

THE PROJECT NEWSLETTER

MAIN RESULTS AND MILESTONES

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SPOTLIGHT

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GO FAST-Results and milestones

Governing ultrafast the conductivity of correlated materials

The project is now in the second year of its life. Up to now, the project is characterized by a set of encouraging scientific results.

Focusing on the activities of the 24-30th months, the major breakthroughs have been achieved by the unique combination of the theoretical concepts and ultrafast techniques developed within the first part of the project. This joint modelling/experimental effort had shed new light onto the physics of correlated materials in the very first instants (femtoseconds) after a strong optical perturbation. Among the results, we highlight:

- Time-resolved optical and photoemission spectroscopies have been employed to unravel the relaxation dynamics at the surface of the prototypical Mott insulator Cr-V₂O₃. The interplay between the impulsive excitation and the lack of well-defined quasiparticles at the surface leads to a relaxation dynamics, which is strongly surface-dependent. Coherent lattice oscillations are excited and propagate from the surface to the bulk. This process is accompanied by the development of a transient metastable phase characterized by an electronically-driven anomalous hardening of the oscillation frequency.
- The ultrafast electronic relaxation in either doped and undoped copper oxides have been experimentally and theoretically investigated. A rich relaxation dynamics, strongly dependent on the excitation pathways and on the position in the momentum space has been evidenced. These results have boosted the development of codes for k-dependent dynamical mean field theory, based on the dynamical cluster approximation.
- The GO-FAST Exploitation Board highlighted the materials and mechanisms that are emerging as potentially technologically interesting. Among the possible impact of the modelling developed within the GO-FAST project we cite:
 - Addressing the dynamics at the interfaces between conventional metals and correlated materials. This would increase the understanding of the ultrafast switching processes in realistic configurations.
 - Understanding the dynamics of the switching process in conventional materials on a timescale that was previously inaccessible.
 - Investigating the nature of the resistive switching process in metal oxides and narrow-gap Mott insulators. The clarification of the order of the phase transition, along with the need of having pre-formed seeds to trigger the transition, would boost the technological interest in these materials.
 - Testing novel excitations schemes for resistive switching, like impulsive excitation with ultrashort and intense THz fields and the combination of a pulsed electric field and ultrashort light pulses which could inject novel seeds of free carriers in the system.



The Project is funded by the 7th Framework Programme, under the **NMP.2011.2.1-2** topic *Modelling of ultrafast dynamics in materials*. The Project started the **1st April 2012**, involving both academics and industrial partners focused on potential application, ensuring an effective exploitation of results.



The consortium is composed by 7 partners, coming from 4 Countries: Italy, Germany, Netherlands and France. The consortium includes 4 Universities, 2 Research Centres, and a SME.

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SPOTLIGHTS

24th Month Meeting



The **24th Month Meeting** took place in **Nijmegen** (Netherlands), at the **Radboud University**, on **6th – 7th May 2014**.

All the partners, through their representatives and people in charge for scientific matters, attended the meeting including the Project Technical Advisor from the European Commission.

The meeting was coordinated by the Project coordinator, **Michele Fabrizio** from **SISSA**. The aim of the meeting was the presentation of the objectives achieved so far, then the overall status of the Project itself throughout a careful examination of each of the seven Work Packages, and the future activities to be performed by the Partners and the future steps of the Project.

Particular attention was dedicated to the participation of the Project Technical Advisor that presented his comments, suggestions and recommendations for the next phase of the Project.

Cluster Workshop



The **27th and 28th November**, GO FAST, CRONOS and FEMTOSPIN will join together for a **CLUSTER Workshop** in order to share views and



approaches with the industrial community in order to develop an exploitation strategy and to

identify potential future scenarios in this area. This workshop will be held at the Trinity College of Dublin.



GO FAST recent publications

The recent publications of the GO FAST project are presented below:



