

Ludovica Falsi

Curriculum Vitae

Personal data

About Me

As a physicist and researcher, one of my main features is a broad background of knowledge motivated by a deep interest in different fields. Although this interest includes theoretical descriptions, my approach to understanding physical phenomena is mainly experimental, and I am really enthusiastic about performing lab experiments. During my PhD I developed a strong background in nonlinear optics and photonics, acquiring good theoretical and experimental skills. The goal of my research is focused on the investigation of a new generation of 3D photonic materials with improved efficiencies and enhanced nonlinear functionality, which can open hereto unexplored and groundbreaking applications in imaging, spectroscopy, biology, and medical diagnosis. I am a proactive, very curious, and determined person who strongly believes in multidisciplinary teamwork, as reflected in the extensive scientific collaborations that I have already developed. I am very keen to learn new arguments and experimental techniques, and I am particularly open to address new issues.

Professional

01/05/2022- 30/04/2023 ◦ **Postgraduate Research Grant**, *Physics Departement*, University of Rome "La Sapienza" , 00185 Rome, Italy.

Announcement 246/2021- CAT A.

Education

1/11/2018- 31/10/2021 ◦ **PhD in Electromagnetism**, *Physics Departement*, University of Rome "La Sapienza" , 00185 Rome, Italy.

01/05/2018- 30/09/2018 ◦ **Winner of a Scholarship**, *Physics Departement*, University of Rome "La Sapienza" , 00185 Rome, Italy.

Supervisor Prof. Eugenio Del Re

Research title "Studio della modulazione in polarizzazione in super-cristalli ferroelettrici e fenomeni di ottica senza scala".

Description I performed refraction and diffraction experiments in a ferroelectric perovskite realized by a periodic structural design, that demonstrate an unnaturally high refractive index ($n > 26$) across the entire visible spectrum.

01/10/2017- 01/05/2018 ◦ **Postgraduate Visitor at Photonics Lab**, *Physics Departement*, University of Rome "La Sapienza" , 00185 Rome, Italy.

Supervisor Prof. Eugenio Del Re

25/01/2017 ◦ **Master Degree in Physics**, *Physics Department*, University of Rome "La Sapienza" , 00185 Rome, Italy.

25/01/2017 ◦ **Bachelor Degree in Physics**, *Physics Department*, University of Rome "La Sapienza" , 00185 Rome, Italy.

PhD Thesis

Title *Photonics in the ferroelectric super-crystal phase.*

Supervisor Eugenio Del Re

Description Nanodisordered ferroelectric perovskites belong to the family of relaxor ferroelectrics, and have long been attracting considerable attention in view of their unique physical properties. The introduction of compositional disorder on the nanoscale leads to the appearance of a broad temperature and frequency dependent peak in the dielectric susceptibility that manifests thermal, electric field, and strain hysteresis and is associated with anomalous relaxation. The presence of different compounds introduces, for specific composition concentrations, competing structural phases leading to unique polarization properties, such as the anomalous large capacitance and the giant piezoelectric effect. Recently, a new ferroelectric phase of matter, the spontaneous super-crystal phase (SC), has been discovered in bulk solid-solution of nanodisordered ferroelectric perovskite, several degrees below the Curie point. In this phase, domains, instead of locking into a disorganized pattern of clusters, form a 3D regular lattice of spontaneous polarization with micrometer lattice constant across macroscopic samples. This phase mimics standard solid-state structures but on scales that are thousands of times larger. The work presented in this thesis is an experimental investigation, through several photonics techniques, of the SC phase. In order to investigate the properties of the underlying ferroelectric domains, we first analyze the light-polarization dynamics which emerge from the interplay of mesoscopic domain ordering and anisotropy. Results indicate that polarized light propagating through the SC spatially separates in its polarization components, of mutually orthogonal linear polarization states. Furthermore, performing diffraction and refraction experiments, we discover that the SC phase is also accompanied by a broadband giant refraction (GR). Here the effective index of refraction is greater than 26 across the entire visible spectrum, even though no optical resonance is in place. The result is a material with no chromatic aberration and no diffraction. The discovery of GR opens up a wholly new realm of study, allowing us to expand our investigation to the field of nonlinear optics. Enhanced response causes wavelength conversion to occur in the form of bulk Cherenkov radiation with an arbitrarily wide spectral acceptance, more than 100 nm in the near infrared spectrum, an ultra-wide angular acceptance, up to $\pm 40^\circ$, with no polarization selectivity. From a more fundamental point of view, trying to understand the behavior and physics of complexity-driven GR, in particular the role played by ferroelectric clusters, using a 3D orthographic cross-polarizer projection technique, we provide for the first time, direct imaging of fractal cluster percolation. We also study the effect that the SC, of micrometer-scale, has on the average atomic structure, using several results, obtained through different experimental techniques, from X-ray diffraction, to calorimetry. What we have found, is that the emergence of the SC is accompanied by a large scale and coherent anomalous lattice deformation. Alongside the investigation of the SC phase, we have exploited the strong nonlinear optical response of disordered ferroelectric crystals at the phase transition, which makes these materials suitable to study the physics of nonlinear waves. In our study, we focus principally on the exploration of applications in electro-optic integrated

