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Physics of high field magnetic white dwarf stars – relevance to silicon quantum information applications?[1]

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Shallow donor impurities in silicon, once frozen out at low temperature, share many properties in common with free hydrogen atoms [1]. They have long been the subject of spectroscopic investigation, but it is only very recently [2,3] that it has been possible to investigate the time-domain dynamics of orbital excitations such as the 1s to 2p, due to the difficulty of obtaining short, intense pulses in the relevant wavelength range. These new techniques make shallow donors, and also acceptors [4], attractive for studying atomic physics effects, and for applications in quantum information. We have measured the population dynamics [2] of electrons orbiting around phosphorus impurities in commercially-available silicon, and shown that the lattice relaxation lifetime is about 200ps, only 1 order of magnitude shorter than the radiative lifetime of free hydrogen. Recently we also showed that high magnetic fields can introduce enormous changes in the electron wavefunction [1], and that easily available fields could be used for spatial control of the Rydberg orbital, and hence the overlap with adjacent atoms. A spin off benefit of the analogy with free hydrogen, is that we can use the results to better understand the spectroscopy of free hydrogen atoms on the surface of white dwarf stars where the magnetic field can be as high as one gigagauss.

[1] BN Murdin et al Nature Communications 4, 1469 (2013);
[2] NQ Vinh, et al, Proc Nat Acad Sci USA 105, 10649 (2008);
[3] PT Greenland, et al Nature 465, 1057 (2010);
[4] NQ Vinh, et al Phys Rev X 3, 011019 (2013).

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