NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Advanced Photonic Inertial Sensors for Autonomous Systems

Ph.D. candidate
Ludovico DINDELLI

Cycle
XL

Tutors
Prof. Francesco Dell'Olio (Supervisor)
Dr. Pietro Peliti (Co-supervisor)

1.Description of the research program

The progress in autonomous systems, such as satellites and robotics, necessitates the development of more compact, efficient, and cost-effective components. This is particularly true for Attitude and Orbit Control Subsystems (AOCS), which include Inertial Measurement Units (IMUs) essential for precise navigation and control. These units typically rely on accelerometers and gyroscopes; however, these critical components encounter limitations concerning size, weight, power consumption, and cost. Silicon photonics represents a cutting-edge technology with the potential to revolutionize IMU design by enabling significant miniaturization and enhanced performance. This research project focuses on integrating this silicon technology within the context of gyroscopes. In particular, we focuses on the design of Interferometric Fiber Optic Gyroscopes (IFOGs) to meet the increasing demands for high-precision autonomous navigation systems. A key aspect of our research is to optimize the IFOG system by significantly reducing their size and cost (SWaP-C), all while ensuring energy efficiency and precision required in aerospace, autonomous vehicles, and defense applications. A significant work has previously been carried out by my colleagues, in which a prototype of a FOG was designed and built. My future work will be characterized by the following main activities:

1)Characterization and experimental testing: we will conduct bench tests of the IFOG to assess its performance and identify the critical issues.

2)Theoretical modeling of the IFOG signal output: we aim to find a good theoretical model which ensure a good agreement between the experimental data and the expected behavior.

3)Miniaturization and performance improvement: based on the theoretical studies and current miniaturization techniques, we aim to design and improve a more efficient, compact, and reliable version of the IFOG, optimizing its performance.

The whole research project is grounded in preliminary work conducted by the group led by Prof. Francesco Dell'Olio at the Politecnico di Bari, which has indicated substantial advancements in the compactness and performance of IMUs. Moreover, a key partnership with Northrop Grumman Italia is central to this research. This collaboration is crucial not only for validating our designs but also for accelerating the transition from prototype to practical application. By working closely with an industry leader, we aim to set new benchmarks in performance and durability for autonomous systems, driving innovation across sectors like aerospace and robotics.

2.Schedule of the research activities

First academic year (completed/planned)

	Description	Period	Activity abroad
First steps into the project	I will conduct a comprehensive study on the functioning of Sagnac effect gyroscopes, with a focus on FOG devices. I will join the ongoing project and align myself with the work previously conducted by my colleagues.	1-4 month	NO
First prototype testing	We will conduct experimental tests to verify the capabilities of the first prototype built and analyze its critical issues to identify areas for improvement.	5-8 month	NO
Theoretical model of the prototype	I will focus on the theoretical model describing the behavior of the gyroscope, attempting to improve it as much as possible to provide an accurate analytical/numerical description of the output.	9-12 month	NO

Second academic year (completed/planned)

	Description	Period	Activity abroad
Investigation of miniaturization techniques	A research period aimed at studying the potential technologies that would enable the miniaturization of the prototype.	13-16 month	NO
Design of the second prototype	After studying how to address the issues of the previous prototype and how to exploit the miniaturization techniques, we will propose a new design for the gyroscope to enhance its performance are reduce the volume.	17-20 month	NO
Theoretical model of the second prototype	By studying the characteristics of the new design, I will attempt to develop a comprehensive theoretical model that allows for predicting the gyroscope's output.	21-24 month	NO

Third academic year (completed/planned)

	Description	Period	Activity abroad
Second prototype test	We will take the second prototype to Northrop Grumman Italy's facility in Pomezia to carry out precision tests, utilizing the advanced equipment provided by the company.	25-30 month	NO
Silicon photonics research activity	Research Period at DTU (Technical University of Denmark)	31-36 month	YES (6 months abroad)

3.Training and research activities plan

First academic year (completed/planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Advanced Fiber Optic Technologies for Biosensing	First semester	Yes	2
	Research methodologies	First semester	Yes	2
	Introduction to partial differential equations and applications	First semester	Yes	2
B.Master's degree courses	Digital Programmable Systems	Second semester	Yes	6
C. Soft skill courses				
D. Participation to seminars	2025 Siegman International school on lasers	Second semester	No	5
	SIDRA Summer School	Second semester	No	5
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			2
G.Individual research activity				2 3
H.Supervision of students				2
I. Integrative teaching activities	Didactic integration activities for bachelor's and master's students.	Second semester		2
J. Preparation of manuscripts for conferences or journals	Preparation of papers	First and second semesters		4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			
	TOTAL OF ECTS			60

Second academic year (completed/planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Inertial sensors	First semester	Yes	2
	Design of optical fiber devices with Finite Element Method	Second semester	Yes	1
	Electromagnetic design via professional softwares	First semester	Yes	1
	Matlab recipes for measurement signal processing		Yes	2
B.Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	2026 Siegman International school on lasers	Second semester	No	5
	11th ePIXfab Silicon Photonics Summer School	Second semester	No	5
E. Participation to international congresses or workshops	63th DGON ISS 2023	Second semester	No	2
F. Presentation of research products at international congresses or workshops	63th DGON ISS 2023	Second semester	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			2
G.Individual research activity				03
H.Supervision of students				0
I. Integrative teaching activities	Didactic integration activities for bachelor's and master's students.	First and second semesters		2
J. Preparation of manuscripts for conferences or journals	Preparation of papers	First and second semesters		8
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			
	TOTAL OF ECTS			60

Third academic year (completed/planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B.Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	2027 Siegman International school on lasers	Second semester	No	5
	12th ePIXfab Silicon Photonics Summer School	Second semester	No	5
E. Participation to international congresses or workshops	64th DGON ISS 2023	Second semester	No	2
F. Presentation of research products at international congresses or workshops	64th DGON ISS 2023	Second semester	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			1
G.Individual research activity				4 3
H.Supervision of students				0
I. Integrative teaching activities	Didactic integration activities for bachelor's and master's students.			6
J. Preparation of manuscripts for conferences or journals	Preparation of papers			10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			
	TOTAL OF ECTS			60

4.List of the publications written by the candidate in the triennium

Ludovico Dindelli

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Francesco Dell’Olio (Supervisor)

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