VORTEX VI: Scientific Highlights

January 22, 2009 (HE39). We received a report on scientific highlights of the VORTEX VI Conference held at Rhodes Island, Greece, in September 2009. We reproduce that report below.

Report on Scientific Highlights
of the Sixth International Conference in School Format (VORTEX VI)
Rhodes, Greece (17-24/09/2009)

presented to the

European Science Foundation (ESF)
Standing Committee for PHYSICAL AND Engineering Sciences (PESC)

within the framework of the programme

Nanosciences and Engineering in Superconductivity – NES
http://www.kuleuven.be/inpac/nes
(2007-2012)

In May 2007 the European Science Foundation has launched a new Research Networking Programme "Nanoscience and Engineering in Superconductivity (NES)" for 2007-2012. Together with the JSPS-NES Programme, and the research carried on in this field by the teams from the US, this created a unique coordinated global research effort in the area of "Nanoscience and Engineering in Superconductivity". To support this truly global activity, a series of Conferences has been organized, including the previous VORTEX IV Conference (September 3-9, 2005, Crete, EU), the MesoSuperMag (August 28-September 1, 2006, Chicago, USA) and the previous VORTEX V Conference (September 8-14, 2007, Rhodes, EU). The VORTEX VI conference continued in this series and was supported by the ESF - NES Programme.

The main focus of the VORTEX VI Conference was on the fundamentals of the vortex confinement phenomena in superconductors with nano-engineered pinning arrays and superconductivity at nanoscale, as well as on the novel vortex phases and dynamics in low dimensional superconductors. Besides the above mentioned traditional VORTEX topics, we are expanding our efforts to study vortex matter in magnetic ferromagnet/superconductor hybrids and nanoscale high-T_c superconductor Josephson junctions, as well as in superfluid helium and Bose–Einstein Condensates. This time we expanded the set of topics by adding the section Optical Vortices. We are sure that remarkable similarities in the behaviour of vortices in these different systems will considerably improve our understanding of vortex matter.

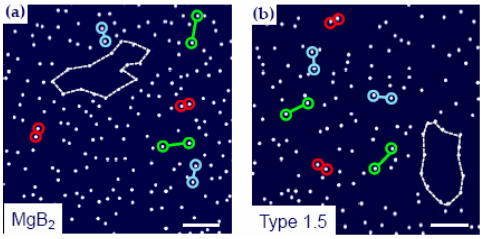
In total 128 participants, coming from 25 countries (AT, AU, BE, BR, CH, CZ, DE, DK, EE, ES, FI, FR, GB, IL, IT, JP, NL, NO, RS, RU, SE, SI, SK, UA, US) witnessed an interesting and dense scientific programme consisting out 71 talks and 57 poster presentations. The organizer (Prof. V.V. Moshchalkov) achieved through this and previous conferences a coherence in the vortex community, and enhanced scientific collaborations,

within Europe and further on a global scale. During the conference many new and fascinating highlights have been presented. Four such highlights are included here.

Scientific Highlights of VORTEX VI:

Type-1.5 Superconductivity and Vortex Matter in Nanostructured Superconductors

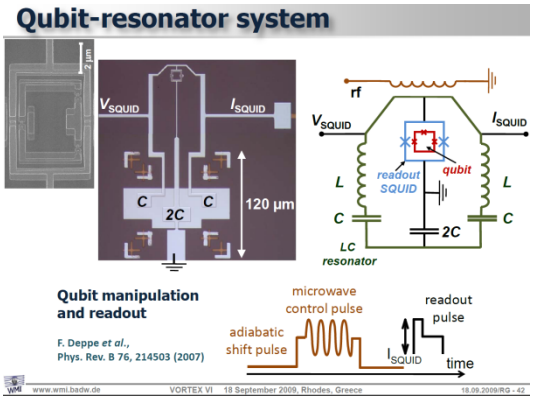
V.V. Moshchalkov et al.



The existence of the novel superconducting state was demonstrated in high quality MgB_2 single crystalline superconductors with two-component order parameter. Here a unique combination of both type-1 and type-2 conditions is realized in a single material: $\lambda_1/\xi_1<1/\sqrt{2}$ for the first component of the order parameter and $\lambda_2/\xi_2>1/\sqrt{2}$ for the second one. Such materials are, in fact, type-1.5 superconductors (PRL 102, 117001, 2009), since they combine simultaneously both type-1 and type-2 superconductivity. In the figure above, (a) and (b) represent the experimental and theoretical picture of a vortex arrangement, respectively. Typical for Type 1.5 superconductors are the molecule-like and line-like geometrical arrangements of the vortices (the latter shown as white dots).

