# Summary


The exploration of the quantum world is a fascinating and very active field of current research. Experiments with gases of ultracold atoms are building on a long history of precision measurements and have been particularly successful in reaching ever lower temperatures. The first Bose-Einstein condensate was created about two decades ago and ignited the investigation of quantum-degenerate samples. But for a few exceptions, these experiments have utilized alkali atoms, which have a relatively simple electronic structure.

Alkaline-earth atoms, on the other hand, carry two valence electrons and exhibit a rich electronic structure of singlet and triplet states, connected by narrow intercombination lines. Such transitions of mHz-width are driven in optical clock experiments, which are outperforming microwave clocks by orders of magnitude. The unique properties of these elements are at the basis of recently proposed schemes of quantum simulation, targeted at the investigation of quantum magnetism and spin models. The proposed experiments rely on the availability of quantum-degenerate gases, and require a supreme control over all relevant parameters.

This thesis is aimed to provide a solid foundation for such experiments, choosing strontium as the atomic species. We report on the first Bose-Einstein condensation of this element, choosing the isotope $^{84}$Sr for its favorable scattering properties. This achievement received widespread recognition, and we are able to attain condensates of the two other bosonic isotopes, $^{86}$Sr and $^{88}$Sr, as well.

The proposed schemes of quantum simulation require isotopes with nonzero nuclear spin, sparking considerable interest in the fermionic isotope $^{87}$Sr, which has a large nuclear spin of $I = 9/2$. We develop a set of experimental techniques to control the spin composition of an atomic sample, and we present deeply-degenerate Fermi gases with a variable number of spin states.

Dipolar quantum gases are another active field of research. Diatomic molecules in their internal ground state, made up of an alkali and an alkaline-earth atom, possess both an electric and a magnetic dipole moment. Magnetic Feshbach resonances, which are commonly used to associate bi-alkali molecules, are absent or very weak in bi-alkaline-earth and alkali/alkaline-earth systems. We develop a novel technique of molecule association, demonstrated for the homonuclear case of $Sr_2$. This approach uses atoms on doubly-occupied sites of an optical lattice as the starting point for a coherent optical transfer into the molecular state.

Finally, we expand the capabilities of laser cooling to reach a long-standing goal: Bose-Einstein condensation without evaporative cooling, purely by laser cooling and thermalization within the atomic gas. This work holds prospects for the generation of a continuous atom laser.