Controlling stripe ordering in $IrTe_2$ with ultrafast optical pulses

***G. Jecl*[1,2*], *V. Nasretdinova*[3], *Y. Gerasimenko*[1,†], *T. Mertelj*[1,2], *C. Monney*[4], *F. von Rohr*[5], *D. Mihailović*[1,2,3]**

[1]*Department of Complex Matter, Jožef Stefan Institute, Ljubljana, SI-1000, Slovenia*
[2]*Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, SI-1000, Slovenia*
[3]*CENN Nanocenter, Ljubljana, SI-1000, Slovenia*
[4]*Département de Physique and Fribourg Center for Nanomaterials, Université de Fribourg, Fribourg, CH-1700, Switzerland*
[5]*Department of Chemistry, University of Zürich, Zürich, CH-8057, Switzerland*
*E-mail: gregor.jecl@ijs.si

Superconductivity was recently shown to emerge in van-der-Waals material $IrTe_2$ in thermally quenched nanoflakes [1]. In bulk samples, superconductivity competes with the Ir^{3+}/Ir^{4+} charge stripe order and is stabilized by Pt or Pd substitution [2]. In pristine samples, superconductivity is found only in hexagonal domains formed at three-fold stripe intersections [3], with similar hexagonal patchwork structures observed in the doped material [4]. Despite the recent advances in the domain structure engineering in transition metal dichalcogenides with ultrafast optical pulses, optical control over superconductivity in IrTe2 remain elusive.

Here we study possible ways to control the stripe order in $IrTe_2$ with ultrafast pulses using optical pump-probe time domain spectroscopy and *in situ* STM studies. STM imaging of the sample surface at helium temperatures reveals that exposure to high fluence pulses heals the stripe ordering defects. After exposure to longer pulse trains we first observe stabilization of the higher temperature 1/5 periodicity and even change in orientation of the stripe order. Pump-probe spectroscopy first reveals non-thermal behaviour at high excitation fluences and the analysis of the relaxation components reveals increased anisotropy on the picosecond timescale as well an additional, probe-polarisation-independent relaxation component suggestive of either a new, non-thermal process or a photoinduced phase transition.
In three-pulse destruction-pump-probe measurements at 10 K we observe definite evidence of a transition to a mixture of higher temperature phases several picoseconds after the arrival of the high fluence destruction pulse, but no persistent changes are induced at this temperature. By tracking the relaxation of transient reflectivity versus the time of arrival of the destruction pulse, we are able to map the temporal evolution of the material undergoing successive phase transition as well as its relaxation back into the equilibrium state, which occurs on the timescale of hundreds of picoseconds. Alternatively, exposure at higher temperatures creates longer-lived, mixed metastable configurations visible in the phonon spectrum which relax on the timescale of hours.

Thus, we reveal two well-defined ways to control the stripe phases – thermal and non-thermal – and discuss the implications of domain formation kinetics. However, ultrafast optical control over superconductivity in $IrTe_2$ apparently requires the careful mixture of the above mechanisms.

References:

[1] H. Oike at. al., Science Advances 4, eaau3489, 2018
[2] S. Pyon et.al., Journal of the Physical Society of Japan, 81, 053701 (2012)
[3] H. S. Kim et.al., Nano Letters, 16, 4620-4265, 2016
[4] R. Wei et. al., Scientific Bulletin, 60, 8, 798-805, 2015
[5] K.-T. Ko et. al., Nature Communications 6, 7342, 2015

[†] *Present affiliation: Faculty of Physics, Universität Regensburg, 93040 Regensburg, Germany*