- ✓ ***Gutzwiller electronic structure calculations applied to transition metals: Kinetic energy gain with ferromagnetic order in bcc Fe***, G. Borghi, M. Fabrizio and E. Tosatti, Physical Review B, 02nd September 2014.
- ✓ ***Nonadiabatic stationary behavior in a driven low dimensional gapped system***, A. Maraga, P. Smacchia, A. Silva and M. Fabrizio, Physical Review B, 29th July 2014.
- ✓ ***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 and E. Pedersoli, Faraday Discussions, 21st July 2014.
- ✓ ***Photo-enhanced antinodal conductivity in the pseudogap state of high T_c cuprates***, F. Cilento, S. Dal Conte, G. Coslovich, S. Peli, N. Nembrini, S. Mor, F. Banfi, G. Ferrini, H. Eisaki, M.K. Chan, C. Dorow, M. Veit, M. Greven, D. van der Marel, R. Comin, A. Damascelli, L. Rettig, U. Bovensiepen, M. Capone, C. Giannetti and F. Parmigiani, **Nature Communications 5:4353**, 11st July 2014.
- ✓ ***Reflectivity enhancement in titanium by ultrafast XUV irradiation***, F. Bencivenga, E. Principi, E. Giangrisostomi, R. Cucini, A. Battistoni, F. D'Amico, A. Di Cicco, S. Di Fonzo, A. Filippini, A. Gessini, R. Gunnella, M. Marsi, L. Properzi, M. Saito & C. Masciovecchio, Scientific Reports 4, 15th May 2014.
- ✓ ***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, 07th April 2014.
- ✓ ***Photoinduced changes in the cuprate electronic structure revealed by femto second time- and angle-resolved photoemission***, J. D. Rameau, S. Freutel, L. Rettig, I. Avigo, M. Ligges, Y. Yoshida, H. Eisaki, J. Schneeloch, R. D. Zhong, Z. J. Xu, G. D. Gu, P. D. Johnson, and U. Bovensiepen, Phys. Rev. B 89, 13rd March 2014.
- ✓ ***Witnessing the formation and relaxation of massive quasi-particles in a strongly correlated electron system***, F. Novelli, G. De Filippis, V. Cataudella, M. Esposito, I. Vergara Kausel, 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, D. Fausti, **Nature Communications 5:5112**, (2014).



- ✓ ***Dynamical coupling between off-plane phonons and in-plane electronic excitations in superconducting YBCO***, D. Fausti, F. Novelli, G. Giovannetti, A. Avella, F. Cilento, L. Patthey, M. Radovic, M. Capone, F. Parmigiani, (submitted).
- ✓ ***Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cuprates***, S. Dal Conte, L. Vidmar, D. Golez, M. Mierzejewski, G. Soavi, S. Peli, F. Banfi, G. Ferrini, R. Comin, B.M. Ludbrook, L. Chauviere, N.D. Zhigadlo, H. Eisaki, M. Greven, S. Lupi, A. Damascelli, D. Brida, M. Capone, J. Bonca, G. Cerullo, and C. Giannetti, (submitted).



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Summer School

From 4th to 15th August 2014, GO FAST and FEMTOSPIN had co-organized the **Summer School “Multiscale dynamics in Condensed Matter”**, which was host by the Radboud University of Nijmegen. The School has been an opportunity of meeting the FEMTOSPIN consortium, exchanging ideas, methods and tools, meanwhile giving young European students and researchers the chance of keeping in touch with the world of scientific research, and with the opportunities of being part of an EU funding project.

To introduce the main concepts of the GO FAST project to the young audience, Prof. Massimo Capone and Dr. Claudio Giannetti gave the following lectures:

- Prof. Massimo Capone (SISSA Trieste)
Dynamical Mean Field Theory for correlated materials (from Mott insulators to cuprates and iron-based superconductors)
- Dr. Claudio Giannetti (Università Cattolica del Sacro Cuore, Brescia)
Non-equilibrium spectroscopy of correlated materials and superconductors

Enjoy the experience with the following video!

<https://www.youtube.com/watch?v=DVny5ZuEWu4>



Events



The recent and future dissemination activities of the GO FAST project are presented below:

<i>Type of activities</i>	<i>Event title</i>	<i>Date</i>	<i>Place</i>	<i>Main leader</i>	<i>Dissemination</i>
Presentation/ Talk	Invited talk at the International Workshop "Dynamics of Quantum Many-body Systems far from Equilibrium"	14 th - 17 th December 2014	Krvavec, Slovenija	UNICATT	Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cuprates
Presentation/ Talk	Invited talk at the International Workshop "Dynamics of Quantum Many-body Systems far from Equilibrium"	14 th - 17 th December 2014	Krvavec, Slovenija	ELETTRA	Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cuprates



