**CV Daniele Fausti**

**Personal Data**

Name Fausti Daniele

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**Education**

* **PhD in Physics (June 2008),** Zernike institute for Advanced Materials, University of Groningen. Thesis title: “Phase transitions and optically induced phenomena in cooperative systems”. Advisor: Prof. Paul H. M. van Loosdrecht.
* **MSc in Physics (Dec. 2002),** Dipartimento Matematica e Fisica, Universitá Cattolica Brescia. Thesis title: “Electron Dynamics at Surfaces” (“Dinamiche elettroniche di superficie”).
* **High School Diploma (1997),** (Maturità scientifica), at “Liceo A. Calini” Brescia (Italy).

**Employment and international experience**

09/2018-now: Visiting research fellow, Department of Chemistry, Princeton University

2017-now: Associate Professor at the Physics Department University of Trieste

2010-2017: Researcher at the Physics Department University of Trieste (tenure track).

2008-2010: Postdoctoral Associate at the Max Plank Group for Structural Dynamics, Hamburg.

2009-2010: Visiting Scientist, at the Clarendon Laboratory, University of Oxford.

2003-2008: PhD Student at the Zernike Institute for Advanced Material, Groningen University.

2002-2003: Research Scholar at the Elphos labs, Catholic University Brescia.

**Teaching experience**

* Introduction to Quantum Optics (“Elementi di ottica quantistica”), University of Trieste (2012-18).
* Introduction to atomic and molecular physics (2018, 2019), University of Trieste.
* Various working classes in “Condensed Matter courses” in the Rug Groningen (2006-07), and “Electromagnetism” in the University of Trieste (2010-16).
* Supervision of 8 master students, 12 bachelor students and 7 PhD students (4 finished, 3 ongoing).

**Peer review activities**

-Journals: Nature publishing group (Nature, Nature Materials and Nature Communications) and various Journal of the Elsevier publishing group; Phys. Rev. Letters, PRB.

-Funding Agencies: Department of Energy (USA), European Research Council (Eu), different national foundations for various EU countries.

**Scientific event organization**

-“Taming non-equilibrium systems: from quantum fluctuation to decoherence”, ICTP Conference (to be held 08/2018)

Role: Local Organizer

-“New Generation in strongly correlated electron systems 2016” (NGSCES2016)

Role: Local organizer (http://www.ngsces2016.org/)

-Coorganizer of various local workshops at Elettra Sincrotrone Trieste S.c.p.a.

**Funding ID:**

**Ongoing Grants:**

- **ERC\_Starting Grant2015:** Starting grant from the European Research Council (ERC) under the call ERCStG2015 (project started 1st June, 2016).

Role: PI

Project title: “INhomogenieties and fluctuations in quantum CohErent matter Phases by ultrafast optical Tomography”(**INCEPT**)

Budget: 1.500.000 Euro

-**Scientific Independence Research grants (SIR, Funding 503KEuro, Role: PI):** Starting grant funded by the Italian ministry of science and education under the call for Scientific Independence Research (SIR) grants, for the establishment of an independent research lab.

Role: PI

Project title: “CONtrolling quantum CohErent Phases of matter by THz light pulses” (**CONCEPT**)

Budget: 503.800 Euro

**-PRIN 2017:** collaborative project funded by the Italian ministry of educations (MIUR) (project funded, start date tbd)

Role: localPI for University di Trieste unit

Project Title: Excitonic insulator in two-dimensional long-range interacting systems (**EXC-INS**)

Budget: Total 1154992 Euro; Budget University of Trieste: 194000 Euro:

-**Proof Of Concept** **2019**: Innovation project for development Proof of Concepts from the European Research Council (ERC). The project is due to start on the 1st July, 2019

Role: PI

Project title: COvariance Based Raman Spectrometer (**COBRAS**)

Budget: 150000 Euro (lump sum)

**Prizes and awards**

-I Lamp Prize for early career academic achievements (I-Lamp labs, Brescia, 2017)

-Community prize for outstanding achievements (Local community Marcheno (Bs) Italy)