circuits, based on linear and nonlinear waves, and on the analysis of the physical origin of so-called soliton rogue waves.

Final Mark Magna cum laude

Topics Nonlinear optics, Photonics, Condensed matter physics.

Master Thesis

Title *Scale-free optical propagation and imaging*

Supervisor Prof. Eugenio Del Re

Description I worked for 8 months carrying out experiments in the laser light imaging of holes of different shapes, realized onto a ferroelectric perovskite, in the scale-free regime, which allows the canceling or inverting diffraction, without conditions on the propagating waveform, thus overcoming diffraction limits.

Final Mark 110/110 magna cum laude

Topics Nonlinear optics, Photonics, Condensed matter physics.

Bachelor Thesis

Title *Coalescenza Bosonica con Beam Splitter e Triter Supervisor*

Prof. F. Sciarrino

Description Theoretical study of the generalization of the three-photon Hong Ou Mandel effect, leading to the demonstration of three-photon bosonic coalescence in a tritter.

Topics Quantum Optics, Photonics.

Publications

Publications in international peer-reviewed journals:

1. Y. Gelkop, F. Di Mei, S. Frishman, Y. Garcia, **L. Falsi**, G. Perepelitsa, C. Conti, E. DelRe and A. J. Agranat "Hyperbolic optics and superlensing in room-temperature KTN from self-induced k-space topological transitions", *Nat Commun* **12**, 7241 (2021).
2. F. Xin, F. Di Mei, **L. Falsi**, D. Pierangeli, A. J. Agranat and E. DelRe "Evidence of chaotic dynamics in three-soliton collisions" *Phys. Rev. Lett.* **127**, 133901 (2021)
3. **L. Falsi**, M. Aversa, F. Di Mei, D. Pierangeli, F. Xin, A. J. Agranat and E. DelRe "Direct Observation of Fractal-Dimensional Percolation in the 3D Cluster Dynamics of a Ferroelectric Supercrystal" *Phys. Rev. Lett.* **126**, 037601 (2021).
4. L. Lo Presti, J. Parravicini, R. Soave, G. Parravicini, M. Mauri, L. Loconte, F. Di Mei, **L. Falsi**, L. Tartara, S. Binetti, Aharon J. Agranat and E. DelRe "Observation of an exotic lattice structure in the transparent $\text{KTa}_{1-x}\text{Nb}_x\text{O}_3$ perovskite supercrystal" *Phys. Rev. B* **102**, 214110 (2020).
5. **L. Falsi**, L. Tartara, F. Di Mei, M. Flammini, J. Parravicini, D. Pierangeli, G. Parravicini, F. Xin, P. Di Porto, A. J. Agranat and E. DelRe "Constraint-free wavelength conversion supported by giant optical refraction in a 3D perovskite supercrystal" *Commun. Mater.* **1**, 76 (2020).
6. F. Xin, F. Di Mei, **L. Falsi**, D. Pierangeli, A. J. Agranat and E. DelRe "Soliton Maxwell demons and long-tailed statistics in fluctuating optical fields" *Opt. Lett.* **45**, 648-651 (2020).
7. F. Xin, M. Flammini, F. Di Mei, **L. Falsi**, D. Pierangeli, A. J. Agranat and E. DelRe "Using Bessel Beams to Induce Optical Waveguides" *Phys. Rev. Applied* **100**, 043816 (2019).
8. F. Xin, M. Flammini, F. Di Mei, **L. Falsi**, D. Pierangeli, A. J. Agranat and E. DelRe "Observation of extreme nonreciprocal wave amplification from single soliton-soliton collisions" *Phys. Rev. Applied* **11**, 024011 (2019).
9. F. Di Mei, **L. Falsi**, M. Flammini, D. Pierangeli, P. Di Porto, A.J. Agranat and E. DelRe "Giant broadband refraction in the visible in a ferroelectric perovskite," *Nat. Photon.* **12**, 734-738 (2018).

