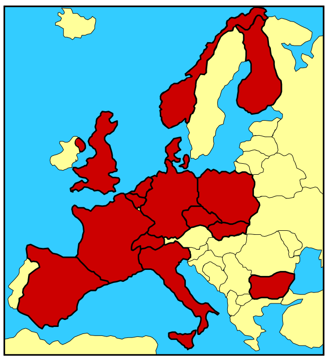
Programme title:

NANOSCIENCE AND ENGINEERING IN SUPERCONDUCTIVITY

Programme acronym: **"NES"**
Acronym of the Standing Committee: **PESC**

Principal proponent[1]

Prof. Victor V. Moshchalkov
INPAC – Institute for Nanoscale Physics and Chemistry
Katholieke Universiteit Leuven
Celestijnenlaan 200 D, B-3001 Leuven, Belgium
Tf: (+32)-(0)16 32 7618, Fax: (+32)-(0)16 32 7983, E-mail address:
Victor.Moshchalkov@fys.kuleuven.be



This proposal is presented by *68 leading teams*, in the area of nanoscience and engineering in superconductivity, coming from *15 European countries* and contains a pronounced international ESF-JSPS-NSF dimension.

Keywords: superconductivity, quantum size effects, nanostructured materials, superconducting elements for quantum computing.

Abstract

Confined condensate and flux in superconductors will be investigated at nanoscale by using various confinement patterns introduced artificially in the form of individual nanoplaquettes, their clusters and huge arrays. The dependence of the quantization effects on the confinement length scale and the geometry will be studied. The boundary conditions, defining the confinement potential, will be tuned by using the hybrid superconductor/normal and superconductor/magnet interfaces in superconducting nanosystems. The evolution of superconductivity at nanoscale will be revealed by determining the size dependence of the superconducting critical temperature and the gap in mass selected clusters and nanograins and also by studying superfluidity in different restricted geometries. Flux confinement by magnetic dipoles and other periodic pinning arrays in superconductors will be investigated. By tailoring the confinement, physical properties of the confined condensates and flux can be designed starting from the fundamental Ginzburg-Landau equations (including their generalization to two component order parameter) and applying them to the real samples with the boundary conditions imposed at the physical sample's boundary. This research will reveal the fundamental relations between quantized confined states and the physical properties of the superconducting quantum coherent systems, which will be also of importance for other scientific fields (superconducting elements for quantum computing, nanoelectronics, hydrodynamics, liquid crystals, plasmas).

Previous applications to the ESF: ESF-Programme "Vortex Matter in Superconductors at Extreme Scales and Conditions" ("VORTEX"), 1999-2003.

[1] Contact Person

1. Status of the relevant research, scientific context, objectives and envisaged achievements

Status of the relevant research. Superconductivity is a remarkable quantum phenomenon, which is characterized by the coherence of the charged condensate over a macroscopic length scale. Due to that a single wave function, called also the order parameter, can be used to describe this quantum state of the matter composed of large ensembles of Cooper pairs. The essential quantum equations defining the behaviour of these condensates are Nobel Prize winning Ginsburg-Landau (GL) equations. The boundary conditions for them, strongly influencing their solutions, must be imposed at the physical sample boundaries, thus implying that the properties of confined condensates can be tuned and tailored by applying pre-designed specific confinement configurations. This creates a unique possibility for a "quantum design" of the requested physical properties of the confined condensates through the application of specially defined boundary conditions. ***The latter affects and controls the solutions of the fundamental differential GL equations and can eventually lead to the practical implementation of the confined condensates possessing the combination of some specific properties needed, for example, for the applications in fluxonics and quantum computing.*** Confinement plays an essential role not only for condensates themselves but also for the flux applied to them. For charged Cooper pairs in superconductors it is the magnetic flux, which is quantized in units of the flux quantum, while for neutral bosons in superfluids the role of the magnetic field is taken by the circulation which is also quantized.

Since the characteristic length scale of quantum condensates, the coherence length, lies in the range of 0.1-100 nm, the efficient control of the confinement can be only achieved by using *nanoscale* confinement. Recent impressive progress in nanofabrication has provided necessary instruments and tools needed for the practical realization of a variety of the nanoscale confinement patterns. Nowadays individual nanoplaquettes, their clusters and huge arrays can be designed and fabricated by using advanced e-beam lithography, electro-chemical self-organized processing and other modern techniques. The boundary conditions themselves can be tuned by taking *hybrid* superconductor (S)-normal metal (N) or superconductor-magnet (M) systems.