**Short Scientific Profile**

My scientific background is in the fields of condensed matter physics, ultrafast laser spectroscopy, and quantum optics. My past activities, mainly experimental, range from non-linear photoemission processes from metal surfaces, static studies of transition metal oxides and correlated electron systems, time-resolved spectroscopic techniques and ultrafast laser technology. I have a good familiarity with both table top spectroscopic techniques and synchrotron (or Free Electron Laser) based experiments. More recently I focused on quantum state reconstruction techniques for ultrashort light pulses. The major scientific achievements of my career up to now have been the development of a unique spectroscopic tool capable of measuring the time evolution of the spontaneous Raman response following laser excitation [Fausti2009], the optical control of superconductivity in the cuprates [Fausti2011; Dienst&Fausti2011, 2013], the discovery of an ultrafast dressing of subgap excitation in in insulating transition metal oxides [Novelli2014], and the direct measurement of fluctuation in time domain experiments [Esposito2014, 2016].

**Former PhD Students:**

-Dr. Martina Esposito, now associate researcher at the University of Oxford

-Dr. Francesco Randi, now associate researcher at the University of Princeton

-Dr. Fabio Novelli, now associate researcher at Ruhr-University Bochum

-Dr. Francesca Giusti, now associate researcher in the University of Trieste.

**Collaborations**

**Experimental:** The manifold nature of my expertise across the ultrafast and condensed matter community is testified by the diverse backgrounds of the people I have collaborated and published with in the past. Among those I still have ongoing collaborations with group leaders in different fields: **Prof. Andrea Cavalleri**, director of the Max Plank research department for structural dynamics at the University of Hamburg; **Prof. Paul H. M. van Loosdrecht**, group leader of the Optical Condensed Matter Physics Group of the University of Cologne and **Prof. Thom T. M. Palstra**, now rector magnificus of the University of Twnte; **Prof. Andrea Damascelli** University of British Columbia (Canada); **Prof. Gregory Scholes**, University of Princeton; **Prof. Martin Greven**, University of Minnesota; **Prof. Davide Boschetto** ENSTA Paris Tech, LOA; **Dr. Claudio Giannetti** Catholic University of Brescia; **Prof.** **Fulvio Parmigiani**,University of Trieste.

**Facilities:** I also have collaboration with several scientists at international facilities: **Dr. Matthias Hoffman**, Stanford Linear Accelerator Laboratory (Stanford University); **Dr. Claudio Masciovecchio** head of the science program of the Fermi@elettra free electron laser project; **Dr. Ra’anan Tobey** Los Alamos National Laboratory; **Dr.** **Andrea Perucchi**, Synchrotron Infrared Source for Spectroscopy and Imaging (SISSI, Elettra) and lead scientist of the THz beamline project in Fermi FEL; **Prof. Simon Wall**, junior group leader at ICFO, Spain; **Dr.** **Wolfgang Seidl** and **Dr.** **Stephan Winnerl** Felbe, Free Electron Laser, Forschungszentrum Dresden-Rossendorf (De). **Dr. Milan Radovic** Paul Scherrer Institut (PSI), Switzerland..

**Theoretical:** Together with the collaborations dedicated to experimental activities I am currently working in close collaboration with various groups dedicated to different theoretical approaches to correlated electron systems. In particular I participate in the European network (FP7-NMP-2011-SMALL-5, project GoFast) led by **Prof. Michele Fabrizio** and **Prof. Massimo Capone** (Sissa, International school for advanced studies, Trieste, Italy) world leading group in Dynamical mean field theory. I collaborate with **Prof. Vittorio Cataudella**, **Dr. Giulio De Filippis** (University of Naples), **Dr. Andrey Mishenko**, and **Prof. Naoto Nagaosa** (Riken institute, Tokyo) who have developed a calculation scheme to solve the Hubbard Holstein model, ideal to threat insulating correlated electron systems and **Prof. Martin Eckstein** (University of Erlangen) leader in tdDMFT approaches. More recently my interest moved towards addressing condensed matter problems using quantum information approaches. In this respect I collaborate with **Prof.** **Fabio Benatti** (University of Trieste and International Centre for Theoretical Physics (ICTP)) and **Prof. Mauro Paternostro** (Queen’s University of Belfast) on open quantum systems and **Prof. Adolfo Avella** (University of Salerno) whose main expertise is in the Density matrix formalism; finally the new methodology we propose for **Prof. Shaul Mukamel** University of California, Irvine.

