Curriculum: Fisica della Materia / Physics of Matter

Referente/Contact person: Prof. C. de Lisio

❑ Regolamento didattico / Didactic Regulations

- ❑ Il Curriculum "Fisica della Materia" ha l'obiettivo specifico di trasmettere al laureato magistrale una conoscenza approfondita di almeno un'area disciplinare della fisica della materia, tra cui la fisica dello stato solido, inclusi semiconduttori e sistemi nanostrutturati, superconduttori e altri materiali fortemente correlati, la fisica della materia condensata soffice, inclusi polimeri, cristalli liquidi e sistemi biologici, la fisica atomica e molecolare, nonché l'ottica moderna e la fotonica, e la capacità di applicare tale conoscenza in ambiti lavorativi connessi con lo sviluppo e l'applicazione di tecnologie avanzate, ad esempio nei settori industriali dei semiconduttori, della tecnologia dell'informazione e della comunicazione, dell'opto-elettronica, dei nuovi materiali, e delle tecniche diagnostiche avanzate, operando con elevato livello di autonomia e affrontando e risolvendo problemi con caratteristiche non standard.

Articolazione del Corso di Studi

I Anno

Insegnamenti e attività formative

Insegnamenti	CFU	Ambito disciplinare	
Elettrodinamica Classica	9	Microfisico e della struttura della materia	obbligatorio
Fisica dello Stato Solido I	6	Microfisico e della struttura della materia	obbligatorio
Laboratorio di Fisica	9	Sperimentale applicativo	obbligatorio
Meccanica Quantistica	9	Teorico e dei fondamenti della fisica	obbligatorio
Meccanica Statistica I	6	Teorico e dei fondamenti della fisica	obbligatorio
Insegnamento a scelta autonoma	6		obbligatorio

Altre attività

Ulteriori attività formative (art.10 c.5)	4	Ulteriori conoscenze linguistiche	obbligatorio
Ulteriori attività formative (art.10 c.5)	2		obbligatorio

Articolazione del Corso di Studi

II Anno

Tre insegnamenti a scelta tra:

Insegnamenti	CFU	Ambito disciplinare	
Biofotonica	6x3		obbligatorio (3 a scelta)
Fasi quantistiche della Materia			
Fisica dei Plasmi			
Fisica della Materia Soffice			
Fisica dello Stato Solido II			
Fondamenti di Nanomagnetismo e Applicazioni			
Fotonica			
Modellazione Computazionale dei Materiali			
Ottica e Informazione Quantistica			
Ottica Moderna			
Sistemi Aperti Quantistici			
Spettroscopia Ottica			
Tecnologie Quantistiche Superconduttive			
Termodinamica Computazionale			

Articolazione del Corso di Studi

II Anno

Un insegnamento a scelta tra:

Insegnamenti	CFU	Ambito disciplinare	
Laboratorio di Ottica Moderna	6	Microfisico e della struttura della materia	obbligatorio (1 a scelta)
Meccanica Quantistica dei Molti Corpi		Microfisico e della struttura della materia	
Metodi Sperimentali per Nanotecnologia e Materia Condensata		Microfisico e della struttura della materia	

