y
SIE 2023	Summer School	20	4	4-6/09/23	Prof. C.Ciofi	Y

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	-	**0.20**	**10**	-	**10.20**
Bimonth 2	**2**	**5**	**5**	-	**12**
Bimonth 3	**4**	-	**3**	-	**7**
Bimonth 4	**18**	-	**5**	-	**23**
Bimonth 5	-	**5.2**	**5**	-	**10.2**
Bimonth 6	**4**	-	**7**	-	**11**
Total	**28**	**10.40**	**35**	--	**73.40**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

During this year, I numerically investigated the possibility of exploiting the degrees of freedom offered by the LOF technology for the design of high-sensitivity optical fiber-based ultrasound detectors characterized by extreme level of integration for high-resolution photoacoustic imaging. Such a structure can be effectively realized on a standard single-mode optical fiber by exploiting the 2-photon Polymerization (TPP) technique. The analyzed structures have been modeled by exploiting a Finite Element Method (FEM) and simulation on MATLAB. The study aims to detect, starting from the state of the art, the best structure to maximize the sensitivity of the sensor for the detection of ultrasound. The analysis devices essentially work as interferometers. An incident acoustic wave can deform the structure modulating the cavity length and consequently the wavelength position of the spectral fringes. The analysis has been carried out from both acoustic and optical points of view, defining a sensitivity S which describes the reflectivity spectrum variation as a function of the incident field amplitude P at a fixed optical working wavelength. Among interferometer structures, the behaviors of the plano-concave microresonator, a polymeric slab, a membrane structure essentially work as a Fabry-Perot cavity and a multilayer structure.

Plano concave microresonator analysis

An article by Beard "Ultrasensitive plano-concave optical microresonators for ultrasound sensing" it was investigated the effect of the radius of curvature on the focalization of light inside the optical fiber for a Fabry-Perot sensor. This geometry potentially can correct the divergence by refocusing the light upon each round trip and preventing the beam from walking off laterally as it would in a planar

Fabry-Perot etalon. To understand the optical behavior of the fiber structure I tried to model the problem considering the propagation of a Gaussian beam and its interaction with a curved surface. I considered that the radius of curvature of the surface must be equal to the radius of curvature of the Gaussian beam to correct the divergence. To validate the study, I implemented a model on Comsol based on modeling the Gaussian beam output from the fiber and implementation of a plano-concave structure characterized by a certain radius of curvatures. The study shows that the Gaussian beam in the range of interest (near the optical fiber) is collimated. Coupling the radius of curvature of the plano concave FP with that of the Gaussian beam leads to an improvement in the reflection spectrum. However, it should be noted that the achieved improvement is still less than what was expected. Further from an acoustic behavior standpoint, it appears that both the planar and plano concave models exhibit similar responses.

Multilayer structure analysis

It is numerically investigated the possibility of realizing a multilayer structure on the tip of the optical fiber as a sensing element. The objective of the analysis is to find the optimized geometrical parameters characteristics for the structure to enhance the sensitivity of the acoustic detector. The multilayer structure is simulated on Matlab, using a toolbox "multidiel" to evaluate the optical behavior. From a preliminary analysis, it seems that the optical sensitivity is comparable with that of a Fabry-Perot cavity. Studies are still ongoing.

Compact models for complete simulation

To study the behavior of the devices with Comsol Multiphysics it is necessary to simulate the interaction between the incident acoustic wave (acoustic-structural interaction), which causes a deformation of the cavity thickness of the interferometer, and the shift of the reflection spectrum. Considering the acoustic-structural interaction and the electromagnetic field propagation as two different phenomena allowed us to define the sensitivity of the structure but with an approximation of the effect of the deformation on the structure. This activity has as objective to overcome this problem by implementing a compact model for acousto-optic interaction with Comsol Multiphysics to obtain accurate simulation. More in detail, the idea was to obtain the deformed solid geometry caused by the incident acoustic wave and use it as an initial geometry for the electromagnetic simulation. The study allowed the separate approach to be validated.

4. Research products:

B. Rossi, M. Giaquinto, M. A. Cutolo, A. Cusano, A. Cutolo, "Advanced integrated optical devices for ultrasound diagnostics", Springer Nature, Proceedings of SIE 2023 - 54th Annual Meeting of the Italian Electronics Society, A Springer book series Lecture Notes in Electrical Engineering

5. Conferences and seminars attended

- *China-Italy Joint Laboratory on Advanced Manufacturing (CI-LAM 2023),* Napoli, Italy, 17-21 July 2023.

- *SIE PhD School***,** Messina, Italy, 4-6 September 2023.
- *SIE Meeting***,** Noto (SR), Italy, 6-8 September 2023**. Poster presentation.**

6. Activity abroad:

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7. Tutorship

Co-supervision of bachelor's degree student (Lorenzo Fiore) thesis on "Rivelazione ecografica in fibra ottica".