**Recent Invited talks at international conferences, workshops, and Schools**

* 10th international conference on metamaterials photonics crystals and plasmonics (META2019)
* International Conference on Ultrafast Spectroscopy of Correlated Quantum Materials (USCQM - 2019) July 15 - 17, 2019, Liyang, China
* The Challenge of 2-Dimensional Superconductivity (08-12 Jul 2019) Lorentz Center (Leiden)
* CLEO/Europe-EQEC 2019, 23 – 27 June 2019, Munich, Germany
* Ultrafast and Nonlinear Dynamics of Quantum Materials" at University of Paris-Diderot (June 4-7, 2019)
* Photonics West 2019 (not attended)
* The 49th Winter Colloquium on the Physics of Quantum Electronics (PQE2019) (not attended)
* None-quilibrium Quantum Dynamics and Relaxation Phenomena in Many Body Systems (Krvavec2018)
* Resonant X-ray scattering and related topics (Simon's Foundation's, New York, 2018)
* [Gordon Research Conference on "Ultrafast Phenomena in Cooperative Systems”](https://mail.elettra.trieste.it/Redirect/AD6ADE3F/www.grc.org/programs.aspx?id=14993) (Galveston, Texas, 2018, C)
* Non-equilibrium phenomena in complex matter conference (Krvavec 2017, W)
* Workshop Quantum Materials Trends (Brescia, Italy, 2017, W, not attended)
* 2nd International Conference on Applied Crystallography (Chicago, USA, 2017)
* Workshop on Spectroscopy and Dynamics of Photoinduced Electronic Excitations (Trieste, Italy, 2017, W)
* International Symposium on Ultrafast Intense Laser Science 15. Session “Quantum photonics in condensed matter” (Cassis, France, 2016, C)
* Testing the limits of the quantum superposition principle in nuclear, atomic and optomechanical systems(Trento, Italy, 2016,W)
* International Conference on New Theories, Discoveries, Applications  of Superconductors and Related Materials (Bled, Slovenia, 2016, C)
* 4th Quantum Thermodynamics Conference (Erice, Italy, 2016, C)
* School on Synchrotron and Free-Electron-Laser Based Methods: Multidisciplinary Applications and Perspectives (Trieste, Italy, 2016, S)
* Non-equilibrium phenomena in complex matter conference (Krvavec 2015, S)
* Trendoxides2015(Brescia, Italy, 2015, C)
* M2S (Geneva, Switzerland, 2015, C).
* SCSR (Trieste, Italy, 2014, W).
* Non-equilibrium phenomena in complex matter conference (Krvavec, Slovenia, 2014, W).
* COX2013 (Trieste, Italy, 2014, W).
* SLAC user meeting (Stanford, USA, 2013, C).
* NGSCES conference (Sestri Levante, Italy, 2013, C).
* New Sources for THz research (Trieste, Italy, 2012, W).
* Edgar Lüscher Seminars (Kloster (CH), 2012, W).
* PIPT4 (Warsaw, Poland, 2011, C).
* Terahertz spectroscopy and its high-field applications (Dresden, Germany, 2010, W).
* EMRS Fall Meeting (Warsaw, Poand, 2008, C).

**Peer reviewed publications**

underscored = first, last or/and corresponding author\* or project leader

**Articles and letters**

1. Title: “[Quantum model for Impulsive Stimulated Raman Scattering](https://iopscience.iop.org/article/10.1088/1361-6455/ab0bdc/meta)”

Authors: F. Glerean, S. Marcantoni, G. Sparapassi, A. Blason, M. Esposito, F. Benatti, **D. Fausti\***

**Journal of physics B** (Accepted in Journal of optics B)

1. Title: “Femtosecond Covariance Spectroscopy”

Authors: J. O. Tollerud, G. Sparapassi, A. Montanaro, S. Asban, F. Glerean, F. Giusti, A. Marciniak, G. Kourousias, F. Billè, F. Cilento, S. Mukamel, **D. Fausti\***

**PNAS** 201821048, 2019

1. Title: “[Signatures of Enhanced Superconducting Phase Coherence in Optimally Doped Bi2Sr2Y0.08Ca0.92Cu2O8+δ Driven by Midinfrared Pulse Excitations](https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.122.067002)”

