Applied Experimental Physics

Department of Computer Science
University of Verona
Research in **Experimental Physics** is aimed at the study of mesoscopic phenomena in **condensed matter physics**.

Research topics span in the field of **structural and dynamical properties** of **solid state systems** in form of crystalline compounds or nanostructured films.
Main current topics

- Study of the optical and electronic properties of nano-structured systems
- Study of vibrational dynamics of micro-crystalline solids
- Development of thin films devices for photovoltaics
- Development of advanced optical devices and light modulators
- Interdisciplinary applications of infrared Spectroscopy and Microspectroscopy
Research in Applied Physics is aimed at developing new technologies and methods based on application of physical concepts for investigating problems in different fields.

- Biomedicine
- Biotechnology
- Cultural Heritage

Interdisciplinary activities - biological, medical, humanistic areas
Main current topics

- **Multimodal imaging** based on Magnetic Resonance Imaging, Optical Imaging, Nuclear Medicine and Optical Microscopy for biomedical studies
- **FT-IR microspectroscopy** on plants and microorganisms for biotechnological applications
- **Optical techniques** for Cultural Heritage, with implementation of devices based on IR imaging, laser profilometry, speckle imaging
- **Lab spectroscopy and surface analysis**
Physics @ UNIVR

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RAMAN Lab

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LAPS Lab

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IRIS Lab

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MRI Lab

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OPTICAL IMAGING Lab

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RAMAN Lab
7 Physics LABS

- RAMAN
- FLUO-LAB
- IRIS
- OPTDATE
- LAPS
- OPTICAL IMAGING
- MRI
**RESEARCH**

- Vibrational dynamics of micro-crystalline solids
- Phonon confinement effects in nanostructured systems, i.e.: metal nanoclusters, quantum dots
- Structural and dynamics of carbon-based low-dimensional systems

**COMPETENCES**

- Fully polarized Raman analysis of single micro-crystals in both backscattering and 90° scattering geometry
- Raman mapping of composite films
- Vibrational imaging of biological systems (cells and tissues)

**PEOPLE - G. Mariotto, M. Giarola, A. Kumar, M. Zanatta**
Vibrational Raman spectroscopy

- Vibrational dynamics studies on micro-crystalline solids
- Frequency and symmetry detection of vibrational modes
- Symmetry selection of vibrational modes exploits the polarization of laser beam in combination with single crystal orientation
- Raman micro-spectroscopy
  - high spatial resolution - micrometric scale
90° micro-sampling + micro-manipulation

90° scattering experiments on single micro-crystals properly orientated by using a micro-manipulator operated under direct optical monitoring.

Accurate symmetry selection of Raman active modes of preliminary oriented single micro-crystals (the case of of YPO₄):

- **Twelve expected Raman modes:**
  \[ \Gamma_R = 2A_{1g} \oplus 4B_{1g} \oplus 1B_{2g} \oplus 5E_g \]

- **Twelve observed modes (cm⁻¹):**
  - \( A_{1g} \): 485; 1001
  - \( B_{1g} \): 185; 316; 659; 1058
  - \( B_{2g} \): 331
  - \( E_g \): 155; 209; 299; 581; 1026
use of spectra of components to create images.

Acquisition of many spectra in different points on the sample, through a controlled motorized stage.

Raman spectra from a single, two and multi-layers graphene sample.

Raman micro-spectroscopy image and optical image overlay.

G. Mariotto
The "create" clustering procedure automatically identifies a number of reference spectral components using a factor analysis algorithm.

Raman imaging of biological tissue

Nuclear vacuoles

Nucleus

Tail

Raman map - optical image overlay

motorized stage (XY plane)
RESEARCH

• Optical characterization of light emitting materials and nano-materials
• Study of nanomaterials for drug delivery
• Optimization of the fluorescence for new bio-markers

COMPETENCES

• Optical and structural characterization of nano-materials
• Complete platform (visible-IR) for optical characterization in fluorescence:
  Absorption spectra, Excitation/Emission (with 3D maps), Lifetime (time resolved fluorescence), Quantum efficiency

PEOPLE - N. Daldosso, Ali Ghafarinazari
Fluorescence lab: examples

3D map (excitation-emission) carbon nanotubes

Time-resolved PL (Si nanoparticles)

Eu: (TTA)3Phen Emission and excitation spectrum

Emission spectra of microporous silicon in relation of superficial functionalization
Conventional Confocal microscopy confirmed that HDS up taken pSi and pSi is light emitting in different colours inside the cells.
RESEARCH

- Deposition of thin films, fabrication and study of second generation solar cells.
- Morphological analysis of nanostructures for biomedical applications.

COMPETENCES

- Vacuum deposition: thin film growth by RF sputtering, Thermal vacuum evaporation, Pulsed Electron deposition.
- Chemical deposition: nanofilms growth by chemical bath deposition, spin coating, doctor blading
- Electrical and Morphological characterization: Current-voltage, capacitance-voltage, admittance spectroscopy, atomic force microscopy.