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Presentation/ Talk	Invited talk at the International Workshop "Light pulses for investigating the time dimension across the fs ns scales: An integrated users facility of complementary Table Top Laser, Seeded Free Electron Laser and Storage Ring sources for time-resolved spectroscopies"	1 st – 2 nd December 2014	ELETTRA Trieste, Italy	UNICATT	Unfolding the ultrafast relaxation processes in correlated materials by non-equilibrium spectroscopies
Presentation/ Talk	Invited talk at the International Workshop on Probing and Understanding Exotic Superconductors and Superfluids	27 th – 31 st October 2014	ICTP Trieste, Italy	UNICATT	Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cuprates
Presentation/ Talk	Invited talk at the Research Frontier of Transition-metal Compounds Opened by Advanced Spectroscopies	30 th September – 2 nd October 2014	Sendai – Japan	UDE	Non-equilibrium electronic structure of transient, laser-excited states in Bi-2212
Presentation/ Talk	Invited talk at the International Conference "Correlations and Coherence at Different Scales"	5 th – 10 th September 2014,	Ustron, Poland	UNICATT	Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cupra
Presentation/ Talk	JMC14-CMD25 Condensed Matter Div.	24 th – 29 th August 2014	Paris, France	CNRS	Talk: "Ultrafast evolution of the prototype Mott-Hubbard compound V ₂ O ₃ "
Poster presentation	Poster presentation at the ELI Beamlines Summer School 2014	24 th – 29 th August 2014	Prague, Czech Republic	UDE	Talk: "Time-resolved X-ray scattering on high TC superconductors"
Presentation/ Talk	BrillMics 2014	03 rd August 2014	Saratov, Russia	RU	Talk: "Terahertz emission spectroscopy of ultrafast



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					spin dynamics"
Lectures	Invited Lecture at the Summer School Multiscale Dynamics in Condensed Matter	03-15 August 2014	Nijmegen, the Netherlands	RU	Non-equilibrium spectroscopy of correlated materials and superconductors
Participation in a summer school	Summer School Multiscale Dynamics in Condensed Matter	03-15 August 2014	Nijmegen, the Netherlands	RU	Time-resolved optical spectroscopy on Na ₂ IrO ₃
Organization of a summer school	Summer School Multiscale Dynamics in Condensed Matter	03-15 August 2014	Nijmegen, the Netherlands	RU	Non-equilibrium spectroscopy of correlated materials and superconductors
Presentation/ Talk	SCES14	7 TH – 11 ST July 2014	Grenoble (France)	SISSA	Talk: "Thermalization in a Fermi Liquid"
Presentation/ Talk	NTPF 2014	4 th – 5 th July 2014	St. Petersburg, Russia	RU	Talk: "Terahertz emission spectroscopy of ultrafast spin dynamics"
Presentation/ Talk	Invited talk at the International Workshop "(Towards) Room Temperature Superconductivity"	30 th June – 4 th July 2014	Leiden, the Netherlands	UNICATT	Universal nature of antinodal pseudogap states in cuprates disclosed by non-equilibrium spectroscopies
Presentation/ Talk	MISM 2014	29 th June – 4 th July 2014	Moscow, Russia	RU	Talk: "Optical manipulation of the super-exchange Interaction on a sub-picosecond timescale"
Presentation/ Talk	Invited talk at the International Conference Low Energy Electrodynamics in Solids	29 th June – 4 th July 2014	Loire Valley, France	UNICATT	Talk: "Snapshots of the retarded interaction of charge carriers with



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	(LEES2014)				ultrafast fluctuations in cuprates"
Presentation/ Talk	Invited talk at the Photo-induced phase transitions 5	08 th – 13 th June 2014	Bled – Slovenia	UDE	Talk: "Non-equilibrium electronic structure of transient states"
Presentation/ Talk	Workshop MICO "Correlations in Materials"	26 th – 29 th May 2014	Grenoble (France)	CNRS	Talk: "Time resolved ARPES in strongly correlated materials"
Presentation/ Talk	SPLDS 2014	21 st May 2014	Nancy (France)	CNRS	Talk: "Ultrafast dynamics of complex materials by time resolved ARPES"
Posters	IMM symposium 2014	19 th May 2014	Nijmegen, Netherlands	RU	Poster: "Terahertz spectroscopy of ultrafast processes in magnetic materials"



