The dimensional crossover in the unconventional superfluids

M. Bąk,[1] K. J. Kapcia,[1] and A. Cichy[1]

[1] *Adam Mickiewicz University, Uniwersytetu Poznańskiego 2, 61-614, Poznań, Poland*

The lattice geometry is a fundamental characteristic of many-body systems and has large influence on their physical properties. Ultracold atomic gases in optical lattices give the opportunity of realization of systems with different geometries. The high degree of tunability of the model parameters enables to investigate systems in various regimes. Experimentally, the geometry of the lattice can be changed by different spatial arrangement of laser beams [1]. Quite recently, the occurrence of antiferromagnetic spin correlations in different lattice geometries of varying dimensionality, also including crossover configurations between different geometries, was investigated [2]. However, there exists, beside the quantum magnetism, an equally interesting phenomenon in the context of dimensionally tunable lattices - fermionic superfluidity. It was shown that the magnetized superfluid phase in the presence of a Zeeman magnetic field (population imbalance) is unstable in two-dimensional system against the phase separation [3,4]. However, such phase is stable in simple cubic lattice, for strong attraction and low electron concentrations [5]. Hence, it is very interesting to investigate the dimensional crossover in the context of stability of exotic phases with non-trivial Cooper pairing in systems with population imbalance.

Our studies are aimed at investigating the effects of dimensional crossover (2D$\rightarrow$3D) in the attractive Hubbard model with a Zeeman magnetic field, in the context of stability of unconventional superfluid phases.

The model is considered on L layers of the square lattice ($\infty\times\infty\times L$) to investigate how geometry affects the stability of the magnetized superfluid phase. The dimensionality along the z-axis can be tuned by including the effects of adding an arbitrary number of single layers along with variable tunneling between them (including anisotropy of tunneling between and within planes) in the density of states used for solving the mean-field equations. Competition between superfluidity and CDW diagonal ordering is analyzed.

References:

[1] I. Bloch, J. Dalibard, W. Zwerger, Rev.Mod.Phys. 80 (2008) 885
[2] D. Greif, G. Jotzu, M. Messer, R. Desbuquois, T. Esslinger, arXiv:1509.00854 (2015)
[3] G. Sarma, J. Phys. Chem. Solids 24 (1963) 1029
[4] A. Kujawa-Cichy, R. Micnas, Europhys. Lett. 95 (2011) 37003
[5] A. Kujawa-Cichy, R. Micnas, Ann. Phys. 347 (2014) 207