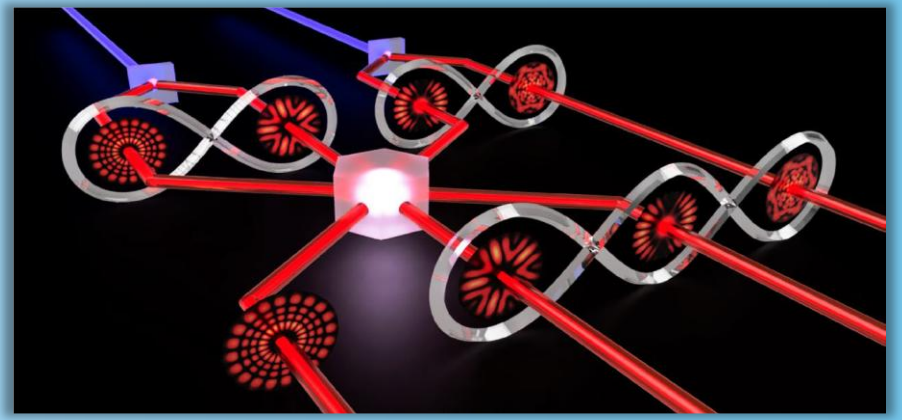
Insegnamenti

Insegnamento a scelta autonoma	6		obbligatorio

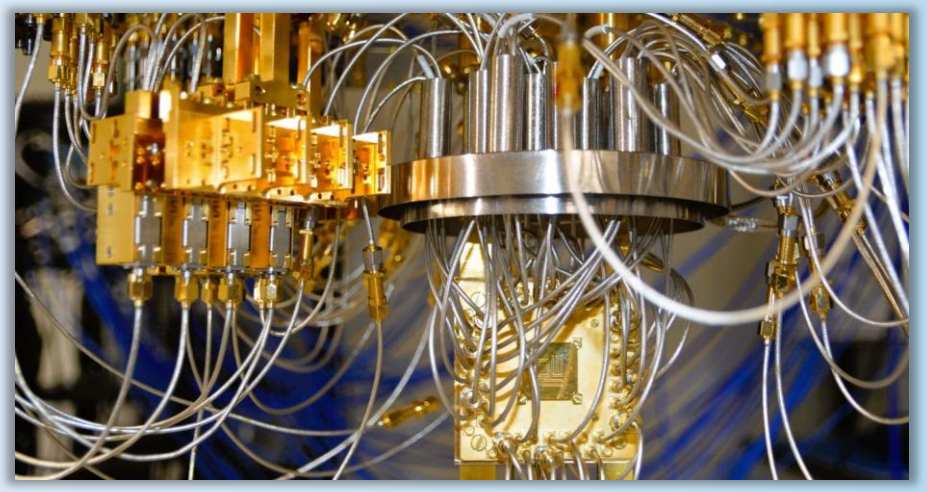
Prova finale

Prova finale	39		obbligatorio

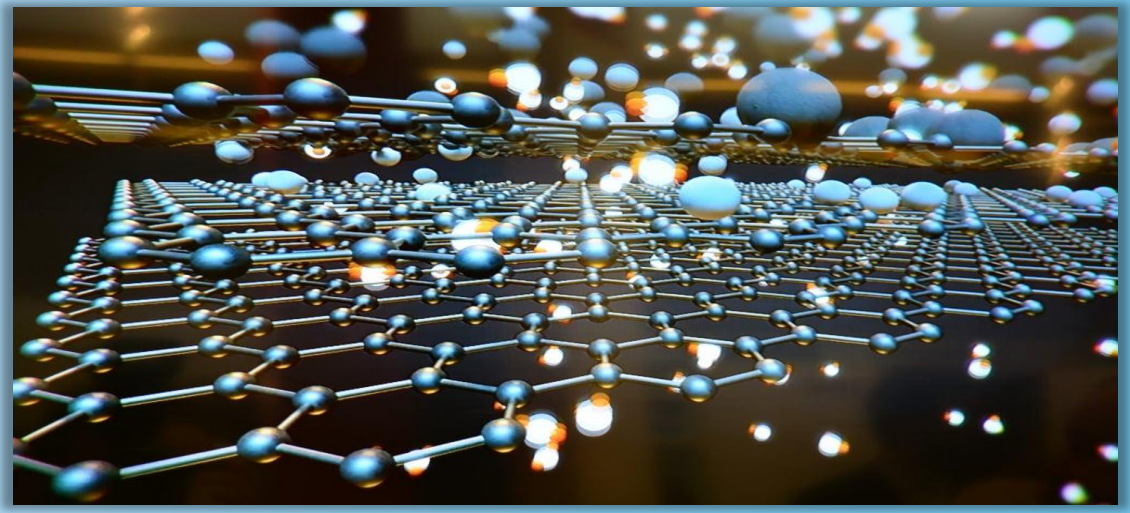
Aree disciplinari



- Ottica, fotonica e spettroscopia
  - Ottica quantistica, ottica non lineare e ultraveloce, fotonica
  - Bio-fotonica, nano-ottica, ottica applicata
  - Spettroscopia



- Materiali e dispositivi
  - Superconduttività, tecnologia e informazione quantistica
  - Magnetismo, film sottili, materia soffice, materiali innovativi
  - Sensori, nuovi dispositivi



- Modellizzazione della materia condensata
  - Scienza computazionale dei materiali, materiali 2D
  - Sistemi fortemente correlati, struttura elettronica, nano-sistemi quantistici
  - Informazione e calcolo quantistico

