
# Felicidades al nuevo graduado de doctorado del ICFO

## El Dr. Igor Tyulnev se ha doctorado con una tesis titulada "Investigation and Control of Phase Transitions by Ultrafast Strong-field Techniquesï¿½

February 05, 2026

Felicitamos al Dr. Igor Tyulnev que ha defendido su tesis esta manana en el auditorio del ICFO.
El Dr. Tyulnev obtuvo su Master en Fisica por la University of Hamburg, antes de unirse al grupo de investigacion de Attoscience and Ultrafast Optics dirigido por el profesor ICREA en ICFO Dr. Jens Biegert. Su tesis titulada "Investigation and Control of Phase Transitions by Ultrafast Strong-field Techniques" ha sido supervisada por el Prof. Dr. Jens Biegert.

**RESUMEN:**
This work presents the experiments and results on the application of mid-infrared laser sources towards condensed matter systems for the study and control of manybody interactions within material phases and at phase boundaries. Utilizing the decades in

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know-how and development of intense, few-cycle waveforms at high repetition rates, the here demonstrated applications leverage the mid-infrared wavelengths to study and control strong-field phenomena at ultrafast time-scales and across phase transitions. To this end non-linear techniques are employed to extend the source capabilities towards a variety of driving and probing wavelengths, meanwhile tailoring spin-angular momentum multi-color beams as driving fields with unique patterns. With strong-field driven dynamics happening at sub-cycle time scales, techniques such as high harmonic generation (HHG) are applied to a variety of materials which undergo electronic and structural transitions. For bulk transition metal dichalcogenides, as the investigated MoS2, the induced spatial and temporal symmetry breaking from a tailored trefoil-shaped strong-field allowed the detection of valley polarization, i.e. a carrier population imbalance between neighboring bandgap extrema. The specific control of the energy bands at these sites, first, allows the realization of a valley switch to be used for optical computing, and second, realizes a hybrid system of light and matter with band topology akin to the Haldane model, which paves the way towards field-induced and controlled topological phase transitions in two-dimensional materials. Furthermore, the field-induced currents and the emerging harmonics are used to probe the potential landscape of the lattice and therefore, simultaneously detect signatures of the crystal and band structure encoded in a static spectrum. Interference within the spectra further reveal the underlying electron-hole dynamics and timings. In high-temperature superconducting ceramics like YBCO, the temperature induced changes in electronic properties are also sensitively detected via HHG, even for more elusive material phases. Meanwhile higher order transitions like the correlated charge density wave (CDW) phase shows a mixture of electronic and structural changes in the HHG crystallography as investigated in TiSe2. The macroscopic and nonlinear approach yields major changes in the harmonic spectra even from small changes in e.g. atom displacement and identifies phase anisotropies which eluded conventional or microscopic techniques.

**Tribunal de Tesis:**

Prof. Dr. Martin Wolf, Fritz-Haber Institute Berlin - Max Planck Society
Prof. Dr. Javier Garcia de Abajo, ICFO
Prof. Dr. Anna Palau Masoliver, Institut de Ciencia de Materials de Barcelona


Thesis Committee