Simulating dipolar energy transport with giant atoms

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Energy transport is an important theme in natural processes, e.g., chemical reactions and photosynthesis. There is ongoing debate on how the environment influences the efficiency of energy transfer in these systems and to which extent quantum mechanics plays a role. By interfacing electronically highly excited (Rydberg) atoms with laser light we simulate energy transfer dynamics in a controlled many-body system. In particular, Rydberg atoms experience quantum state changing interactions similar to Förster processes in complex molecules, offering a model system to study the nature of dipole-mediated energy transport. The extension to multiple interacting excitations could enable elementary realizations of quantum spin models involving strong and long-range spin-dependent interactions. We report on a new imaging method, which we apply to monitor the migration of electronic excitations with high time and spatial resolution using a background atomic gas as an amplifier. Through precise control of interactions and the coupling to the environment via the laser fields, we find different mechanisms at work which shed new light on the nature of energy and spin transport in complex quantum systems.