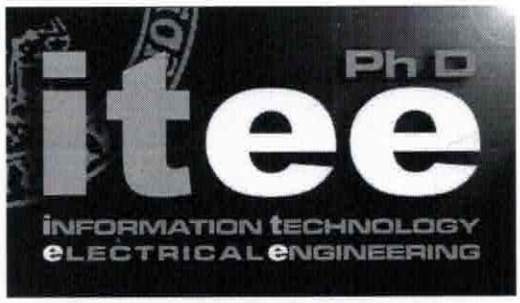

PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Roberto Tricarico

XXXII Cycle

Training and Research Activities Report – Third Year

Tutor: Prof. Carlo Forestiere

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

1. Information

a. Roberto Tricarico, bachelor's degree and master's degree in electronic engineering – Università degli Studi di Napoli Federico II
b. XXXII Cycle- ITEE – Università degli Studi di Napoli Federico II
c. Athenaeum Fellowship
d. Tutor: Prof. Carlo Forestiere

2. Study and Training activities

a. Courses (credits in brackets)
   I. Spanish course, level A1.1 (3).
   II. PhD school in "Light Matter Interaction in Dilute Media and Individual Quantum Systems" in Les Houches (3).

3. Credits Summary

	Credits year 1								Credits year 2								Credits year 3									
	Ef	bil 1	bil 2	bil 3	bil 4	bil 5	bil 6	Si	Ef	bil 1	bil 2	bil 3	bil 4	bil 5	bil 6	Si	Ef	bil 1	bil 2	bil 3	bil 4	bil 5	bil 6	Si	Tc	Cf
Modules	30	8	3	11	0	0	8	**30**	20	0	8	4	0	0	4	**16**	0	3	0	3	0	0	0	**6**	**52**	**30-70**
Seminars	10	0.4	0	0.4	6	3	0	**9.8**	10	0	2.3	3.5	0	3.8	0	**9.6**	0	0	0	0	0	0	0	**0**	**19.4**	**10-30**
Research	20	3	5	3	3	6	1	**21**	30	8	3	3	8	7.4	5	**34.4**	60	7	10	6.2	10	10	10	**53.2**	**108.6**	**80-140**
	60	11	8	14	9	9	9	**60.8**	60	8	13.3	10.5	8	11.2	9	**60**	60	10	10	9.2	10	10	10	**59.2**	**180**	**180**

4. Research activity

The third year of my PhD was entirely devoted to the research activity, subdivided in two different topics. On one side (1), I continued to work on the scattering by nanoparticles, as in the previews two years. On the other side (2), I started a new research line on Rydberg atoms at the Institute of Photonic Sciences ICFO, in Barcelona, where I spent the whole year. At ICFO I worked under the supervision of Prof. Dr. Darrick Chang, who also co-supervised the writing of the thesis.

a. Topic (1)
   Classical and Quantum Electromagnetic Theory of Nanoparticles
b. Study (1)
   Classical and Quantum Plasmonics
c. Research description (1)
   I'm involved in all the activities of the research group. In general, we study the electromagnetic scattering by plasmonic and dielectric nanoparticles and by two dimensional materials. We continue to develop the Material-Independent Modes (MIM) decomposition introduced in 2016 as a clever way to design Photonic nanostructures. This year we have applied the MIM decomposition to the study of the scattering by 2D materials and by quasi-1D resonators. Then, using the MIM, we have provided the first complete hybridization theory for dimers of dielectric spheres. More recently, we have proven the magnetoquasistatic nature of the long-wavelength resonances in high-index dielectrics.
   In addition, my personal main interest is in the quantum electrodynamic analysis of standard plasmonic structures, having the goal to understand how this modern vision can give relevant corrections to the classical electromagnetic scattering theory,

considering that, nowadays, the structures are becoming smaller and smaller. Recently, we have provided a time-domain quantum analysis of the radiative decay rate and of the frequency shift for arbitrarily-shaped metal nanoparticles and dimers.

