INSD NanoScience Seminar (No.19)

Date and Time: **Thursday, August 4th, 2016, 16:20-17:50**

Place: **Room 305 INSD Seminar Room, Interdisciplinary Research Building 3rd floor, Toyonaka Campus**

Title:

Giant vortex states and proximity Josephson vortex in confined superconductors

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When put in rotation, macroscopic quantum condensates develop a very peculiar collective response: Instead of rotating as a whole, they split in a huge number of small quantum tornados - vortices – that organize in a regular lattice. The vortex currents circulate owing to the gradient of the condensate wave function Ψ(r) that accumulates exactly 2π phase difference around each vortex core -the eye of the cyclone - where Ψ(r) vanishes. This general quantum phenomenon as observed in superconductors, superfluids, Bose-Einstein condensates of ultra-cold atoms. The confinement of quantum condensates to the scales comparable to their characteristic coherence length should modify the vortex lattice, leading to novel configurations. Despite of 45 years of theoretical efforts, till recently there have not been relevant experiments on this topic. In our lecture we discuss the results of recent Scanning Tunneling Spectroscopy studies of confined superconductors [1,2], which allowed for direct visualizing the vortex phases strongly confined in individual superconducting nano-crystals of Pb. Starting from the simplest case of a single vortex confined in a superconducting box [1], we will show how the confinement influences the vortex lattice leading to novel ultra-dense vortex clusters, impossible in bulk superconductors. At even higher confinement the Giant Vortices - quantum tornados characterized by a multiple phase accumulation L x 2π, L = 2; 3; 4 - are revealed for the first time [2]; their unusual cores will be discussed.

In a second part we will show some results of a new kind of vortex in normal metals: proximity Josephson vortices. Superconducting correlations may propagate between two superconductors separated by a metallic barrier, allowing a dissipationless electric current to flow. In the presence of a magnetic field, the maximum supercurrent oscillates and each oscillation is interpreted as the entry of one Josephson vortex into the junction. Using scanning tunneling microscopy we succeeded to map proximity vortices inside proximity Josephson junctions. We found that, contrary to the common belief, these vortices are quite similar to Abrikosov vortices: they present a normal core surrounded by a proximity gap. By following the Josephson vortex formation and evolution we demonstrate that they originate from quantum interference, and that the phase portraits of the two superconducting quantum condensates at edges of the junction decide their generation, shape, spatial extent and arrangement. Our observation opens a pathway towards the generation and control of Josephson vortices by applying supercurrents through the superconducting leads of the junctions, that is, by purely electrical means without any need for a magnetic field, which is a crucial step towards high-density on-chip integration of superconducting quantum devices.

[1] Cren, T., Fokin, D., Debontridder, F., Dubost, V. & Roditchev, D. Ultimate vortex confinement studied by scanning tunneling spectroscopy. Phys. Rev. Lett. 102, 127005 (2009).
[2] Cren, T., Serrier-Garcia L., D., Debontridder, Roditchev, D. Vortex fusion and Giant Vortex states in confined superconducting quantum condensates. Phys.Rev. Lett. 107, 097202 (2011).
[3] D. Roditchev, C. Brun, L. Serrier-Garcia, J. C. Cuevas, V. H. Loiola Bessa, M. V. Milošević, F. Debontridder, V. Stolyarov & T. Cren, Direct observation of Josephson vortex cores, Nature Physics11, 332–337 (2015)

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