

Towards strongly interacting many-body states of dipolar spin mixtures in optical lattices.

L. Lafforgue^{*1}, J.J. A. Houwmann², S. Embacher² M.J. Mark^{1,2},
F. Ferlaino^{1,2}

*1. Universität Innsbruck, Fakultät für Mathematik, Informatik und Physik, Institut für
Experimentalphysik, 6020 Innsbruck, Austria*

*2. Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften,
6020, Innsbruck, Austria*

Ultracold atoms in optical lattices have been established as a powerful toolbox for quantum simulation, enabling the study of many-body physics and strongly correlated condensed matter systems. At the same time, lanthanides, such as erbium and dysprosium, have emerged as valuable resources in ultracold quantum gas experiments. Among many interesting properties, like their strong magnetic dipole-dipole interactions and their rich optical spectrum, they are known for their large spin manifold in the ground state. These characteristics are ideal for engineering exotic many-body phenomena in optical lattice. To fully exploit them, precise control of the spin population and a detailed understanding of the underlying collisional processes are required.

Here, we demonstrate a novel method for manipulating the spin population in bosonic erbium by using a laser tuned to a clock-like transition present in erbium at 1299nm. By applying a sequence of Rabi-pulse pairs we can climb the ladder of Zeeman sublevels and prepare arbitrary superpositions of spin states. This allows us to record Feshbach resonance spectra of various spin mixtures to investigate spin-dependent scattering processes. We have successfully transferred this preparation scheme to our optical lattice system, which enables us to shield the atoms from collisions. Our latest results indicate that the lifetime of our metastable excited state is not affected by the lattice, and this additional shielding yields an improved determination of the natural linewidth of 0.48(3) Hz. This enables in-situ, spin-resolved imaging and, moreover, paves the way for observing collective effects arising from the interplay between light exchange and magnetic dipole-dipole interactions.

*Louis.Lafforgue@uibk.ac.at