PEOPLE - A. Romeo, D. Menossi, E. Artegiani
Deposition of thin films & solar cells

3 Thermal Vacuum deposition systems

RF-magnetron sputtering  Pulsed Electron deposition  Chemical deposition systems
Characterization of materials and devices

I-V and Impedance spectroscopy systems with N2-cryostat

2 NT-MDT Atomic Force Microscopes

Rigid and flexible solar cells

Bio structures analysis
RESEARCH

• development of innovative and **multimodal** imaging applications based on Magnetic Resonance Imaging, Optical Imaging, Microscopy, Nuclear Medicine

• characterization of novel nanoparticle materials as potential diagnostic /therapeutic agents

COMPETENCES

• **Advanced MRI methods**: Diffusion Tensor Imaging, functional MRI and in vivo localized spectroscopy

• **Fluorescence, Bioluminescence, Cerenkov** imaging

• Confocal and Multi-photon **Microscopy**

PEOPLE - F. Boschi, P. Marzola
OPTICAL IMAGING

techniques based on detection of VIS and Near-IR coming from:

- Fluorescence sources (FLI)
- Bioluminescence sources (BLI)
- Radioactive sources
  - Radionuclide imaging (RLI)
  - Cerenkov imaging (CLI)

Optical Imaging LAB

IVIS Spectrum optical imager (Perkin Elmer)
**Fluorescence (FLI)**

- Detection of fluorescent light from dyes linked to biological molecules and nanoparticles.

**Bioluminescence (BLI)**

- Detection of light emitted by cells in enzimathic process (reaction luciferine-luciferase in firflies).

**Radioactive sources (RLI, CLI)**

- Detection of photon emission in biological tissue interacting with radioactive contrast agent.

**APPLICATION - imaging of living organisms and materials**

- Cancer disease, inflammation, neurodegenerative processes, drug evaluation, stem cell imaging.

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F. Boschi
MAGNETIC RESONANCE IMAGING (MRI)

based on the Nuclear Magnetic Resonance Signal from protons in water and fat tissues

- Spin inversion by absorption of radiofrequency wave
- Emission of the resonance signal

PHYSICS - Nuclei in an external magnetic field

\[ f_n = \gamma B \]
<table>
<thead>
<tr>
<th>In Vivo Magnetic Resonance Imaging</th>
<th>Cellular Imaging</th>
<th>Biotech Imaging</th>
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<tbody>
<tr>
<td>MRI provides morphological and functional information of living organisms in non-invasive way with high spatial resolution</td>
<td>MRI is a powerful technique for detection of living cells - stem cells labeled with nanoprobes are detected with high sensitivity</td>
<td>MRI can also be applied to study morphology and physiology of vegetables</td>
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APPLICATION - imaging of living organisms and materials
RESEARCH

• FT-IR spectroscopy and micro-spectroscopy in conjunction with multivariate statistical analysis for molecular characterization of microorganisms and plant cell wall
• IR spectroscopy for sample analysis

COMPETENCES

• Mid-Infrared spectroscopy experimental techniques
• Spectral data analysis through data mining techniques (PCA, HCA, Heat-maps)
• Characterization of biochemical components and metabolic processes

PEOPLE - F. Monti, C. Daffara
FT-IR micro-spectroscopy

- absorption of MID-IR radiation by chemical bonds
- various measurement techniques:

- VIS/IR microscope
- Transmission
- ATR

Vertex 70 spectrometer, Hyperion 3000 microscope (Bruker)
FTIR analysis on biosynthesized Selenium nanoparticles

FTIR analysis on grape berry skin
RESEARCH

- development of optical techniques for nondestructive analysis
- implementation of portable devices
- Artwork diagnostics “in situ”

COMPETENCES

- Optical and IR imaging, spectral techniques
- Thermal imaging
- Surface analysis
  - laser profilometry, speckle techniques
- IR spectroscopy on artwork materials

PEOPLE - C. Daffara, F. Monti, G. Marchioro
2D - Infrared imaging
Reflective - Thermal band

VIS                        NIR                           MIR REFLECTION       FAR EMISSION

PHYSICS
radiation interaction - heat diffusion

Art diagnostics in situ
- multispectral
- multi layer

→ Novel TQR (UNIVR)
3D - Surface Analysis
Laser profilometry

- Roughness texture
- Surface map

Surface texture - subsurface defect

Integration 2D-3D
- Material analyses
- Surface - subsurface

PHYSICS
optical interferometry

C. Daffara
Monocromo
by Leonardo da Vinci
Milano - Castello Sforzesco

COLLABORATION
G. Orlandi (Appl Math)

TQR (surface) - Termography (subsurface)
“Multimodal Scanning of Cultural Heritage Assets for their multilayered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing”

- INTERDISCIPLINARY RESEARCH
  Applied Physics - Applied Computing

- 8 Partners from 5 countries

| CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS | Greece          |
| IDRYMA ORMYLIA - ART DIAGNOSIS CENTRE    | Greece          |
| FRAUENHOFER INSTITUTE                   | Germany         |
| UNIVERSITY OF VERONA                    | Italy           |
| OPIFICIO DELE PIETRE DURE               | Italy           |
| CENTER FOR ADVANCED STUDIES, RESEARCH AND DEVELOPMENT SARDINIA | Italy |
| BW TEK Inc.                             | Germany         |
| AVASHA GmbH.                            | Switzerland     |
| RESEARCH FOR SCIENCE, ART & TECHNOLOGY Ltd. | UK              |

E. Daffara (App Exp Phys) - A. Giachetti (Appl Comp)
“Sonic Drilling coupled with Automated Mineralogy and chemistry: On-Line-On-Mine-Real-Time ”

CALL: Climate action, environment, resource efficiency and raw materials

TOPIC: New sustainable exploratintechonologies SC5-11d-2015

9 Partners, 9,791,000 euro of EU contribution ➔ about 970,000 euro to UniVERONA

SOLSA is the first automated expert system for on-site mineralogy cores analysis that combines for the first time: X-ray fluorescence, X-ray diffraction, vibrational spectroscopies and 3D imaging along the drill core.
Спасибо большое!