Authors: F. Giusti, A. Marciniak, F. Randi, G. Sparapassi, F. Boschini, H. Eisaki, M. Greven, A. Damascelli, A. Avella, and **D. Fausti\***

**Physical Review Letter** 122, 067002 (2019) [the paper was awarded the title of Editor’s pick]

1. Title: “Probing the fluctuation of optical properties in time resolved spectroscopies”

Authors: F. Randi, M. Esposito, F. Giusti, O. Mishochko, F. Parmigiani, **D. Fausti\***, M. Eckstein

**Physical Review Letters** 119 (18), 187403 (2017)

1. Title: “Localized vibrations in superconducting YBa2Cu3O7revealed by ultrafast optical coherent spectroscopy”

Authors: F. Novelli, G. Giovannetti, A. Avella, F. Cilento, L. Patthey, M. Radovic, M. Capone, F. Parmigiani, and **D. Fausti\***

**Phys. Rev. B** 95, 174524 (2017)

1. Title: “Bypassing the energy-time uncertainty in time-resolved photoemission”

Authors: F. Randi, **D. Fausti**, M. Eckstein

**Phys. Rev. B** 95, 115132 (2017)

1. Title: “Generation and detection of squeezed phonons in lattice dynamics by ultrafast optical excitations”

Authors: Fabio Benatti, Martina Esposito, **D. Fausti**, Roberto Floreanini, Kelvin Titimbo, Klaus Zimmermann

**New Journal of Physics** 19, 2, 023032 (2017)

1. Title: “Insights into ultrafast Ge-Te bond dynamics in a phase-change superlattice”

Authors: Marco Malvestuto, Antonio Caretta, Barbara Casarin, Federico Cilento, Martina Dell'Angela, **D. Fausti**, Raffaella Calarco, Bart J Kooi, Enrico Varesi, John Robertson, Fulvio Parmigiani

**Physical Review B** 94 (9), 094310 (2016)

1. Title: “Quantum interferences reconstruction with low homodyne detection efficiency”

Authors: M. Esposito, F. Randi, K. Titimbo, G. Kourousias, A. Curri, R. Floreanini, F. Parmigiani, **D. Fausti**, K. Zimmermann, F. Benatti

**EPJ Quantum Technology**, Vol. 3, p.1, 2016

1. Title: “Phase separation in the nonequilibrium Verwey transition in magnetite”

Authors: F. Randi, I. Vergara, F. Novelli, M. Esposito, M. Dell'Angela, V. A. M. Brabers, P Metcalf, R. Kukreja, H. A Dürr, **D. Fausti\***, M. Grüninger, F. Parmigiani

**Physical Review B** 93 (5), 054305, 2016

1. Title: “Photon number statistics uncover the fluctuations in non-equilibrium lattice dynamics”

M. Esposito, K. Titimbo, K. Zimmermann, F. Giusti, F. Randi, D. Boschetto, F. Parmigiani, R.Floreanini, F. Benatti, **D. Fausti\***

**Nature communications 6, 4, 2015**

1. Title: Witnessing the formation and relaxation of dressed quasi-particles in a strongly correlated electron system.

Authors: F. Novelli, G. De Filippis, V. Cataudella, M. Esposito, I. Vergara,F. Cilento, E. Sindici, A. Amaricci, C. Giannetti, D. Prabhakaran, S.Wall, A. Perucchi, S. Dal Conte, G. Cerullo, M. Capone, A. Mishchenko, M. Grüninger, N. Nagaosa, F. Parmigiani, and **D. Fausti\***

**Nature communications 5, 18, 2014**

1. Title: “Pulsed homodyne Gaussian quantum tomography with low detection efficiency”

M. Esposito, F. Benatti, R. Floreanini, S. Olivares, F. Randi, K. Titimbo, M. Pividori, F. Novelli, F. Cilento, F. Parmigiani, **D. Fausti\***

**New Journal of Physics** 16 (4), 043004, 2014

1. Title: “Multi-colour pulses from seeded free-electron-lasers: towards the development of non-linear core-level coherent spectroscopies”

F. Bencivenga, F. Capotondi, F. Casolari, F. Dallari, M. B Danailov, G. De Ninno, **D. Fausti**, M. Kiskinova, M. Manfredda, C. Masciovecchio, E. Pedersoli

