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Rydberg excitation of cold atoms: dipole blockade and ionization.

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Cold Rydberg atoms are fascinating because they are at the frontier of atomic, solid state and plasma physics. Spectacular effects have their origin in the long-range dipole-dipole interactions between cold Rydberg atoms. In the presence of an electric field or at a Förster resonance, the Rydberg excitation can be limited. Electric-field induced dipole blockade allows us to limit the excitation of p levels (principal quantum number n=80) up to 80 % in a volume of typical dimension of 0.1 mm. The Förster resonance configuration, for which Rydberg atoms exchange resonantly internal energy, is observed for n below 42 and leads to 30 % efficiency in dipole blockade [T. Vogt *et al.*, Phys. Rev. Lett. 97, 083003 (2006)]. Both experiments have permitted us to analyze the role of saturation and the role of the presence of one or a few spurious ions. The application of the dipole blockade effect in the realization of scalable quantum gates will be discussed. In a dense ensemble, cold Penning collisions between Rydberg atoms can be at the origin of an ionic space charge, important enough to then trap the electrons leading to the evolution towards an ultracold plasma formed in a ionization avalanche process. We demonstrate the possibility to control the mutual dipolar force between Rydberg atoms.