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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Babar Ali**

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**Student ID: DR995148**

**PhD Cycle: XXXVI**

PhD Cycle Chairman: Prof. Stefano Russo

**PhD program student's start date: 01/11/2020**

**PhD program student's end date: 31/10/2023**

**Supervisor: Prof. Cutolo Antonello**

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**PhD scholarship funding entity: University of Federico II**

## General information

Babar Ali received in year 2020 a Master's Science degree in Electronics and Communication Engineering from the Beijing University of Posts and Telecommunications. He attended a curriculum in Photonics (Nanophotonic, Plasmonic, Photonics Biosensors) within the PhD program in Information Technology and Electrical Engineering. He received a grant from the University of Federico II.

## Study activities

### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1	From observability to privacy and security in discrete event systems	Ad hoc course	5	Prof. G. De Tommasi, DIETI - Prof. F. Basile, Univ. of Salerno - Prof. C. Sterle, DIETI	ITEE
1	Data Science for Patient Records Analysis	Ad hoc course	2.5	Prof. Marcello Cinque Prof.ssa Carmela Bravaccio	ITEE - ICTH
1	Cooperative and Non-Cooperative Localization Systems	Ad hoc course	3	Proff. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - DIETI	Proff. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - ITEE-DIETI
1	Scientific Programming and Visualization with Python	Ad hoc course	3	Prof. Alessio Botta, DIETI	DiSt department - Scuola Politecnica e delle Scienze di Base - UNINA
1	Lab VIEW Core 1,	External course	1.6		National Instruments
1	Advanced Topics in Radar Signal Processing	Ad hoc course	2	Prof. Alfonso Farina - Technical Consultant, previously with Selex ES (retired) Rome, Italy	Proff. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - ITEE-DIETI
1	Matrix Analysis for Signal Processing with MATLAB Examples	Ad hoc course	2	Prof. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - DIETI	Prof. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - ITEE-DIETI
1	Optoelectronics	Master Course	9	Prof. Cutolo Antonello, UNINA	DIETI, UNINA
1	Real-Time Embedded Systems for I4.0 and IoT	Ad hoc course	5	Prof. Marcello Cinque, Alessandro Cilardo - DIETI, UNINA	proff. Marcello Cinque, Alessandro Cilardo - ITEE-ICTH

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2	Software Defined Radio Applications for Radar and Localization Systems	Ad hoc course	3	Prof. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto	Prof. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - DIETI
2	Ultra-High Field Magnetic Resonance Imaging	Ad hoc course	3	Prof. Giuseppe Ruello, Rita Massa, Riccardo Lattanzi, Christopher Collins, Arturo Brunetti	Prof. G. Ruello - DIETI - ICTH
2	Virtualization technologies and their applications	Ad hoc course	5	Dr. Luigi De Simone, DIETI	Dr. Luigi De Simone, DIETI
2	Imprenditorialità Accademica	Ad hoc course	4	Coordinamento scientifico a cura di P. Rippa (Direttore StartCup Campania 2022 "Mario Raffa")	Università degli Studi di Napoli Federico II

### Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1 <sup>st</sup>	5G INTERNATIONAL PHD SCHOOL, PhD School - 5G Italy 2020	ONLINE Italy	3	01-03/12/2020	PhD School - 5G Italy 2020 University of Napoli Federico II
1 <sup>st</sup>	Optimization and Data Science: Trends and Applications, AIRO PhD School 2021 and 5th AIRO-Young Workshop	ONLINE Italy	3.6	08-12/02/2021	Sterle C., Sforza A., Boccia M., Masone A <a href="http://opslab.dieti.unina.it/index.php/en/">http://opslab.dieti.unina.it/index.php/en/</a> University of Napoli Federico II
1 <sup>st</sup>	Reinforcement Learning Virtual School, 2021	ONLINE	6.4	25-26/03/2021 01-02 & 08-09/04/2021	Sébastien Gerchinovitz The Toulouse AI institute ANITI
2 <sup>nd</sup>	School title		...		University of Napoli Federico II

### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	Robot Manipulation and Control	0.5	Prof. Bruno Siciliano	University of Naples Federico II	Prof. B. Siciliano, DIETI
1 <sup>st</sup>	Digital Project Management: practices, processes, techniques, tools and scientific approach	0.4	Prof. Dario Carotenuto	Project Management Institute, DIETI	Dip. di Fisica "Ettore Pancini" & DIETI

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1 <sup>st</sup>	Beyond Einstein gravity: Dark energy and dark matter as curvature effects	0.3	Ettore Pancini	Department of Physics, University of Naples Federico II – Italy Scuola Superiore Meridionale	Salvatore Capozziello
1 <sup>st</sup>	Patent Searching Best Practices with IEEE Xplore	0.2	Dr. Eszter Lukacs	IEEE - Client Service Manager	IEEE
1 <sup>st</sup>	How to Get Published with IEEE	0.3	Dr. Paul Henriques	IEEE - Client Service Manager Trainer	IEEE
1 <sup>st</sup>	Artificial Intelligence between Research and Industry	0.35	Mr. Davide Bargna	The Italian Chamber of Commerce and Industry (External seminar)	Italian Institute of Culture in Edinburgh and the Consulate General of Italy for Scotland and Northern Ireland
1 <sup>st</sup>	GDPR basics for computer scientists	0.3	Dr. Rigo Wenning	European Research Consortium for Informatics and Mathematics	Prof. P. Bonatti, DIETI
1 <sup>st</sup>	Seeing the Sound: Optical Neural Interfaces for In Vivo Neuromodulation	0.2	Dr. Guosong Hong	Stanford Materials Science and Engineering and Neurosciences (External seminar)	Sarah Weiler Photonics Media
1 <sup>st</sup>	Virtual Reality Optics: Present and Future	0.2	Pablo Benitez	Technical University of Madrid, Spain, Optical Engineering group (External seminar)	Sarah Weiler Photonics Media
1 <sup>st</sup>	Advances in Machine learning for Modelling and Understanding in Earth Sciences	0.3	Gustau Camps-Valls	Image Processing Lab (IPL), Universitat de Valencia (External seminar)	Prof. Antonio Iodice (DIETI)
1 <sup>st</sup>	Unraveling microscopic mechanisms in condensed matter systems with local magnetic field probes	0.2	Martino Poggio	Professor of Physics University of Basel (External seminar)	Lorenzo Ceccarelli, Martino Poggio's Lab, University of Basel, Zurich Instruments Physics Today
1 <sup>st</sup>	Designing a Socially Assistive Robot for adaptive and personalized assistance to patients with dementia	0.2	Dr. Antonio Andriella	Technical University of Catalonia (UPC) Barcelona, Spain	Prof.ssa S. Rossi, PRISCA Lab. - DIETI
1 <sup>st</sup>	Robo Ludens: A game design taxonomy for human-robot interaction	0.2	Dr. John Edison Muñoz Cardona	University of Waterloo, Canada	Prof.ssa S. Rossi, PRISCA Lab. - DIETI
1 <sup>st</sup>	Why Do We Cooperate? Understanding and	0.2	Mirco Musolesi	Professor at Department of	Dr. Marco Coraggio, Dr. Micol Benetti, Scientific Colloquium