**Faraday discussions** 171, 487-503, 20, 2014

1. Title: “Speed limit of the insulator–metal transition in magnetite”

S. De Jong, R. Kukreja, C. Trabant, N. Pontius, C.F. Chang, T Kachel, M. Beye, F. Sorgenfrei, C.H. Back, B. Bräuer, W.F. Schlotter, J.J. Turner, O. Krupin, M. Doehler, D. Zhu, M.A. Hossain, A.O. Scherz, **D. Fausti**, F. Novelli, M. Esposito, W. Lee, Y.D. Chuang, D.H. Lu, R.G. Moore, M. Yi, M. Trigo, P. Kirchmann, L. Pathey, M.S. Golden, M. Buchholz, P. Metcalf, F. Parmigiani, W. Wurth, A. Föhlisch, C. Schüßler-Langeheine, H.A. Dürr

**Nature materials** 12 (10), 882-886, 46, 2013

1. Title: “Two-colour pump–probe experiments with a twin-pulse-seed extreme ultraviolet free-electron laser”

E. Allaria, F. Bencivenga, R. Borghes, F. Capotondi, D. Castronovo, P. Charalambous, P. Cinquegrana, M.B. Danailov, G. De Ninno, A. Demidovich, S. Di Mitri, B. Diviacco, **D. Fausti**, W.M. Fawley, E. Ferrari, L. Froehlich, D. Gauthier, A. Gessini, L. Giannessi, R. Ivanov, M. Kiskinova, G. Kurdi, B. Mahieu, N. Mahne, I. Nikolov, C. Masciovecchio, E. Pedersoli, G. Penco, L. Raimondi, C. Serpico, P. Sigalotti, S. Spampinati, C. Spezzani, C. Svetina, M. Trovò, M. Zangrando

**Nature communications** 4, 82, 2013

1. Title: “Optical excitation of Josephson plasma solitons in a cuprate superconductor”

A. Dienst, E. Casandruc, **D. Fausti**, L. Zhang, M. Eckstein, M. Hoffmann, V. Khanna, N. Dean, M. Gensch, S. Winnerl, W. Seidel, S. Pyon, T. Takayama, H. Takagi, A. Cavalleri

**Nature materials 12 (6), 535-541, 34, 2013**

1. Title: “Mixed regime of light-matter interaction revealed by phase sensitive measurements of the dynamical Franz-Keldysh effect”

F. Novelli, **D. Fausti\***, F. Giusti, F. Parmigiani, M. Hoffmann

**Scientific reports** 3, 11, 2013

1. Title: “Ultrafast optical spectroscopy of the lowest energy excitations in the Mott insulator compound YVO 3: Evidence for Hubbard-type excitons”

F. Novelli, **D. Fausti\***, J. Reul, F. Cilento, P.H.M. van Loosdrecht, A.A. Nugroho, T.T.M. Palstra, M. Grüninger, F. Parmigiani

