

Politecnico di Milano, Building 19 (Cesnef), via Ponzio 34/3, Milan

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Seminar Room, 1° floor Building 19, Politecnico di Milano

Ultrafast coherent manipulation of free electrons *via* quantum interaction with shaped optical fields

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The interaction between light and electrons can be exploited for generating radiation, such as in synchrotrons and FEL, or for controlling electron beams for dynamical investigation of materials, enabling new applications in light-assisted quantum devices and diagnostics at extremely small timescales. In this contribution, I will describe an innovative method for coherent longitudinal and transverse manipulation of a free-electron wave function. Using appropriately shaped light fields in space and time, I will demonstrate how to modulate the energy, linear momentum and orbital angular momentum (vorticity) of the electron wave function with sub-fs precision [1-4]. The experiments have been performed in an ultrafast-TEM, where a relativistic pulsed electron beam was made to interact with properly shaped near-field. The energy-momentum exchange resulting from such interaction was directly mapped via momentum-resolved ultrafast electron energy-loss spectroscopy. Our approach for longitudinal and transverse electron phase modulation at the sub-fs timescale would pave the way to achieve unprecedented insights into non-equilibrium phenomena in advanced quantum materials [5], playing a decisive role in the rational design and engineering of future photonics and electronics application [6].

- [1] G. M. Vanacore et al., *Nature Communication* **9**, 2694 (2018).
- [2] G. M. Vanacore et al., *Nature Materials* **18**, 573-579 (2019).
- [3] I. Madan*, G. M. Vanacore* et al., *Science Advances* **5**, eaav8358 (2019).
- [4] I. Madan, et al., and G. M. Vanacore, *ACS Photonics* **9**, 3215 - 3224 (2022).
- [5] I. Madan*, G. M. Vanacore* et al., *Appl. Phys. Lett.* **116**, 230502 (2020).
- [6] G. M. Vanacore et al., *La Rivista del Nuovo Cimento* **43**, 567–597(2020).

About the speaker:

Giovanni Maria Vanacore studied Physics Engineering at the Politecnico di Milano (Milano, Italy). In 2011 he received a Ph.D. in Physics from the Politecnico di Milano and the École Polytechnique X (Paris, France) for the investigation of the electronic and structural properties of semiconductor nanostructures using spectro-microscopy techniques. In November 2011, he joined the group of Prof. Ahmed H. Zewail at the California Institute of Technology (Caltech), where he studied ultrafast phenomena in nanomaterials via ultrafast electron diffraction and ultrafast electron microscopy. In February 2016, he moved to the École Polytechnique Fédérale de Lausanne (EPFL), where he explored new methods for the coherent phase manipulation of a free-electron wave function using light pulses with attosecond precision. Since December 2019, he is a Tenure Track Assistant Professor at the University of Milano-Bicocca and leader of the Laboratory of Ultrafast Microscopy for Nanoscale Dynamics (LUMiNaD).



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