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	Modelling Societies using Reinforcement Learning			Computer Science, University College London (External seminar)	at SSM
1 <sup>st</sup>	Logic-based Learning of Answer Set Programs	0.2	Mark Law	Imperial College London (External seminar)	Milano Logic Lunch Series 2021
1 <sup>st</sup>	IEEE Authorship and Open Access Symposium: Best Practices to Get Published to Increase the Exposure and Impact of Your Research	0.3	Dr. Josep M. Guerrero	Director, Center for Research on Microgrids Aalborg University, Denmark (External seminar)	Eszter Lukács, Paul Canning, IEEE
1 <sup>st</sup>	Molecular and cellular predictors of response to Cancer immunotherapy: beyond Tumour Mutational Burden	0.3	Francesca Ciccarelli	Cancer Genomics at King's College London and Group Leader at the Francis Crick Institute.	Prof. Michele Ceccarelli, DIETI
1 <sup>st</sup>	Artificial Intelligence and 5G combined with holographic technology: a new perspective for remote health monitoring	0.4	Dr. Pietro Ferraro, Dr. Pasquale Memmolo	Istituto di Scienze Applicate e Sistemi Intelligenti "Eduardo Caianiello", Consiglio Nazionale delle Ricerche	Prof. A.Maria Tulino - DIETS
1 <sup>st</sup>	Optimized Graph Representations for Right-Wing Reddit Community Using Graph Neural Networks	0.2			Prof.ssa Silvia Rossi.
1 <sup>st</sup>	Introduction Underwater Robotics	0.4	Prof. Gianluca Antonelli	University of Cassino - Italy	Dr. Fabio Ruggiero - DIETS - Unina
2 <sup>nd</sup>	Single cell omics leverage Machine Learning to dissect tumor microenvironment and cancer immuno editing	0.4	Dr. Raoul JP Bonnal	IFOM - the FIRC Institute of Molecular Oncology	Prof. Anna Corazza - DIETS, Unina
2 <sup>nd</sup>	Threat Hunting Essentials	0.4	Group-IB	Group-IB	Prof. D. Cotroneo, Prof. SP Romano, Dr. R. Natella, DIETS - Unina
2 <sup>nd</sup>	GDPR basics for computer scientists	0.4	Dr. Rigo Wenning	European Research Consortium for Informatics and Mathematics	Prof. Piero Bonatti, DIETS - Unina

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2 <sup>nd</sup>	All roads lead to WebRTC: an introduction to Janus	0.4	Dr. Lorenzo Miniero	Chairman and co-founder of Meetecho	Prof. SP Romano, DIETS - Unina
2 <sup>nd</sup>	Using Delays For Control	0.2	Prof. Emilia Fridman	Tel Aviv University, Tel Aviv, Israel, School of Electrical Engineering Tel Aviv University	Prof. Stefania Santini - DIETS - Unina
2 <sup>nd</sup>	Explainable Natural Language Inference	0.3	Dr. Marco Valentino	University of Manchester, Manchester, United Kingdom, Idiap Research Institute, Martigny, Switzerland	Prof. Francesco Cutugno, DIETS, Unina
2 <sup>nd</sup>	An Introduction to Deep Learning for Natural Language Processing	0.2	Dr. Marco Valentino	University of Manchester, Manchester, United Kingdom, Idiap Research Institute, Martigny, Switzerland	Prof. Francesco Cutugno, DIETS, Unina
2 <sup>nd</sup>	Vine robots: design challenges and unique opportunities	0.2	Dr. Nicholas Naclerio	University of California Santa Barbara - USA	Dr. Mario Selvaggio, DIETS - Unina
2 <sup>nd</sup>	Probing and infusing biomedical knowledge for pre-trained language models	0.4	Dr. Zaiqiao Meng	<i>University of Glasgow - UK</i>	Prof. Francesco Cutugno, DIETS, Unina
	5G Networks in Action - The Private Mobile Era	0.4	Athonet at 5G Academy	<i>University of Naples Federico II</i>	Alessandra Baldi
3 <sup>rd</sup>	N/A	...			

### Research activities

During his three-year academic career, Babar Ali has made considerable efforts to overcome the challenges associated with his PhD project. The main objective of this research was to design, fabricate and analyze a low-cost plasmonic substrate for attenuated total reflectance (ATR) – surface enhanced infrared absorption spectroscopy (ATR-SEIRA) applications.