Therefore, current situation in the field of nanoscale superconductivity is such that through the optimization of the confinement we can design templates, needed for specific nano-modulated boundary conditions, not only theoretically, but can also provide their practical realization by making nano-modulated samples and investigating them experimentally.

For nano-superconductors, important knowledge and expertise have been accumulated in the field of quantization and confinement phenomena in different nanostructured superconductors and in individual nano-cells. *The physics of superconducting condensates at nanoscale will benefit enormously from the synergy and complementarities of different fields to be studied in the framework of a single ESF Programme.*

Strongly motivated by the success and the impact of the ESF programmes, JPSP has launched recently a 3 year Core-to-core programme "Nanoscience and Engineering in Superconductivity", where already now leading European teams are participating. In the USA similar research efforts have been supported via the Argonne National Laboratory *(Nobel Laureate A.A. Abrikosov, G. Crabtree and W. Kwok)* ***and NSF****. To keep the European leadership in this strategically important field the new ESF programme "Nanoscience and Engineering in Superconductivity" is needed to run together with the JSPS NES Programme.* ***This will create a unique coordinated global research effort (ESF, JSPS, NSF) in the area of "Nanoscience and Engineering in Superconductivity"****.*

Scientific context. The nanoscale confinement phenomena have recently shifted into the focus of modern condensed matter physics, and a very intense research on confined condensates has already started across the world. This brings us to ***<u>the main objective of the proposed programme</u>: to investigate the effect of the nanoscale confinement of condensate and flux on superconductivity in order to reveal its nanoscale evolution and to determine the fundamental relations between quantized confined states and the physical properties of these systems, enabling "quantum design" of their properties.*** Along the line of the main objective, the proposed research will be focused on the following topics:

-Evolution of superconductivity at nanoscale, superfluidity in restricted geometries (Task 1). The correlation between the nanograin size and the superconducting gap and the critical temperature T_c will be investigated theoretically and experimentally. *We will systematically reduce the characteristic size of superconducting grains and clusters in order to reveal the crossover between the bulk superconducting regime and fluctuation-dominated superconductivity regime.* For comparison, superfluidity in nanopores will also be studied as a function of the size of the nanopores.

-Superconductivity in hybrid superconducting – normal (SN) and superconducting – magnet (SM) nanosystems with tuneable boundary condition (Task 2). Confined condensate will be studied in superconducting nano-islands surrounded by normal metallic or magnetic material. The role of proximity effects and the Andreev reflection in modifying the transparency of the sample boundaries will be revealed. The variation of the superfluid density near the boundary will be mapped by using the local scanning tunnelling spectroscopy (STS) techniques. Different vortex configurations, including those with symmetry induced antivortices, and their dynamics will be investigated in individual nanostructures of different geometries. *Here we expect to find strong effect of the specific boundary conditions on confined flux and condensate.*

-Confined flux in nanostructured superconductors and hybrid SN and SM nanosystems (Task 3). Three different types of nanostructured superconductors will be investigated: individual nanoplaquettes of different topology, their clusters and huge arrays. By using local probe techniques, such as STM and scanning Hall-probe microscope, the distributions of the order parameter density and local magnetic fields will be mapped simultaneously and then compared with the calculations of these parameters based on the solution of the GL equations with the realistic boundary conditions imposed though nanostructuring. Hybrid SN and SM arrays will be also studied. Magnetic dots will be used to generate local vortex-antivortex dipole loops, which will be strongly interacting with the flux lines in superconductors, creating a tunable magnetic periodic confinement. Different novel flux phases, including stable vortex-antivortex patterns, will be studied. *Here we can anticipate a very interesting interplay between flux generated by an applied field and magnetic dipoles, which can substantially enhance flux pinning. Magnetic domains will be used to achieve vortex manipulation.*

