Signatures of many-body phenomena in low-dimensional systems: from nano-structures to columnar materials

Piotr Chudzinski* [1], Lenart Dudy[2]

[1] Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B, 02-105 Warsaw, Poland pchudzin@ippt.pan.pl

[2] TEMPO Beamline, Synchrotron SOLEIL, L'Orme des Merisiers Saint-Aubin, B.P.48, 91192 Gif-sur-Yvette, France

Key Words: *Nanotechnology, collective phenomena, bosonization*

When electrons' motion is constrained, interactions between carriers start to play the dominant role. The behavior of electronic liquid becomes collective, and new exotic instabilities may emerge. This will affect all measurable quantities. In my talk, I will first briefly introduce the theoretical formalism that can describe collective phenomenology and then show how to extract measurable correlation functions. In the following, I will provide a few examples of such physics.

The first is an artificially created nanostructure, Si(553)-Au, consisting of gold atoms evaporated on the top of a stepped silicon surface. The system hosts several competing instabilities, making it a subject of numerous experimental studies (STM, ARPES, SPA-LEED). Despite these efforts [1], the physics of the system has not been fully understood, and attempts to provide its full explanation using plain single-particle theory have turned out to be a failure. In the talk, I will focus on the Peierls phase transition that acts on selected bands. I will show how various instabilities are expressed in the language of collective excitations [2]. Based on that, I will derive a peculiar form of a dielectric function in the material, which enables Peierls's transition despite only partial nesting.

The second example is a quasi-1D material, lithium molybdenum purple bronze (LMO). It is one of the most perfect columnar materials in that the motion of electrons is confined to one direction only and inhibited in other directions. In this way, the material provides an ideal testing ground for theoretical concepts that can be later applied in nano-materials. I will show how various anomalous instabilities can emerge near the Mott transition[3]. The material has been the subject of numerous experimental studies (like ARPES and STM), particularly magneto-transport measurements. I will focus on the latter to show how they can reveal the presence of collective instabilities in the system [4]. Remarkably, the experiment allows for direct access to measure the symmetry enlargement in the material.

I will conclude my talk with a brief discussion on the conditions that must be met to arrive at a regime where collective behavior can be entirely described and about the potential advantages of such collective behavior for future applications.

REFERENCES

[1] L. Dudy et al, One-dimensional quantum matter: gold-induced nanowires on semiconductor surfaces, *J. Phys.: Condens. Matter* **29** 433001 (2017).

[2] P. Chudzinski et al, Partial gap in two-leg ladders with Rashba effect and its experimental signatures in Si(553)-Au, PHYSICAL REVIEW B 104, 205407 (2021).

[3] J. Lu et al, *Emergence of a real-space symmetry axis in the magnetoresistance of the onedimensional conductor Li0.9Mo6O17*, Science Advances, Vol.5, No.7, pp.eaar8027-1-7 (2019).

[4] P. Chudzinski et al, Emergent symmetry in a low-dimensional superconductor on the edge of Mottness, Science, Vol . 382, pp.792-796 (2023).

Biography of the presenting author

Dr. Piotr Chudzinski studied Physics at Poznan University of Technology, Poland, and graduated with an MSc degree in Nanotechnology from the Institute of Molecular Physics PAS in 2004. He then joined, as Marie-Sklodowska-Curie fellow, the Theory research group at the Laboratoire de Physique des Solides, Université Paris-Sud in Orsay, France. He received his PhD degree in theoretical solid state physics in 2008 with Prof. Marc Gabay (LPS) as his PhD advisor. He then obtained a series of postdoctoral fellowships in Switzerland, Germany, and the Netherlands (Utrecht), including four years with Prof. Thierry Giamarchi in Geneva. Since 2017, he has been hired as a Research Fellow, later Senior Research Fellow, at Queen's University Belfast. In 2021, he moved back to Poland, to Warsaw, to work at the Institute of Fundamental Problems of Technology PAS, now as the head of the theory lab in the Department of Theory of Continuous Media and Nanostructures. He has published more than 30 research articles, including in *Science* and *Science Advances*, in the research fields spanning from materials science to mathematical physics.