Charge coherence and Fermi-edge singularity in dopant-based devices in silicon

B. Voisin[1], B. Roche[1], E. Dupont-Ferrier[1], X. Jehl[1], R. Wacquez[2], M. Vinet[2], S. De Franceschi[1] and M. Sanquer [1]

[1] *SPSMS, UMR-E CEA / UJF-Grenoble 1, INAC, 17 rue des Martyrs, 38054 Grenoble, France*

[2] *CEA, LETI, MINATEC Campus, 17 rue des Martyrs, 38054 Grenoble, France*

Single donors in silicon are attracting much attention in view of their potential use as qubits for quantum computing [1]. Their deep and sharp confinement potential induces a large valley-orbit splitting [2], which results in a single, spin-degenerate ground-state level well separated from all the other orbital levels. This is a favourable property to realize either single-donor spin qubits or two-donor charge qubits. Yet interactions with nearby fluctuating charges can be an important source of orbital dephasing. We have measured a charge coherence time T_2 of 0.3 ± 0.1 ns using Landau-Zener-Stückelberg interferometry in the first double-donor transistor in silicon [2, 3]. Through charge pumping experiments [4] we have studied the impact of the coupling to the source and drain leads on the dynamics of double-donor systems. In such doped devices, these donors strongly couple to ionized donors (charge fluctuators) located at the edges of the reservoirs. Short-range Coulomb interactions between these fluctuating charges and the electrons in the reservoirs can lead to a phenomenon known as Fermi edge singularity (FES) [5]. This effect can limit the orbital coherence of coupled donors [6].

To further explore the role of these fluctuating charges, we have measured resonant tunneling transport through donors implanted in a very short silicon nanowire. Experimental studies of the FES have so far been reported only for resonant tunneling vertical devices in III-V heterostructures [7]. Here, using a lateral device geometry, we have taken advantage of local gate electrodes to tune the different energy levels with respect to each other. A current peak is observed when the donor level aligns with the Fermi energy of the reservoir, followed by a power-law decrease of the current, which is in qualitative agreement with the theory of FES [5].

Acknowledgements: The authors thank H. Baranger, M. Houzet and J. Meyer for very fruitful discussions. This work is supported by the French ANR under Project SIMPSSON n 2010-Blan-1015.

[1] F. Zwanenburg *et al.*, accepted for publication in Rev. Mod. Phys., arxiv:1206.5202

[2] B. Roche, E. Dupont-Ferrier, B. Voisin, M. Cobian, X. Jehl, R. Wacquez, M. Vinet, Y.-M. Niquet, and M. Sanquer Phys. Rev. Lett. **108**, 206812 (2012).

[3] E. Dupont-Ferrier, B. Roche, B. Voisin, X. Jehl, R. Wacquez, M. Vinet, M. Sanquer and S. De Franceschi, accepted for publication in Phys. Rev. Lett., arXiv:1207.1884v1.

[4] B. Roche, R.-P. Riwar, B. Voisin, E. Dupont-Ferrier, R. Wacquez, M. Vinet, M. Sanquer, J. Splettstoesser and X. Jehl, accepted for publication in Nature Communications, arXiv:1212.1142.

[5] K. A. Matveev and A. I. Larkin, Phys. Rev. B **46**, 15337 (1992).

[6] Igor V. Yurkevich, Jim Baldwin, Igor V. Lerner, and Boris L. Altshuler, Phys. Rev. B **81**, 121305 (2010).

[7] A.K. Geim, P.C. Main, N. La Scala, Jr., L. Eaves, T.J. Foster, P.H. Beton, J.W. Sakai, F.W. Sheard, and M. Henini, G. Hill and M. A. Pate , Phys. Rev. Lett. **72**, 2061-2064 (1994).