**Physical Review B** 86 (16), 165135, 2012

1. Title: “Bi-directional ultrafast electric-field gating of interlayer charge transport in a cuprate superconductor”

A. Dienst, M.C. Hoffmann, **D. Fausti**, J.C. Petersen, S. Pyon, T. Takayama, H. Takagi, A. Cavalleri

**Nature Photonics 5 (8), 485-488, 58, 2011**

1. Title: “Light-Induced Superconductivity in a Stripe-Ordered Cuprate”

**D. Fausti\***, R.I. Tobey, N. Dean, S. Kaiser, A. Dienst, M.C. Hoffmann, S. Pyon, T. Takayama, H. Takagi, A. Cavalleri

**Science 331 (6014), 189, 273, 2011**

1. Title: “Polaronic Conductivity in the Photoinduced Phase of 1T-TaS\_ {2}”

N. Dean, J.C. Petersen, **D. Fausti**, R.I. Tobey, S. Kaiser, L.V. Gasparov, ...

**Physical Review Letters** 106 (1), 16401 37, 2011

1. Title: “Magnetodielectric and magnetoelastic coupling in TbFe 3 (BO 3) 4”

U. Adem, L. Wang, **D. Fausti**, W. Schottenhamel, P.H.M. van Loosdrecht, ...

**Physical Review B** 82 (6), 064406, 24, 2010

1. Title: “Raman signatures of charge ordering in K 0.3 WO 3”

D.M. Sagar, **D. Fausti**, S. van Smaalen, P.H.M. van Loosdrecht

Physical Review B 81 (4), 045124, 8, 2010

1. Title: “Ultrafast photoinduced structure phase transition in antimony single crystals”

**D. Fausti\***, O.V. Misochko, P.H.M. van Loosdrecht

**Physical Review B** 80 (16), 161207, 9, 2009

1. Title: “Cross-linking of multiwalled carbon nanotubes with polymeric amines”

Y. Zhang, A.A. Broekhuis, M.C.A. Stuart, T. Fernandez Landaluce, **D. Fausti**, ...

**Macromolecules** 41 (16), 6141-6146, 40, 2008

1. Title: “Phonon and crystal field excitations in geometrically frustrated rare earth titanates”

T.T.A. Lummen, I.P. Handayani, M.C. Donker, D. **Fausti**, G. Dhalenne, P. Berthet, ...

**Physical Review B** 77 (21), 214310, 59, 2008

1. Title: “A Raman study of the charge-density-wave state in A0. 3MoO3 (A= K, Rb)”

D.M. Sagar, **D. Fausti**, S. Yue, C.A. Kuntscher, S. van Smaalen, ...

**New Journal of Physics** 10 (2), 023043, 9, 2008

1. Title: “Hybridization, superexchange, and competing magnetoelastic interactions in TiOBr”

R. Macovez, J. Luzon, J. Schiessling, A. Sadoc, L. Kjeldgaard, S. van Smaalen, **D. Fausti**,...

**Physical Review B** 76 (20), 205111, 11, 2007

1. Title: “Coherent amplitudon generation in blue bronze through ultrafast interband quasi-particle decay”

D. M. Sagar, A. A. Tsvetkov, **D. Fausti**, S. van Smaalen, P.H.M. van Loosdrecht

**Journal of Physics: Condensed Matter** 19, 346208, 7, 2007

1. Title: “Symmetry disquisition on the Ti O X phase diagram (X= Br, Cl)”

**D. Fausti\***, T.T.A. Lummen, C. Angelescu, R. Macovez, J. Luzon, R. Broer, ...

**Physical Review B** 75 (24), 245114, 22, 2007

1. Title: “Raman scattering from phonons and magnons in RFe 3 (BO 3) 4”

**D. Fausti**\*, A.A. Nugroho, P.H.M. van Loosdrecht, S.A. Klimin, M.N. Popova, ...

**Physical Review B** 74 (2), 024403, 78, 2006

1. Title: “Evidence for differentiation in the iron-helicoidal chain in GdFe3 (BO3) 4”

S.A. Klimin, **D. Fausti**, A. Meetsma, L.N. Bezmaternykh, P.H.M. Loosdrecht, ...

**Acta Crystallographica B**: 61 (5), 481-485, 92, 2005

1. Title: “Experimental evidence of above-threshold photoemission in solids”

F. Banfi, C. Giannetti, G. Ferrini, G. Galimberti, S. Pagliara, **D. Fausti**,...

**Physical review letters** 94 (3), 037601, 41, 2005

1. Title: “Measurements of intrinsic linewidth versus parallel momentum of image-potential states on Ag (100)”

C. Giannetti, G. Galimberti, S. Pagliara, G. Ferrini, F. Banfi, **D. Fausti**, ...

**Surface science** 566, 502-507, 3, 2004

1. Title: “Violation of the electric-dipole selection rules in indirect multiphoton excitation of image-potential states on Ag (100)”

G. Ferrini, C. Giannetti, G. Galimberti, S. Pagliara, **D. Fausti**, F. Banfi, ...

**Physical review letters** 92 (25), 256802, 18, 2004

1. Title: “Cascade of phase transitions in GdFe 3 (BO 3) 4”

R.Z. Levitin, E.A. Popova, R.M. Chtsherbov, A.N. Vasiliev, M.N. Popova, ...

