Towards a 2D Fermi gas with tunable point-like disorder on the micron scale

G. Del Pace[1,2], A. Amico[1,2], W. Kwon[1,2], F. Scazza[1,2], M. Zaccanti[1,2] and G. Roati[1,2]
[1]LENS and Dipartimento di Fisica e Astronomia, Università di Firenze, 50019 Sesto Fiorentino, Italy
[2]Istituto Nazionale di Ottica del Consiglio Nazionale delle Ricerche (INO-CNR), 50019 Sesto Fiorentino, Italy
e-mail: delpace@lens.unifi.it

Ultracold atoms and quantum gases are very clean and controllable systems, that can be considered as novel quantum materials and quantum simulators. In ultracold atomic systems, the strength of interactions, the dimensionality and the trapping geometry can be precisely adjusted, such that theoretical models can be directly tested in the laboratory. In this framework, a two-dimensional (2D) Fermi gas can be used to mimic the behavior of layered superconductors, where the transition to the superfluid phase occurs to unusually high temperature.

In our experiment we are currently working on the realization of a 2D strongly interacting Fermi gas of lithium-6 atoms. Our platform will consist of a fermionic superfluid with tunable interactions, trapped in arbitrarily tailored geometries with reduced dimensionality and controllable disorder. Here we present our progress in realizing the 2D system and the upgrade of the imaging optical setup.

The 2D gas is obtained by the combination of two different optical traps: a blue-detuned TEM_{01}-like gaussian mode for the vertical confinement and a red-detuned focused gaussian beam that provides a trap in the plane. In 2D phase fluctuations inhibit true long-range coherence, and only superfluidity of the Berezinskii-Kosterlitz-Thouless (BKT) type can exist [1] [2]. We plan to use transport measurement to characterize the superfluid phase in 2D and probe the BKT transition [3].

In order to improve the resolution in imaging the 2D cloud we built a new imaging system, based on an achromatic microscope objective, that allows for a resolution below the micrometer scale, comparable to the correlation length of the investigated superfluids. The objective is achromatic as it has to both image the atoms with resonant light at 670 nm, and imprint optical potentials with blue-detuned light at 532 nm.

A Digital Micromirror Device (DMD) is used to create tailored optical potentials, imaged on the 2D atomic cloud by the achromatic objective. In particular, we present the capability of such device, together with an high-resolution optical system, to create tunable disordered potentials on the micrometer scale. By acting on the resolution of the optical system, it is possible to realize both speckles and point-like disorder, with tunable characteristic length of the order of μm. So far, speckles disorder has been the standard to introduce randomness in atomic physics experiments, but only point-like disorder can be set not to cause any classical trapping of the atoms [4] [5]. Such point-like disordered potentials will be used to explore the interplay between many-body correlations and localization effects in the 2D BEC-BCS crossover, expecting different behaviors for the various superfluids, characterized by different pair size [6].

Keywords: 2D, FERMI GAS, DISORDER.

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