# JSPS Core-to-Core Program
# FY2007 Implementation Plan (Project No.: 15002)

**Research Theme** Nanoscience and Engineering in Superconductivity
**Duration of Project** April 1st, 2006 ～ March 31st, 2009 (36 months)
**Core Institution in Japan (Co-Chair)** University of Tsukuba
(Kazuo Kadowaki)

## Implementing Organizations

○ **Japan**

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| Japan | Core Institution | University of Tsukuba | |
| | Co-Chair (name and title) | Professor Kazuo Kadowaki | |
| | Cooperating Institutions | Keio University, Tohoku University, University of Tokyo, Tokyo Institute of Technology, Hirosaki University, Utsunomiya University, National Institute for Materials Science, Japan Atomic Energy Agency, RIKEN, Hitachi Advanced Research Laboratory, NEC, Kyusyu University | Number of Cooperating Institutions: 12 |

○ **Partner Countries**

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| EU | Core Institution | Katholike Universiteit Leuven | |
| | Co-Chair (name and title) | Professor Victor Moshchalkov | |
| | Cooperating Institutions | University of Antwerp, CNRS-CRTBT, University of Bordeaux. Research Center Jülich, University of Tubingen, University of Erlangen-Nürunberg, Walther Meissner Institute, University of Naple, Leiden University, University of Twente, University of Madrid, Chalmers University of Technology, University de Geneve, ETH, University of Bath, University of Cambridge, Loughborough University, University College of London | Number of Cooperating Institutions: 18 |

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| USA | Core Institution | Argonne National Laboratory | |
| | Co-Chair (name and title) | Dr. Wai-Kwong Kwok | |
| | Cooperating Institutions | University of Notre Dame, Northern Illinois University, Texas A & M University, The University of Chicago, University of Illinois at Chicago, University of South Carolina, University of California at Davis, University of Chicago at Urbana-Champaign | Number of Cooperating Institutions<br>8 |

## Objectives of Research Exchange (including the five years after the project finishes)

Superconductivity is a most extraordinary phenomenon in nature, exhibiting absolute zero resistance and quantization of magnetic flux. By making use of fast growing nanotechnology development of new science and technology in superconductivity is rapidly progressing. A few typical examples in superconducting material development are applications for quantum computations and Josephson junction devices utilizing quantum coherence. By making sub-micron sized superconductors, which could not be done in the past, and by investigating the properties of the junctions, it is of great importance to establish the solid bases of new quantum mechanical science and applications for the 21st Century. This research initiative aims at setting up the international collaborations between most advanced research institutes in the world and establishing a world leading center in Japan in this fast developing research field in superconductivity.

## Results to the present

Nanotechnology in the field of superconductivity in our point of view is steadily progressing towards mainly two directions: one is to achieve quantum computations using macroscopic quantum tunneling phenomena and another is to explore electromagnetic waves in the terahertz region using high $T_c$ superconducting intrinsic Josephson junctions. Discovery of high cross over temperature $T^*$ above 1 K in high $T_c$ superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ by a member of this initiative has made a great step towards possible operation of quantum computer devices even above 1 K. A great effort has also been made to find materials with higher cross-over temperature $T^*$, which enable us to make such devices even higher than 4.2 K. As for THz radiation we have succeeded in observing a strong emission of THz radiation just recently from a mesa type of intrinsic Josephson junction of $Bi_2Sr_2CaCu_2O_{8+\delta}$. The spectral analysis of the observed THz emission is now under progress. There have been many remarkable developments in various kinds of fields such as vortex phase diagram in microscopic samples, especially with geometrical confinement. The layered structure is a typical example. All these achievements will bring us possible important applications in the future and will create new fields of research.

## Summary of FY 2007 Exchange Plan

**Joint Research**

Just recently, the group of University of Tsukuba in collaboration with the Argonne group in the USA a direct detection of terahertz electromagnetic waves has successfully been made. This result originates from the detailed study of the relation between Josephson plasma phenomena and Fiske steps in the group of University of Tsukuba in the past for a long time. In this year we will continue to do researches and concentrate on this subject, since the direct observation is very important. In NIMS, the Hatano group is developing arrays of Josephson junctions in order to improve efficiency of electromagnetic radiation in micron sized samples in collaboration with the University of Tsukuba group and etc. Furthermore, the other groups such as the Kleiner group at the University of Tübingen and the Ustinov group at the University of Nürnberg-Erlangen have been active very much in studying similar phenomena from their point of view.

Efforts on the observation of the giant vortex in a mesoscopic sample fabricated down to a submicron level will be done by micro-hall probe measurement directly using not only circular disks but also triangular and square samples. Comparison will be made with the result of theoretical calculations.

Recently, study on the macroscopic tunneling phenomena in single crystalline $Bi_2Sr_2CaCu_2O_{8+\delta}$ has been developing very quickly from a point of view of quantum effect on many layered systems. The cross-over temperature $T^*$ below which the quantum mechanical tunneling is dominant was found to be increased up to 1 K in high $T_c$ superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$. Making use of this macroscopic quantum tunneling phenomenon, quantum computational devices can be made. This subject is in progress in collaboration with the group of Warburton at the University College London, with the group of Yurgens at Chalmers University of Technology in Sweeden, and etc.

As to sub-micron sized sample fabrication using world-top level of nanotechnologies, intimate collaboration is in progress with aid of the group of Moshchalkov for the observation of giant vortex, with the group of Müller, with the group of Kleiner, Pedersen and etc. by exchanging Ph. D. students as well as young researchers.

**Seminar**

There will be two major conferences in this year. ①Frontiers of Josephson Physics and Nanoscience (FJPN07) at Palinuro, Italy (from 23rd ～28th, September, 2007) and ②Joint JSPS and ESF Conference on Vortex Matter and Nanostructured Superconductors (VORTEX V) at Rhodes Islands, Greece (from 8th ～14th, September, 2007). The latter is a series of conferences held jointly by the Japanese, European and American three major axes for the activity in nano-science and engineering in superconductivity. Additional small topical (informal) meetings will be organized depending on the development of researches.

**Researcher Exchanges**

Since a few conferences were planned this year, exchange of people, especially young researchers and Ph.D. students are strongly emphasized.