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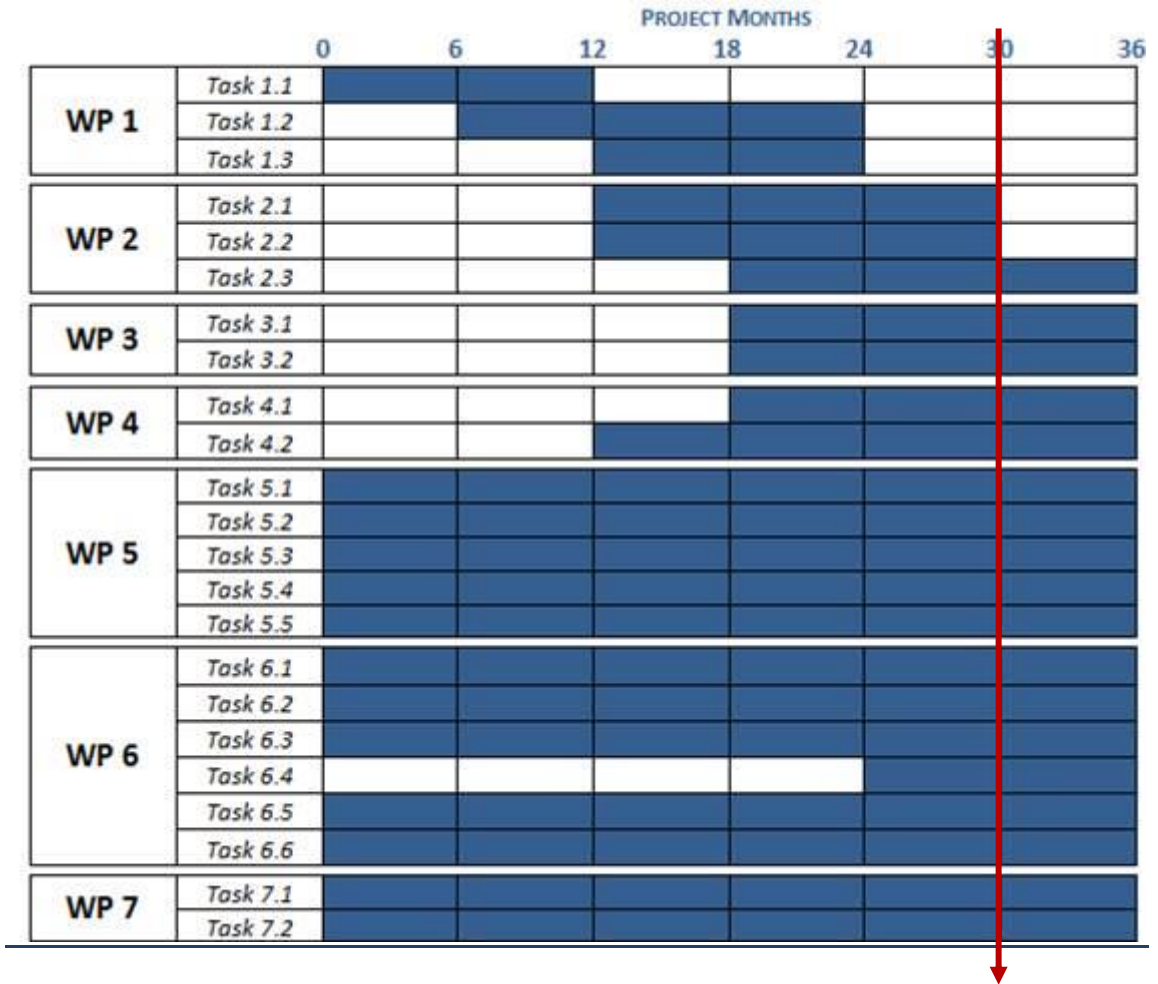
World news

Suggested publications related to the recent breakthrough relevant to the optical control of the electronic properties of correlated materials:



- **How to model the resistive switching in Mott insulators through the Hubbard model:**
J. Li et al. **Electric-field-driven resistive switching in dissipative Hubbard model.**
arXiv:1410.0626v1.
- **Switching a charge-density wave insulator by light pulses or by pulsed electrical charge injection:**
I. Vaskivskiy et al. **Fast non-thermal switching between macroscopic charge-ordered quantum states induced by charge injection.**
arXiv:1409.3794
L. Stojchevska et al., **Ultrafast Switching to a Stable Hidden Quantum State in an Electronic Crystal.** Science 344, 177 (2014)





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Project partners

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Project EXPLOITATION BOARD	MICRON SEMICONDUCTOR ITALIA S.R.L. <i>Data storage devices based on transition metal oxides</i>
	MENLOSYSTEMS GMBH <i>THz photoconductive antennas based on transition metal oxides</i>



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