❑ Light-Matter interaction, Quantum optics, Optical spectroscopy

- ❑ Physics of Structured Light and Matter (*L. Marrucci, B. Piccirillo, A. Rubano, F. Cardano, F. Di Colandrea, D. Paparo*) – Webpage: https://www.slam.unina.it/
  - ❑ Generation, manipulation and detection of classical and quantum structured light
  - ❑ Photonic simulations of quantum processes of fundamental interest
  - ❑ Quantum information processing with free-space photonic circuits
  - ❑ Nonlinear optics and spectroscopy of complex materials (THz spectroscopy)

- ❑ LIDAR (*S. Amoruso, A. Boselli, A. Sannino*)
  - ❑ Characterization of atmospheric particulate matter with physical techniques (LIDAR, Sunphotometer, etc.)
  - ❑ Monitoring of ambient and atmosphere

- ❑ Holographic Surface Patterning (*S. Oscurato, M. Salvatore*)
  - ❑ Illumination strategies to achieve complex surface topographies
  - ❑ Diffractive optical components
  - ❑ Wettability tailoring

- **Light-Matter interaction, Quantum optics, Optical spectroscopy**
  - **Ultrafast Phenomena and Quantum Photonics (*C. de Lisio*, *V. D'Ambrosio*, *B. Sephton*, *C. Schiano*, *R. Thomas*, *E. Darsheshdar*) – Webpage: https://quantumphotonics.unina.it/**
    - Photonic states with complex entanglement
    - Quantum nanophotonics
    - Fundamentals of quantum mechanics
    - Quantum Information and Communication with photonic systems
  - **Photophysics of 2D materials and heterostructures (*F. Gesuele*, *F. Chiarella*)**
    - Correlative Optical Spectroscopy combined with High-Resolution Microscopy
    - Electronic and Vibrational Properties of Low-Dimensional Materials (0D quantum dots, 2D graphene, 2D transition metal dichalcogenides)
    - Photophysics and Optoelectronics of 2D Ruddlesden–Popper Perovskites
    - Charge and Energy Transfer effects in Mechanically Assembled van der Waals Heterostructures (TMD/TMD, TMD/2D Peroskites)
  - **Functional Photocatalytic Nanomaterials (*S. Lettieri*, *A. Fioravanti*, *R. Rega*)**
    - Materials and methods for optical sensing of oxygen
    - Photophysical properties of oxide nanocatalysts for energy and environmental applications

- **Spectroscopy for Life Science, Biosensing and Bio-photonics, Electromagnetic materials and devices**
  - **Amplified Raman Spectroscopy and optical trapping for the analysis of complex systems (*G. Rusciano*, *B. Catalano*, *G. Pesce*, *A. Sasso*)**
    - Study of bio-interfaces by Surface Enhanced Raman Spectroscopy
    - Nanoscale Raman spectroscopy using Tip Enhanced Raman Scattering
    - Non conventional Brownian motion in complex networks
  - **Optical biosensors for medical diagnostics, food safety and environmental monitoring (*B. Della Ventura*, *A. Acunzo*, *D. Marra*, *R. Velotta*)**
    - Paper-based biosensors
    - Nanostructured metasurfaces for plasmon-enhanced biosensing
    - Colorimetric biosensors based on colloidal solutions of functionalized gold nanoparticles

❑ Nano-structured materials, Meta-materials

❑ Laser Ablation (*S. Amoruso, A. Purushothaman, G.M. De Luca*)

- ❑ Fabrication of surface micro- and nano-structures with laser light
- ❑ Laser ablation (laser ablation processes, laser surface texturing, in-situ aerosol analysis system, …)

❑ Low dimensional Materials and Devices for Electronics and Sensors (*A. Cassinese, M. Barra, F. Chiarella, A. Zaheer*)

- ❑ Fabrication and characterization of FET and electrochemical transistors based on organic, 2D and hybrid materials
- ❑ Mechanisms of charge injection and study of transport properties in semiconductive organics, 2D materials or organic/inorganic heterostructures
- ❑ Deposition of innovative organic semiconductors and heterostructures with supersonic beams
- ❑ Quantum technologies based on high-Q microwave resonant cavities coupled to spin ensembles for the development of MASER and quantum sensing

❑ THz Physics (*C. Koral, Z. Mazaheri, A. Passarelli, G. Papari, A. Andreone*)

