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Cold atoms and degenerate quantum gases[1]

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There have been many significant advances in the theoretical understanding of quantum gases over the past decade, setting the stage for a variety of potential directions for future research. It is possible using ultracold atoms and crystals of light to explore directly some aspects of the physics that is believed to underpin novel states of condensed matter. There are, however, a number of advantages of using these systems for fundamental study over their condensed matter counterparts. One of the most striking aspects is the macroscopic length scale allowing one to directly observe the atoms with relatively simple imaging systems. Important also is the ability to control and tune the strength and sign of the atom-atom interactions through Feshbach resonances. One has direct access to both bosons and fermions, as well as atoms and molecules. It is feasible to explore a variety of different trapping potential geometries, artificial gauge fields, and effective dimensionality. Long-range anisotropic dipole-dipole interactions can be achieved through ultracold atomic dipolar BECs. Furthermore, atoms can be coupled to optical cavities giving the potential for realizing the collective synchronization of atomic dipoles and superradiant light emission. This rich playing field offers tremendous possibilities for theorists applying techniques from a variety of traditional fields. In this talk, I will discuss the current state of theoretical atomic, molecular, and optical physics in this area of quantum gases, and provide an overview of what I view will be the scientific themes and important trends for the next decade.

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