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Adjustable Spin-Spin Interaction with ^{171}Yb$^+$ ions and Addressing of a Quantum Byte

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Trapped atomic ions are a well-advanced physical system for investigating fundamental questions of quantum physics and for quantum information science and its applications. When contemplating the scalability of trapped ions for quantum information science one notes that the use of laser light for coherent operations gives rise to technical and also physical issues that can be remedied by replacing laser light by microwave (MW) and radio-frequency (RF) radiation employing suitably modified ion traps. Magnetic gradient induced coupling (MAGIC) makes it possible to coherently manipulate trapped ions using exclusively MW and RF radiation. After introducing the general concept of MAGIC, I shall report on recent experimental progress using ^{171}Yb$^+$ ions, confined in a suitable Paul trap, as effective spin-1/2 systems interacting via MAGIC. Entangling gates between non-neighbouring ions will be presented. The spin-spin coupling strength is variable and can be adjusted by variation of the secular trap frequency. In general, executing a quantum gate with a single qubit, or a subset of qubits, affects the quantum states of all other qubits. This reduced fidelity of the whole quantum register may preclude scalability. We demonstrate addressing of individual qubits within a quantum byte (eight qubits interacting via MAGIC) using MW radiation and measure the error induced in all non-addressed qubits (cross-talk) associated with the application of single-qubit gates. The measured cross-talk is on the order 10^{-5} and therefore below the threshold commonly agreed sufficient to efficiently realize fault-tolerant quantum computing. Furthermore, experimental results on continuous and pulsed dynamical decoupling (DD) for protecting quantum memories and quantum gates against decoherence will be briefly discussed. Finally, I report on using continuous DD to realize a broadband ultrasensitive single-atom magnetometer.