10. M. Ferraro, D. Pierangeli, M. Flammini, G. Di Domenico, **L. Falsi**, F. Di Mei, A. J. Agranat and E. DelRe, "Observation of polarization-maintaining light propagation in depoled compositionally disordered ferroelectrics," *Opt. Lett.* **42**, 3856-3859 (2017).

Conference proceedings

1. L. Falsi et al., "Direct Imaging of Fractal-Dimensional Percolation in the 3D Cluster Dynamics of a Ferroelectric Super-Crystal," in 2021 Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference, OSA Technical Digest (Optical Society of America, 2021), paper ce_10_4.
2. L. Falsi et al., "Constraint-free wavelength conversion supported by giant refraction in a 3D perovskite Super-Crystal," in 2021 Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference, OSA Technical Digest (Optical Society of America, 2021), paper cd_11_4.
3. L. Falsi et al., "Giant broadband refraction in the visible in a nanodisordered ferroelectric perovskite," in 2019 Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference, OSA Technical Digest (Optical Society of America, 2019), paper ce_6_1.
4. L. Falsi et al., "Giant Broadband Refraction in the Visible in a Disordered Ferroelectric Perovskite," 2019 Photonics & Electromagnetics Research Symposium - Spring (PIERS-Spring), Rome, Italy, 2019, pp. 1647-1655.
5. F. Xin, M. Flammini, F. Di Mei, **L. Falsi**, et al., "Using Bessel beams to induce programmable volume integrated optical circuitry," in 2019 Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference, OSA Technical Digest (Optical Society of America, 2019), paper cd_p_42.

Project grants

2020 **Bando per progetti di mobilità di studenti di dottorato di ricerca**, *four-month scholarship for reasearch activity at the KTH-Royal Institute of Technology (Sweden)*.

Project title: High-dimensional quasi-phase-matching in nanodisordered ferroelectric Super-Crystals QUNAFES. Founded by University of Rome "La Sapienza". The aim of the project is the development of a nonlinear material able to enhancing overall nonlinear conversion efficiency. Because of the covid disease, I could not complete the project.

2020 **Progetti di Ricerca (Piccoli, Medi)**, *Progetti Piccoli*.

Project title: Fractal-dimensional ferroelectric cluster percolation in super-crystals -FRACFER. Founded by University of Rome "La Sapienza" (n. RP120172B897A4A2). The FRACFER proposal aims at experimentally exploring ferroelectric cluster percolation during a structural transition. Using giant broadband optical refraction, we will use 3D orthographic projection imaging in ferroelectric KTN:Li to provide, for the first time, direct imaging evidence of self-similar fractal percolation.

2019 **Avvio Alla Ricerca**, *starting grant for young researchers*.

Project title: Self-Aligning Achromatic Optical Transducers. Founded by University of Rome "La Sapienza" (n. AR11916B5B406E00). The goal of the proposal is to demonstrate a viable self-aligning optical transducer for broadband visible light.

Teaching activity

2019–2020 **Co-Advisor**, *master thesis*.

Former student: Marco Aversa.

2014–present **Private tutoring**, *Math and Physics*.