**JETP letters** 79 (9), 423-426, 75, 2004

1. Title: “Effective mass and momentum-resolved intrinsic linewidth of image-potential states on Ag (100)”

G. Ferrini, C. Giannetti, **D. Fausti**, G. Galimberti, M. Peloi, G.P. Banfi, ...

**Physical Review B** 67 (23), 235407, 2003

**Invited Review**

1. Title: “Ultrafast optical spectroscopy of strongly correlated materials and high-temperature superconductors: a non-equilibrium approach”

Authors: C Giannetti, M Capone, **D Fausti**, M Fabrizio, F Parmigiani, D Mihailovic

**Advances in physics** 65, 2, p. 58-238, 2016

**Peer reviewed conference proceedings**

1. Quantum Optics for studying ultrafast processes in condensed matter (CLEO, 2015)
2. Terahertz Josephson plasma solitons in high-Tc superconductors (CLEO, 2013)
3. Controlling Superconductivity with Strong Terahertz Fields, Ultrafast Phenomena (UP) 2012
4. Nonlinear Josephson Effect in High-TcCuprates, UP 2010
5. Photo-Induced Superconductivity in Charge Ordered LESCO (La1.8-xEr0.2SrXCuO4, x=0.125) UP 2010
6. Optically induced phase transition on Bi and Sb single crystal (EMRS, 2008; UP 2008)

**Other publications**

*Book Chapter*: Following the request of the editors Rohit P. Prasankumar and Antoinette J. Taylor, in collaboration with P. H. M. van Loosdrecht, I wrote a part of the book: “Optical Techniques for Characterizing Complex Matter”, that is published by “Taylor & Francis”. I wrote a chapter dedicated to dynamical Raman studies on condensed matter titled: “Time resolved Raman spectroscopy”.

*PhD Thesis:*”Phase transitions and optically induced phenomena in cooperative systems”. ISSN 1570-1530 ISBN: 978-90-367-3476-9.

**Short Research Statement**

**Fluctuations through *non-linear* spectroscopy combined with *quantum* state reconstruction of ultrashort light pulses**

The holy grail of controlling materials’ properties on sub-picosecond timescales led to a large number of experiments exploring *phase transformations* photo-induced by ultrashort light pulses. The basic principle of these experiments is to drive the phase transformation in a material by means of ultrashort light pulses. The most commonly explored schemes are based on the sudden photo-injection of an excess of high-energy (h>1eV) electronic excitations by ultrashort light pulses eventually leading to photo-induced-phase-transitions. Under the conditions of short dephasing times (1-10fs) and of photo-excitation within time windows shorter than the characteristic times of the relaxation processes in the system, ultrashort light pulses act merely as an *impulsive* injector of a large number of excitations. This drives matter into regimes which are characterized by a non-thermal **incoherent** energy distribution between electrons, ions, and spins.

The major emerging limitation of this approach, hampering bi-directional optical control, lies in the fact that while the optical switch between different phases can be driven within picoseconds, the recovery is generally limited to much longer times determined by slower *incoherent* relaxation processes that are ruled by the thermodynamics of the sample.

To overcome this limitation, an important advance came from the implementation of excitation schemes allowing **for resonant excitation of low energy degrees of freedom** in solids such as vibrations, magnetic and electronic excitations. In contrast to the “incoherent” phase transitions induced by high-photon energy pulses, **the phase transitions triggered by coherent long-wavelength pulses are directly due to the large-amplitude low-frequency coherent excitation of the low energy modes and not related to hot-carrier injection**. This means that thermal relaxation processes do not limit the coherently controlled phase transformation and bi-directional changes of material properties at rates exceeding the thermodynamic restrictions become conceivable.

In spite of the infancy of this approach, some important results have already been achieved. In particular, in transition metal oxides, we have shown that resonant excitation of vibrational modes can trigger phase transitions and even drive the formation of superconducting phases on ultrafast timescales. Experiments technologically similar to the ones I led provide strong indication that this approach could be the mean to stabilize quantum coherent matter phases even at ambient conditions.

**These works disclose a largely unexplored regime of physics where strong electromagnetic fields can be used to “beat” thermal disorder and possibly make quantum coherence viable at ambient conditions.**

Major questions are open:

* What is the mechanism leading to the dynamical formation of quantum coherent matter phases at high temperature?
* Is the field “cooling” fluctuations in the material or is it rather increasing the stability of quantum coherent phases with respect to thermal fluctuations?
* What is the role played by the quantum state of the photo-excited low energy mode? Is it really a quasi-classical large amplitude coherent state or are non-classical features, such as squeezing and superposition, the key to unlock the onset of quantum coherent electronic states?
* To what extent can we exploit in realistic devices the mutual feedback between electromagnetic field and quantum coherent matter phases?

