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NEW EMERGENT NANOMATERIALS ALONG THE TIME AXIS

Dragan Mihailovic

J. Stefan Institute, University of Ljubljana, J. Stefen International Postgraduate School JSIPS, and CENN Nanocenter

One way to search for new nanomaterials is to use ever more sophisticated chemistry. Another approach is to use nanomanipulation methods, such as exfoliation in order to unlock the properties of new 2D materials. A third, new and exciting possibility is to look for new metastable materials that self-assemble through interactions of electrons amongst themselves under non-equilibrium conditions.
In this talk I will present new experiments aimed at creating new nano-structured quantum materials with new emergent properties using ultrashort light and electrical pulses. Starting from 2D transition metal dichalcogenides prone to the formation of different electronic ordersvo[1], we have been able to create new types of metastable electronic states that are not found under thermodynamic conditions. Using a combination of techniques (optics, STM etc.) we have beenable to construct for the first time *a phase diagram with a time axis* of the well-known material[2-6]. Not only do the new phases have interesting topological properties but also have very important applications, particularly in ultrafast[7], low-energy computer memory[4], which opens the way to exoscale cryocomputing and quantum computer peripherals. Fundamentally, the non-equilibrium approach opens the way to creation of a very large variety of metastable new materials with interesting emergent properties that outnumber those that we can imagine from the thermodynamic viewpoint.

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2. Stojchevska, L. *et al.* Ultrafast switching to a stable hidden quantum state in an electronic crystal. *Science* 344, 177–180 (2014).
3. Vaskivskyi, I. *et al.* Controlling the metal-to-insulator relaxation of the metastable hidden quantum state in 1T-TaS2. *Science Advances* 1, e1500168 (2015).
4. Vaskivskyi, I. *et al.* Fast electronic resistance switching involving hidden charge density wave states. *Nat Comms* 7, 11442 (2016).
5. Gerasimenko, Y. A., Karpov, P., Vaskivskyi, I., Brazovskii, S. & Mihailović, D. Intertwined chiral charge orders and topological stabilization of the light-induced state of a prototypical transition metal dichalcogenide. *npj Quant Mater* 4, 1–9 (2019).
6. Gerasimenko, Y. A. *et al.* Quantum jamming transition to a correlated electron glass in 1T-TaS_2. *Nat. Mat.* 317, 505–1083 (2019).
7. Ravnik, J., Vaskivskyi, I., Mertelj, T. & Mihailović, D. Real-time observation of the coherent transition to a metastable emergent state in 1T–TaS_2. *Phys Rev B* 97, e1400173 (2018).