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Ultracold atoms in optical quasicrystals: From Many-Body Localization to Fractal Structures

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Quasicrystals are a relatively novel form of solids that is non-periodic, but nonetheless long-range ordered. They can be described by fractal aperiodic tilings with more than one unit cell, similar to the celebrated Penrose tiling. Experimentally, quasicrystals give rise to diffraction patterns consisting of sharp Bragg peaks, similar to periodic crystals, but with rotational symmetries that are forbidden for periodic structures. Even though they are long-range ordered, many foundational concepts of periodic crystals such as Blochwaves or Brillouin zones are not applicable, thereby giving rise to new physics. Examples include many-body localization, phasonic degrees of freedom, fractal band structures, and a direct link to higher dimensions via cut-and-project techniques, where quasicrystals can inherit topological properties from their periodic parents band structures. I will first present our experimental realization of many-body localization of interacting fermions in the presence of quasi- periodic disorder in 1D and 2D, and then discuss extensions to 2D quasicrystals with high rotational symmetries. Furthermore, I will present matter-wave diffraction experiments in an eightfold symmetric optical quasicrystal that directly reveal the self- similarity of the fractal momentum-space structure.