Superconducting Quantum Circuits

R. Gross et al.



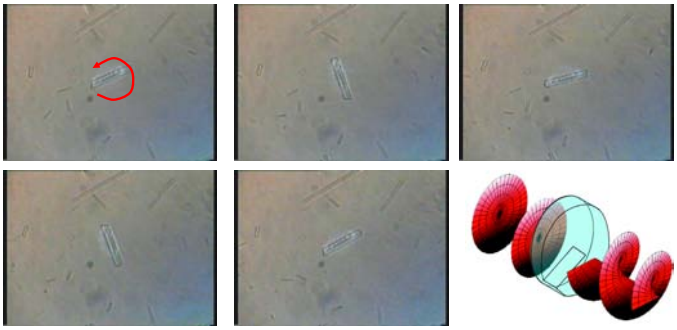
Superconducting circuits with lateral dimensions between 100 nm and a few µm behave in many aspects similar to natural atoms. Despite the fact that these so-called artificial atoms are huge compared to their natural counterparts, they have a discrete level structure and exhibit properties unique to the world of quantum mechanics. In the simplest case, these artificial atoms form quantum two-level systems, also called quantum bits or qubits. They allow for the investigation of fundamental quantum phenomena on a macroscopic scale and the implementation of solid state quantum information systems. A big advantage of these artificial solid-state qubits over natural atoms is their design flexibility and wide tunability by means of external parameters such as electric or magnetic fields. Prof. Gross discussed in a

facinating lecture the realization of superconducting flux qubits and quantum circuits and their quantum coherent dynamics, showing the way into the future of quantum computing.

Vortex Beams and Angular Momentum of Light

Halina Rubinsztein-Dunlop

Light beams with phase singularities exhibit two related features: helical wavefront structures, and persistent dark spots, and applications potentially flow from each of these. The dark spots find application in imaging and atom trapping, while the helical structures can carry information as classical bits or quantum qubits. The helical structures also carry optical angular momentum that can be used for manipulation of microscopic objects. Beams of light with phase singularities can be generated directly by lasers, or produced using phase plates or holograms. Forms of tomography have been developed to detect and classify the singularities in a beam. Recently, the availability of spatial light modulators has allowed such applications to become more dynamic. Optical tweezers can trap and move materials noninvasively at length scales ranging from tens of nanometers to tens of micrometers, and so have provided unprecedented access to physical, chemical and biological processes on a microscale. Since a light beam can carry angular momentum (AM) it is possible to use optical tweezers to exert torques to twist or rotate microscopic objects (see the figure, courtesy of Miles Padgett). Spin angular momentum depends on the degree of circular polarisation of the light, and orbital angular momentum depends on the spatial structure of the beam. If either the spin or orbital angular momentum is altered when the trapping beam is scattered by the particle in the trap, an optical torque will result. These optical rotators provide fine orientation control and using these techniques mechanical properties of cells can be usefully studied.



Understanding of the Mechanism of Emission of THz Electromagnetic Radiation in a Mesa of intrinsic Josephson Junction System $B_2Sr_2CaCu_2O_{8+\delta}$

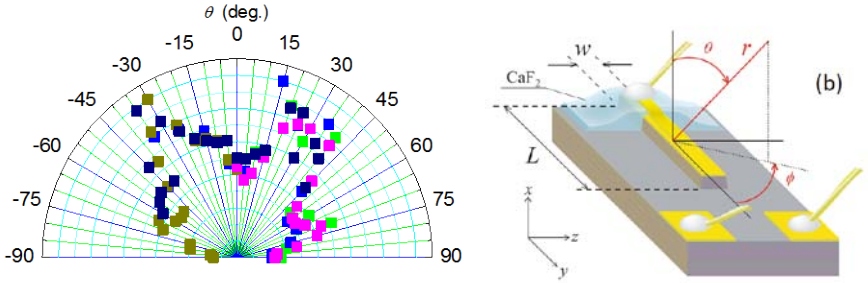
Kazuo Kadowaki et al.

Recently, it was discovered that intense, coherent and continuous electromagnetic radiation at THz frequencies can be generated by dc current driven in a mesa of the intrinsic Josephson junction system of $Bi_2Sr_2CaCu_2O_{8+\delta}$, which is comprised of alternating superconducting CuO_2 double layers and insulating Bi_2O_2 layers. Based on our recent experimental results, the current understanding of the radiation mechanism is attributed to the simultaneous action of the ac Josephson effect and resonant cavity effect. The detailed analyses of the modes of electromagnetic standing wave have been done by comparing the experimental results such as the directivity, higher harmonics and polarization measurements with a model calculation based on the antenna theory under the condition of the strong ac Josephson current in the mesa. Taking a simple synchronization model of all intrinsic Josephson junctions in that mesa having the same phase of the ac Josephson current, a unifom electromagnetic mode with half wavelength resonance in a mesa working as a cavity fits very well as a fundamental mode.

We also show new phenomena associated with the crosstalk effect of few separate mesas which may be useful for the superconducting Q-bits operation. Surprizing is that the direction under which the radiation is emitted by the mesa structure is not maximal at $\theta = 0°$ as can be seen in the figure below.

Author's paper on the angular dependence of the far-field THz emission from mesas of single-crystal $Bi_2Sr_2CaCu_2O_8$ just appeared online [1].

[1] K. Kadowaki *et al*., *J. Phys. Soc. Jpn. Letters*, **79** No. 2 (Feb. issue), p. 023703 (2010).



(End of Report)

To the report above ESNF likes to add that the next NES meeting will be the International Workshop on "Superconductivity in Reduced Dimensions" to be held in Salzburg, Austria, from May 4th to 8th, 2010. Preliminary information on this workshop is already available at http://www.univie.ac.at/supraleitung/NES2010/. As in the case of other NES meetings, the number of participants will be limited, but anyone interested can submit an abstract for evaluation by the organizers.