- ❑ Time domain spectroscopy of innovative materials
- ❑ THz Ellipsometry
- ❑ Plasmonic based devices and metadevices for sensing, metasurfaces and RIS for TLC
- ❑ Novel (tunable, switchable, digital, …) optical components

❑ Nano-structured materials, Meta-materials

❑ Matrix Assisted Pulsed Laser Evaporation – MAPLE (*G. Ausanio*, *G.P. Pepe*)

- ❑ Deposition and characterization of nanostructured materials by MAPLE
- ❑ Laser deposition of Nanomaterials for electronics, energy and biotechnology

❑ Magnetic Nanomaterials for Advanced Functional Systems (*G. Ausanio*, *V. Iannotti*)

- ❑ Magnetic nanoparticles and core@shell heterostructures for magnetic hyperthermia
- ❑ Magnetic nanoparticle–polymer hybrids for stimuli-responsive applications
- ❑ Biocompatible magneto-active nanocomposite membranes

❑ Multifunctional Nanostructured Magnetic Materials and 2D Materials for (Bio)Sensing (*B. Della Ventura*, ***Z.U.D. Babar, M. Fatima***, *V. Iannotti*)

- ❑ Functionalized magnetic nanoarchitectures (core@shell and core@satellite) for magnetoresistive and magnetophoretic biosensing
- ❑ Multifunctional 2D materials (MXenes) and MXene-Gold nanoparticle hybrids for advanced sensing

❑ Oxides and organic interfaces

❑ Physics of functional oxides and oxide-based devices (*E. Di Gennaro, U. Scotti di Uccio, F. Miletto Granozio, A. Sambri, A. Guarino, D. De Luca, D. Stornaiuolo*)

- ❑ Perovskite/oxides interfaces
- ❑ Structural and electronic properties
- ❑ Fabrication of epitaxial structures (LaAlO3/ SrTiO3)
- ❑ Fabrication of a graphene/LaAlO3/ SrTiO3 tri-layer
- ❑ Realization of a field-effect transistor
- ❑ Ferromagnetism and superconductivity in heterostructures

❑ Oxides for electronics and related interfaces (*E. Di Gennaro, D. Stornaiuolo*)

- ❑ Electronic properties of surfaces and interfaces
- ❑ Ferroelectricity and ferromagnetism in STO/BMO
- ❑ Electric transport measurements and STM/STS, XAS, GXID, SPA-LEED, and ARPES techniques
- ❑ Fabrication of nanostructures and nanodevices

❑ Oxides and organic interfaces

❑ Bio-inspired materials for bioelectronics and biosensing (*A. Pezzella, D. Capasso, R. Di Capua, E. Carrella, J. Ahmad, B.-C. Jhang*)

- ❑ Synthesis and applications of Nature-inspired materials
- ❑ Chemical-Physical-Structural characterization of the bio-inspired materials and interfaces (TLC, TGA, UV-Vis. and FTIR spectroscopy, NMR, EPR, dc electrical conductivity, Impedance Spectroscopy, Cyclic Voltammetry)
- ❑ Surface functionalization and nanostructure design and fabrication of bio-interface and devices
- ❑ Investigation of cell-material interaction for use in therapeutic application and bioelectronic devices

❑ Spectroscopic and electronic properties of organic materials and nanomaterials (*R. Di Capua, D. Capasso, A. Pezzella, U. Coscia, G. M. De Luca, J. Ahmad*)

- ❑ Electrical and spectroscopical characterizations of carbon-based materials (for applications in energy storage, catalysis, pollutants capture and desalination, sensing)
- ❑ Study of microscopic transport mechanisms in complex materials
- ❑ Study of the nanostructured interfaces using photoelectron spectroscopy (XPS) and X-ray spectroscopy (XAS)
- ❑ Electronic properties arising from the coupling of multiple nanomaterials

- **Superconducting (SC) Quantum technologies**
  - **High critical temperature SC Materials – Multifunctional Interfaces (*C.A. Perroni, V. Cataudella, D. Stornaiuolo, F. Tafuri*)**
    - **Spintronics and devices**
    - **High Critical Temperature SC's (TS)**
      - **Preparation of SC films**
      - **Study of the mechanisms underlying high CT superconductivity**
  - **Emerging Magnetic Platforms for Spin and Wave-Based Technologies (*G.M. De Luca, S. Amoruso, F. Chiarella*)**
    - **Fabrication of multifunctional materials**
    - **Fabrication of nanostructures and nanodevices**
    - **Fabrication and characterization of Hybrid Organic and Inorganic compounds**
    - **Electric and magnetic measurements and XAS, GXID and ARPES techniques**