ATR is a well-established technique for studying material properties by utilizing the evanescent field at a surface due to the phenomenon of total internal reflection. Infrared absorption spectroscopy, on the other hand, is a powerful tool for detecting and identifying molecules. However, the low infrared absorption cross-section of molecules often leads to low sensitivity and a poor signal-to-

noise ratio. SEIRA spectroscopy overcomes this limitation by utilizing the field-enhancing properties of plasmonic nanostructures to amplify the vibrational signals of trace molecules.

Babar Ali designed and investigated a plasmonic nanostructure based on a periodic Nano disk array using the COMSOL Multiphysics numerical simulator. He developed a numerical model to simulate the effect of a SEIRA substrate in ATR-SEIRA instrumentations (by including the “prism-effect” in the model). He analysed numerically the operation and performance of the device to determine its sensitivity and tunability. Nanosphere lithography was then used as self-assembly technique to fabricate representative SEIRA substrates. The samples were fabricated at the CNR in Milan. Babar Ali characterized the self-assembled SEIRA (Surface Enhanced Infrared Absorption) substrate using methods such as ATR FTIR spectral characterization and morphological imaging. The experimental analysis was performed at CNOS laboratory in Benevento. A bio absorbed analyte was used as a self-assembled monolayer for SEIRA substrate sensitivity testing. The obtained results were used to validate the numerical analysis and have been compared with the state of the art. Overall the experimental results demonstrated that the designed nanostructure combined with an ATR-SEIRA approach is suitable to strongly improve the performance for Infrared absorption bioanalyte characterizations.

## Tutoring and supplementary teaching activities

### Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	33.1	18.65	45	
2 <sup>nd</sup>	15	4.1	44	
3 <sup>rd</sup>	0	0	72	
<b>Total</b>	<b>48.1</b>	<b>22.75</b>	<b>161</b>	

## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1 <sup>st</sup>	N/A	N/A	N/A	N/A
2 <sup>nd</sup>	N/A	N/A	N/A	N/A
3 <sup>rd</sup>	N/A	N/A	N/A	N/A

## PhD Thesis

The PhD thesis collects and resumes the main results of the research activities carried out by Ali Babar. This thesis explores the development of a self-assembling SEIRA-active substrate using a closed array structure based on Nano disks. The aim of this research is to enhance the interaction between evanescent waves and molecular vibrations by using SEIRA metasurfaces. To characterize the spectral properties of the SEIRA substrate, a Nano disks array-based structure is patterned onto

a glass substrate and analyzed using an FTIR-ATR system. As a numerical analysis tool, COMSOL is used to evaluate various characteristics of the SEIRA substrate, including model stability, geometrical parameter effects, plasmonic tunability, and performance. Moreover, the numerical analysis provides a physical understanding of the factors affecting the self-assembled substrate's SEIRA response.

The outcomes of this study present a new approach for enhanced detection of trace chemicals and demonstrate the potential of the SEIRA substrate in boosting the sensitivity of FTIR-ATR measurements. Subsequently, an analysis of the morphology and performance of the SEIRA substrate was conducted using SEM and AFM microscopy. The findings revealed the formation of a uniform, well-ordered nanostructure, featuring nanometric gaps, which, according to the numerical simulation, host strong electromagnetic field enhancements. ATR FTIR spectral characterizations are used in order to assess the performance of the fabricated substrates and compared the results with the numerical predictions. These results confirm the correctness of the numerical modelling and reveal that the proposed cost-effective ATR- SEIRA substrates were repeatable, homogeneous and suitable to provide a boost of sensitivity up to  $10^5$ .

## Publications

We are currently preparing a manuscript of the research findings aim to be published in a peer review journal.

## List of scientific publications

**Authors:** Title: Self assembled Nano disk array-based substrate for SEIRA applications (In Progress).

## Patents and/or spin offs

N/A

## Awards and Prizes

N/A

Date 20/01/2024

PhD student signature



Supervisor signature

