

# Attilio Zilli

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Cardiff University

School of Biosciences

## CURRENT POSITION

### Cardiff University PhD DEGREE

Jan 2014 – Present

My current research focuses on developing and refining new microscopy techniques for linear and nonlinear optical studies of individual **metallic nano-objects**. My work is thus at the intersection of various fields: Microscopy, plasmonics, nonlinear optics and nanotechnology.

In first place, I am striving to demonstrate that **optical micro-spectroscopy** can be a **quantitative** technique, namely, capable of measuring the absolute scattering and extinction cross-sections of individual nano-objects. This requires a detailed mathematical description of the microscope illumination and collection geometry, and of the spatial distribution of scattered light as a function of excitation and environmental conditions.

The accuracy of quantitative spectroscopy is benchmarked against the simulated cross-section obtained by **numerical modelling**, which also provides precious insight on the physics involved (e.g. the spatial distribution of the scattered field and resistive heating). Approaches beyond standard recipes are required in order to include in the model the effect of microscope illumination and finite collection.

A second aspect of my project involves the use of nonlinear optics to investigate the ultrafast dynamics of carrier relaxation in individual metallic nanoparticles and dimers, and its dependence on structural and environmental parameters. The third-order nonlinearity of metal is probed via a transient four-wave mixing (FWM) technique which, in the pioneering implementation developed by our research group, features a heterodyne interferometric detection scheme, simultaneously recording both the amplitude and the phase of the FWM signal.

My work is funded by the European Commission via a **Marie Curie Fellowship**, and I benefit of the many opportunities for knowledge exchange, secondment and training offered by an Initial Training Network gathering academic and industrial partners all across Europe.

Spring 2017

End of PhD planned

## EDUCATION

### Sapienza Univ. of Rome

2011 – 2013

#### MASTER'S DEGREE IN PHYSICS

On top of common, fundamental exams (*Quantum Relativistic Mechanics, Critical Phenomena,...*) I took the **Physics of Matter** curriculum, which included theoretical courses (*Condensed Matter Physics, Nonlinear and Quantum Optics,...*) as well as several laboratory projects.

Final mark: **110/110 cum Laude**

Dec 2013

Master's thesis: *On Semiconductor Nanowire Electronic Properties:*

*A Photoluminescence Spectroscopy Investigation*

Supervisors: Prof. Antonio Polimeni and Prof. Mario Capizzi

Nanowires of **III-V semiconducting compounds** preferentially grow in the anisotropic **wurtzite** crystal structure instead of the cubic zincblende phase displayed by the corresponding bulk materials. I have investigated the electronic states of this new material using photoluminescence and **photoluminescence excitation spectroscopy**. In particular, my work contributed to clarify the temperature dependence of the main critical points of the band structure, as well as the polarization properties of the corresponding optical transitions.

### Sapienza Univ. of Rome

2007 – 2011

#### BACHELOR'S DEGREE IN PHYSICS

The Department of Physics in Sapienza University is very well reputed internationally, regularly scoring within the **top 25** of the prestigious **QS World University ranking**. It offers his BSc students solid foundations of mathematics, as well as classic and modern physics. Courses are mostly theory-oriented, lectures are rather demanding, and exams are often selective.

Final mark: **110/110**

Nov 2011

Bachelor's thesis: *Infrared Properties of Plasmonic Materials*

Supervisor: Prof. Stefano Lupi

### Scientific High School "A. Righi" (Rome)

2002 – 2007

#### SCIENTIFIC HIGH SCHOOL DIPLOMA

The scientific high school complements the traditional, humanity-focused, education of the Italian *Liceo* with subjects like Mathematics, Physics, Biology, and Chemistry. "A. Righi" is traditionally considered one of the best high schools in Rome.

Jul 2007

Final Mark: **100/100 cum Laude**

## RESEARCH SKILLS

### Optical microscopy

As the optical properties of individual nano-objects are my PhD topic, I strive to push the boundaries of current microscopy techniques, developing set-ups and procedures beyond the state of the art. **Widefield imaging** modalities I am most confident with are brightfield, darkfield, and differential interference contrast, with a particular emphasis on extracting **quantitative information**.