**I believe that the major limitation to our understanding and exploitation of complex materials is the lack of a protocol to access the role played by the *quantum state* of low energy degrees of freedom in determining macroscopic material properties.** At best we can access the characteristic population dynamics of low energy bosons but to the best of my knowledge, no direct measurement of the quantum state of low energy modes is possible.

In order to bridge this gap we are focusing on the idea that it may be possible **to map directly the quantum state of low energy modes into the quantum state of the light pulses used to interrogate the dynamical response of the material.** In appropriate scattering conditions, we have recently shown that fluctuation of the atomic position may be mapped one to one on photon number fluctuations which can be measured in repeated stroboscopic pump&probe experiments in shot noise limited condition. The basic idea leading my future research is **to understand how light-matter interactions can map the fluctuations of intrinsic material properties onto fluctuation of ultrashort light pulses which can be measured through a time resolved reconstruction of the quantum state of ultrashort probe pulses**.

A research program I proposed, recently funded by the European Commission, addresses this possibility. It aims at understanding to what extent we can access non-classical features of the quantum states of low energy degrees of freedom. We will start from weakly dressed phonon modes as a benchmark for the technique and gradually increase the level of complexity to finally address fluctuation of electronic degrees of freedom.

The results obtained so far have been very rewarding, we have set the bases, theoretical and experimental, to harness stochastic fluctuation of light (of classical and quantum nature) as a spectroscopic tool. We have shown that both spectrally integrated photon number fluctuations (PRL 119 (18), 187403 (2017) and Nat. Com. 6, 4, 2015) and multimode correlations (PNAS 201821048, 2019) carry information on the microscopic Hamiltonian determining the physical properties of simple materials. The combination of optical fluctuation measurements with the possibility of driving by low energy excitation the onset of quantum coherent phases of matter (PRL 122, 067002 (2019) and Science 331 (6014), 189, 273, 2011) will provides an extraordinary platform to address the onset of collective quantum matter phases in real materials.

The community is reacting vividly to the spectroscopic approach we are proposing. I am regularly invited to the most important meetings on condensed matter and laser physics, but more importantly, I have been invited to contribute to the design of different experiments in international facilities which are bringing the concept we are developing with low photon energy to x-ray.

All those aspects, make me confident that, the combination of time domain techniques with quantum state reconstruction (on optical and x-ray frequencies FEL-based) will offer a new angle to both the condensed matter and quantum information communities. The mutual manipulation between optical and materials degree of freedom, with serve the multifaceted purpose of delivering valuable spectroscopic information to understand and control complex quantum matter phases, and provide a rich platform to explore to what extent the interaction between light and complex materials can be used to produce unconventional quantum states of ultrashort light pulses.

**Teaching statements**

As a physicist and a scientist my major teaching goal is to give the students the tools to face complex problems, to rationalize and dissect them with a problem solving analytical approach. I believe that the best way to achieve such a goal is to stimulate the students’ curiosity towards describing nature. Led by my reductionist experimental approach, whenever the subject allows for this, I try to achieve such goal by means of guiding the students towards the self-discovery of the fundamental laws underneath specific phenomenology. In all courses, basic and more advanced, I develop in parallel the mathematical formalism and a more intuitive approach. The specific path to push forward this parallelism depends strongly on the subject taught: sometimes I proceed by developing the mathematical approach through a route established by intuition, while for more complex subjects I believe it is more viable to use the mathematical approach to challenge the intuition.

In more detail, my teaching philosophy in characterized by:

i) Engaging the students during the lectures by asking questions and encouraging their active participation to the lecture;

ii) Targeting the lecture specifically to the class level. In this respect I make an active effort to receive the students’ feedback, especially the negative ones, and to correct the lecture target according to it;

iii) I make a great use of a comparative approach: energy or length scales;

iv) Guide whenever possible the students towards a self-discovery of the subject;

v) Contextualize the arguments taught with real examples and thought experiments.

In the past years I taught various courses in the bachelor physics program in Trieste. I tried my best to implement the teaching philosophy briefly sketched above and the results have always been encouraging in terms of the evaluation given by the students and their performance at the exams.