Conferences, workshops and collaborations

Scientific Collaborations

- 2020-present **Scientific collaboration** , *Prof. Carlota Canalias*, KTH-Royal Institute of Technology-Stockholm, Sweden.
- 2019-present **Scientific collaboration** , *Prof. Stefano Lupi*, Rome, Italy.
Spectroscopy in disordered ferroelectric crystals.
- 2018-present **Scientific collaboration** , *Prof. Luca Tartara*, Pavia, Italy.
Visiting at the Nonlinear Optics and Ultrafast Spectroscopy Lab (Engineering Department, University of Pavia) for experiments on second harmonic generation in disordered ferroelectric crystals
- 2018-present **Scientific collaboration** , *Prof. A.J. Agranat*, Jerusalem, Israel. A.J.
Agranat developed and synthesized the materials.

Conferences

- January 2022 **Conference**, *EMA 2022*.
Conference on Electronic Materials and Applications 2022, 19-21 January 2022, Orlando - FL, USA. **Invited speaker and session moderator**. Oral contribution with title: Direct Imaging of Fractal Dimensional Percolation in the 3D Cluster Dynamics of a Perovskite Supercrystal.
- June 2021 **Conference**, *CLEO/Europe-EQEC 2021*, Virtual Meeting.
European Conference on Lasers and Electro-Optics and European Quantum Electronics Conference, 21-25 June 2021.
Oral contribution with title: Direct Imaging of Fractal-Dimensional Percolation in the 3D Cluster Dynamics of a Ferroelectric Super-Crystal.
- June 2021 **Conference**, *CLEO/Europe-EQEC 2021*, Virtual Meeting.
European Conference on Lasers and Electro-Optics and European Quantum Electronics Conference, 21-25 June 2021.
Oral contribution with title: Constraint-free wavelength conversion supported by giant refraction in a 3D perovskite Super-Crystal.
- May 2020 **Conference**, *2020 Conference on Lasers and Electro-Optics ("CLEO") presented in an all-virtual, web conference format, from 11-15 May 2020*.
Attendance.
- June 2019 **Conference**, *CLEO/Europe-EQEC 2019*, Munich, Germany.
European Conference on Lasers and Electro-Optics and European Quantum Electronics Conference, 23-27 June 2019, Munich, Germany.
Invited speaker. Oral contribution with title: Giant broadband refraction in the visible in a nanodisordered ferroelectric perovskite.
Poster presenter. Poster contributions with title: Using Bessel beams to induce optical waveguides.
- June 2019 **Conference**, *Piers 2019*, Rome, Italy.
Photonics & Electromagnetics Research Symposium, 17-20 June 2019, Rome, Italy.
Oral contribution with title: Giant broadband refraction in the visible in a disordered ferroelectric perovskite.

School and Workshop

- July 2021 **Online Summer School**, *School of Scientific Computing with MATLAB 2021*, U4Learn, University of Palermo.
I attended the summer school from 19/07/2021 to 30/07/2021, which focusing on programming and scientific computing with MATLAB, parallel and distributed computing, and familiarization with Machine Learning and Big Data Analytics.

2019 **First prize for the Best Student Paper Award** at Piers 2019 in the category Optics and Photonics.
Paper Title: Giant Broadband Refraction in the Visible in a Disordered Ferroelectric Perovskite.

Languages

Italian Mothertongue
English Good
Spanish Basic

September **Online Summer School, Computational Photonics**, KIT.

2020 I attended the summer school from 21/09/2020 to 25/09/2020, which focusing on computational methods to simulate the propagation of electromagnetic waves in complex environments, a key technology in the development of modern photonic devices and structures.

July-August **School and Workshop, Data-driven methods for multi-scale physics and complex systems**, Physics Department, University of Rome "La Sapienza", Rome, Italy.

2017 I attended the summer school and workshop from 24/07/2017 to 04/08/2017, which focusing on emerging theoretical and computational methods at the intersection of data science, complex systems and networked.

Awards

Computer skills

- ☑ Windows, Linux
- ☑ C, Matlab, Python, Latex
- ☑ Origin, MS Office, Autodesk 3ds Max