❑ Superconducting (SC) Quantum technologies

- ❑ Quantum Science & experiments on quantum computing and communication (*H.G. Ahmad, G. Ausanio, D. Massarotti, D. Montemurro, L. Parlato, G.P. Pepe, N. Poccia, R. Satariano, F. Tafuri, M. Esposito, P. Darvehi, P. Mastrovito, V. Reddithota, G. Serpico, C. Bruscino, F. Calloni, I. Chattareje, C. Cosenza, P. Ercolano, M. Peluso, A. Sarno, V. Stasino*)
  - Webpage: http://www.qtlab.unina.it
    - ❑ Physics of the Josephson effect: macroscopic quantum phenomena, SC quantum computer, dc and rf quantum measurements
    - ❑ Hardware and working principles of a quantum computer: SC qubits, components, read-out, control and operation, open issues on coherence
    - ❑ Quantum computation, experimental quantum algorithms on a 25 qubits SC quantum computer
    - ❑ Nanoscience applied to SC materials and Quantum Communication; SNSPDs applications for Quantum Key Distribution
    - ❑ Nano-scale SC devices for mesoscopic physics, quantum components, qubits, and applications
    - ❑ High critical temperature SC's: superconductivity in extreme conditions, Josephson junctions and twistronics
    - ❑ Superconductivity and magnetism in Josephson systems

- **Modelling, Quantum computing, Computational material science**
  - **Quantum Simulation and Computation in solid state systems (*R. Fazio, P. Lucignano, G. Passarelli, A. Russomanno; M. Marciani, E. Tirrito ; G. Salatino, A. Scocco, M. Vizzuso*)**
    - Adiabatic Quantum Computation, Hybrid Varational quantum algorithms
    - Superconducting quantum devices
    - Quantum many body systems, QMBS in non-equilibrium conditions (Many Body Localization, Time crystals)
    - Open QMBS (Measurement induced phase transitions, Topological properties, Entanglement)
  - **Open Quantum Systems and Quantum Thermodynamics (*V. Cataudella, A. de Candia, G. De Filippis, G. Di Bello, D. Farina, R. Fazio, F. Formicola, C.A. Perroni*)**
    - Dissipative quantum phase transitions in open spin chains
    - Dynamical quantum phase transitions
    - Local ergotropy in many-body open batteries
  - **Quantum Computing and Artificial Intelligence (*G. Acampora, A. Vitiello, R. Schiattarella; A. Chiatto; A. Cuzzocrea, A. Massa, A. Senese, A. Caraceni, M. Pignataro*)**
    - Computational Intelligence
    - Quantum Artificial Intelligence
      - Quantum Algorithms for AI
      - AI Methods for Quantum Computers: Quantum Compiling and Error Mitigation

- **Modelling, Quantum computing, Computational material science**
  - **Computational Material Science (*D. Alfè, A. Zen, D. Ninno, G. Cantele, Y. Al-Hamdani, V. Barreca, M. Ali, R. Cardia*)**
    - Advanced simulation methods (Quantum Monte Carlo, Machine learning-based interatomic potentials)
    - Materials modelling
      - Energy storage, molecular crystal stability, confined and bulk water, molecular adsorption on surfaces
      - Materials under high-pressure and high-temperature conditions relevant to the Earth's core
      - Modelling of 2D heterostructures with advanced functional magnetic, electronic and optical properties
      - Molecular-level interpretation of experimental observations through advanced computational modelling
  - **Topological Systems and Transport in Oxides (*F.G. Capone, V. Cataudella, A. de Candia, G. De Filippis, G. Di Bello, F. Pavan, C.A. Perroni, A. Ponticelli*)**
    - Non-Hermitian dissipative topological systems
    - Single and double quantum dots at oxide interfaces
    - Dissipative Josephson junctions
  - **Computational Modelling of Heterogeneous Functional Materials for Energy Applications (*A.B. Muñoz-García, A. Pecoraro, F. Fasulo*)**
    - Perovskite and dye-sensitized solar cells, third-generation photovoltaics
    - Electrode and electrolytes for lithium and post-lithium batteries
    - Methodological development: Density Functional Embedding Theory