d. Collaborations (1)
   We collaborate with the Electrical Engineering group from the University of Cassino (Prof. Tamburrino).

e. Topic (2)
   Nonlinearities in Rydberg EIT

f. Study (2)
   Quantum Optics, Cold Atoms, and Quantum Computing

g. Research description (2)
   The intrinsic noninteracting nature of photons makes light a perfect vehicle to carry the information. However, quantum gates need, by definition, interaction. At ICFO I was involved in the study of Rydberg ensembles of atoms, as a possible route to achieve effective photon-photon nonlinear interaction. In particular, prof. Chang and I focused our attention on the unexplored transient behaviour of these atomic ensembles. In 2019, experimental measurements have indeed shown that pulsed light can be more antibunched than continuous wave light. I worked on the understanding of the physical origin of this behaviour, and on whether this effect can reflect a stronger and "useful" nonlinearity.

h. Collaborations (2)
   At ICFO we collaborate with Prof. Dr. Hugues De Riedmatten and with his experimental group (Quantum Photonics with Solids and Atoms).

5. Products

a. Publications (peer-reviewed journals)
   i. C. Forestiere, G. Miano, M. Pascale, R. Tricarico, "Directional scattering cancellation for an electrically large dielectric sphere", Optics Letters, Apr. 2019.
   ii. C. Forestiere, G. Miano, M. Pascale, R. Tricarico, "Electromagnetic modes and resonances of two-dimensional bodies", Phys. Rev. B, Apr. 2019.
   iii. C. Forestiere, G. Miano, M. Pascale and R. Tricarico, "Electromagnetic Scattering Resonances of Quasi-1-D Nanoribbons", IEEE Transactions on Antennas and Propagation, Aug. 2019.
   iv. M. Pascale, G. Miano, R. Tricarico, and C. Forestiere, "Full-wave electromagnetic modes and hybridization in nanoparticle dimers", Scientific Reports, Oct. 2019.
   v. C. Forestiere, G. Miano, M. Pascale, G. Rubinacci, A. Tamburrino, R. Tricarico, and S. Ventre, "Magnetoquasistatic Resonances of Small Dielectric Objects." Accepted by Physical Review Research.

b. Publications (conference papers)
   vi. M. Pascale, R. Tricarico, G. Miano and C. Forestiere, Full-wave mode hybridization in nanoparticle dimers, International Conference on Electromagnetics in Advanced Applications (ICEAA 19), Granada, Spain, 2019, pp. 1239-1239.
   vii. R. Tricarico, C. Forestiere, G. Miano and M. Pascale, Field Quantization in Arbitrarily-Shaped Metal Nanoparticles, International Conference on Electromagnetics in Advanced Applications (ICEAA 19), Granada, Spain, 2019, pp. 1240-1240.

c. Publications under review

i. C. Forestiere, G. Miano, M. Pascale, R. Tricarico, "Quantum Theory of Radiative Decay Rate and Frequency Shift of Surface Plasmons Modes in Arbitrarily Shaped Nanoparticles", arXiv:2001.11926.

6. Conferences

i. Half-Day Meeting 2019 on cold atoms, Barcelona, February 8
ii. ICFO-IMPRS joint workshop on Quantum Technologies in Barcelona, March 20-22
iii. Superoscillations: Theoretical Aspects and Applications, Cetraro, June 14-17
iv. Plasmonica 2019, Napoli, June 19-21. Oral presentation: "Quantum theory of arbitrarily shaped plasmon nanoparticle".

7. Activity abroad

I spent the third year of my PhD in Castelldefels (Barcelona), at the Institute of Photonics Sciences, under the supervision of Prof. Dr. Darrick Chang in the Theoretical Quantum-Nano Photonics group. At ICFO, I also collaborated with the experimental group, headed by Prof. Dr. Hugues de Riedmatten (Quantum Photonics with Solids and Atoms).

Roberto Tricarico

Roberto Tricarico

Prof. Carlo Forestiere

Carlo Forestiere