Scalable quantum computing with atomic ensembles

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Atomic ensembles, comprising clouds of atoms addressed by laser fields, provide an attractive system for both the storage of quantum information [1], and the coherent conversion of quantum information between atomic and optical degrees of freedom [2].

We describe a scheme for full scale quantum computing with atomic ensembles, in which qubits are encoded in symmetric collective excitations of many atoms [3]. The basic building block of our proposal is an atomic ensemble, which may be realised in an atomic vapour cell. The atoms in the vapour are either 3- or 5-level atoms, depending on the details of the implementation, as shown in the figure.

We consider the most important sources of error – imperfect exciton-photon coupling and photon losses – and demonstrate that the scheme is extremely robust against these processes: the required photon emission and collection efficiency threshold is 86%. Our scheme uses similar methods to those already demonstrated experimentally in the context of quantum repeater schemes, yet has processing capabilities far beyond those proposals.