Cooper-Pair Splitting and Spectroscopy in Double Quantum Dot Devices with Superconducting Charge Injector

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An elegant idea for the creation of entangled electrons in a solid-state device is to split Cooper pairs, which are in a spin singlet state, by coupling a superconductor to two parallel quantum dots (QDs) in a Y-junction geometry [1]. Cooper pair splitting (CPS) was investigated recently in devices based on InAs nanowires [2,3] and carbon nanotubes (CNTs) [4,5] and identified by a positive correlation between the currents through the QDs. I will first discuss recent experiments that demonstrate high splitting efficiencies > 90%. A high CPS efficiency is a prerequisite for Bell state measurements, a clear way of proving that Cooper pairs can be extracted coherently and lead to spatially separated entangled electron pairs. Further requirements on entanglement measurements will be addressed in the talk as well. I will then continue to discuss new results in semiconducting nanowires with Nb contacts that display a great variety of correlations. Using also Nb as the injector another distinct experiment with CNT devices will be discussed. In the regime of a strong tunnel coupling between the QDs and superconducting contact, the CPS efficiency is expected to be small [5]. However, the superconducting proximity effect can support so-called Andreev bound states (ABS) on a QD, which can be detected by conventional transport spectroscopy [6]. Here we use a Niobium contacted CNT Cooper pair splitter and investigate the response of the ABS formed on one QD to CPS. We find an appreciable non-local conductance when the bias is large enough to excite charge fluctuations in the ABS. These non-local signals change sign with opposite bias and, more intriguingly, when the ABS ground state changes from a spin singlet to a doublet. Our experiments can be understood qualitatively in an intuitive picture for ABS and CPS and show that CPS can be used as a tool to investigate complex hybrid nanoelectronic structures.

This is a collaborative effort with the groups of Szabolcs Csonka, Budapst University of Technology and Economy, Jesper Nygard, Nano-Science Center, Niels Bohr Institute of the University of Copenhagen, and Jan Martinek- IFM-PAN, Poznan, Polen. I acknowledge funding from the Swiss NFS, SNI , NCCR-QSIT, FP7-SE2ND and ERC-QUEST.

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