### Spectroscopy techniques

I am confident with principles, construction and operation of different kinds of spectroscopic set-ups. In particular, I am experienced in **micro-spectroscopy** on individual nanoparticles (part of my PhD research) and **luminescence spectroscopy** on semiconducting structures with a low dimensionality (MSc thesis). I also had some experience of Fourier Transform Infrared Spectroscopy on plasmonic metamaterials (BSc final projects) and X-ray Photoelectron Spectroscopy on functionalized metallic surfaces (lab project during MSc).

### Numerical modelling

Within my PhD project, I have been using a commercial finite element solver (**COMSOL** Multiphysics, in particular the Wave Optics module) to simulate the optical properties of nano-objects (metallic and dielectric particles of various shapes, dimers) in homogeneous and inhomogeneous dielectric environment.

### Ultrafast and nonlinear optics

As a part of my PhD, I have addressed the ultrafast dynamics of carrier relaxation in individual metallic nanoparticles and dimers. Specifically, nonlinear **four-wave mixing** processes were measured with a refined version of transient absorption **pump-probe microscopy**, featuring a polarization-resolved, phase-sensitive heterodyne detection. I am thus also familiar with most concepts and devices of continuous-wave and pulse laser set-ups.

### Solid state detectors

I am acquainted with principles and practical operation of several kinds of solid state detectors — both single channel and arrays. In particular, for my imaging and micro-spectroscopy applications, I routinely strive to make the most of **CCD** and **CMOS** sensor-based devices.

## OTHER RELEVANT SKILLS

### Languages

- **Italian:** Mother tongue
- **English:** Used in everyday life — Proficiency level (CEFR C2)
- **French:** Learned at High School — Intermediate level (CEFR B2)
- **German:** Had some classes at University — Elementary level (CEFR A2)

### Computing

- Data analysis and scientific graphing: **Origin**
- Computing: **MATLAB** (mainly to solve numerically mathematical problems)
- Typesetting scientific documents: **LaTeX**
- Image analysis: **ImageJ**
- Presentation and reports: MS **PowerPoint**

## PUBLICATIONS

**ACS Nano 9,4277**    **TEMPERATURE DEPENDENCE OF INTERBAND TRANSITIONS IN WURTZITE InP NANOWIRES**

2015

DOI:

10.1021/acsnano.5b00699

[A. Zilli](#), M. De Luca, D. Tedeschi, H. A. Fonseca, A. Miriametro, H. H. Tan, C. Jagadish, M. Capizzi, and A. Polimeni

**Nano Lett. 15,998**    **POLARIZED LIGHT ABSORPTION**

2015

DOI:

10.1021/nl5038374

**IN WURTZITE InP NANOWIRE ENSEMBLES**

M. De Luca, [A. Zilli](#), H. A. Fonseca, S. Mokkaapati, A. Miriametro, H. H. Tan, L. M. Smith, C. Jagadish, M. Capizzi, and A. Polimeni

## CONFERENCES

**Talk (submitted)**    **PHOTON16 – University of Leeds**

Sep 2016

Abstract: Quantitative optical micro-spectroscopy of individual metal nanoparticles

**Poster**

Sep 2015

**FARADAY DISCUSSION ON SINGLE-MOLECULE MICROSCOPY AND SPECTROSCOPY**

**Royal Society of Chemistry, London**

Poster: Individual gold nanorods – Optical cross-sections and ultrafast dynamics

**Poster**

Sep 2015

**BIONANOPHOTONICS SYMPOSIUM – Cardiff University**

Poster: Individual gold nanorods – Optical cross-sections and ultrafast dynamics

## COURSES

**Doctoral course**    **NONLINEAR OPTICS**

Jul 2015

Intensive one-week course, part of PhD program of EPFL

**Doctoral course**    **NONLINEAR SPECTROSCOPY**

Jul 2014

Intensive one-week course, part of PhD program of EPFL

**Master module**    **MODERN LIGHT MICROSCOPY TECHNIQUES**

Feb – Apr 2014

One-semester module, part of MSc Biophotonics program of Cardiff University

**Doctoral school**    **CHEMICAL IMAGING BY COHERENT RAMAN AND NONLINEAR MICROSCOPY**

Feb 2014

Winter School and conference organized by the Physics School of Les Houches

**Summer course**    **UTRECHT SUMMER SCHOOL IN THEORETICAL PHYSICS**

Aug 2011

Two-week intensive course for BSc students, with topics in Quantum Mechanics, Statistical Mechanics, Electromagnetism and Scientific Programming