Using the recent progress in nanoengineered pinning arrays in superconductors, similar structures can be made to confine flux in rotating superfluids. Keeping in mind that the coherence length for the ^{3}He superfluids is much longer than for ^{4}He, it seems to be much easier to fabricate periodic pinning arrays for ^{3}He. Instead of antidots used in superconductors, an adequate choice here is the periodic array of nanopillars. *Here we expect to find out novel flux phases, which are otherwise not stable in a reference superfluid without a periodic pinning array.*

-Josephson effects and tunneling in weakly coupled condensates (Task 4). We shall investigate a variety of Josephson phenomena and phase shifting effects in coupled superconducting condensates, where nanoscale coupling can be provided through an insulating, metallic or magnetic layer. Hybrid structures are essential here in order to tune the coupling strength. These phenomena will be compared with Josephson effects in coupled superfluids, mostly based on ^{3}He.

- Fundamentals of fluxonics, superconducting devices (Task 5). We will study the devices that control the motion of flux quanta in superconductors and could address a central problem in many superconducting devices; namely, the removal of trapped magnetic flux that produces noise. The controllable vortex motion will be used in nanostructured superconductors for making pumps, diodes and lenses of quantized magnetic flux. Vortex ratchets effects will be studied and then used to achieve vortex manipulation.

One of the important aspects of this work is to investigate ***superconducting nanostructured materials for which the confinement of the condensate inside the samples can be controlled by imposing the proper boundary conditions for the order parameter at the nanofabricated boundaries***. Remarkably, the order parameter, the analogue of the wave function for normal quantum mechanical systems, obeys the Ginzburg-Landau equations, which play a role similar to that of the Schrödinger equation. ***This gives a theoretical background for proving the feasibility of the fundamentals of the quantum design and nanoengineering of the superconducting critical parameters. The concept of quantum design is now the backbone for developing new elements and systems for microelectronics and information technology (quantum computing, SQUIDS with improved sensitivity, sensors, etc).***

Summarizing the proposed tasks in NES on nanostructured superconductors, we can say that the core of the proposal will be focused on the development of the fundamental principles of the "quantum design" of two important superconducting critical parameters - critical currents and critical fields - through the optimization of the flux and condensate confinement. The nanoscale evolution of superconductivity will be investigated. In individual nanostructures topology- and geometry-dependent critical fields, as well as to the symmetry induced antivortices will be investigated. In nanostructured superconductors a rich variety of novel flux phases and patterns will be studied in order to master vortex behaviour and develop fundamentals of fluxonics. Superconducting elements for quantum computing will be designed and investigated.

Objectives and envisaged achievements

Fundamental research:

<u>In task 1</u>: **Evolution of superconductivity at nanoscale, superfluidity in restricted geometries.**
(i) Preparation of well controlled confined superconducting nanograins via cluster-source, ion implantation, self ordered processes and nano-patterning, *(ii)* establishing the relation between the number of atoms (N_{at}) in clusters and the occurrence of superconductivity, $T_c(N_{at})$, *(iii)* the effect of confinement on the superconducting gap Δ*(size), (iv)* the effect of the geometrical confinement shape on the condensate and magnetic flux.

<u>In task 2</u>: **Superconductivity in hybrid SN and SM nanosystems with tunable boundary condition**
(i) Production of periodic arrays of superconducting islands down to 30 nm size in hybrid nanosystems , *(ii)* Effects of proximity coupling between superconducting islands *(iii)* Effects of Andreev reflection on condensate confinement in hybrid SN and SM nanosystems.

In task 3: **Confined flux in nanostructured superconductors and hybrid SN and SM nanosystems**
(i) Preparation of well characterized periodic pinning arrays which cover the size range of the pinning centers from submicron to nanometer dimensions, *(ii)* Enhancement of the critical current density and critical fields through nanostructuring, *(iii)* Enhancing superconducting critical parameters with magnetic templates (arrays of magnetic dots, fields generated by magnetic domains in ferromagnetic substrates), *(iv)* Observation of new field polarity sensitive effects, *(v)* Observation of periodic pinning effects in superfuid ^{3}He which is rotated in presence of arrays of nanopillars.

Research directed towards applications:

In task 4: **Josephson junctions and superconducting realizations of qubits**
(i) Realization of qubits based on superconducting rings with Josephson junctions, (ii) Josephson effects in superconducting/normal/superconducting (SNS) junctions, (iii) Observation of phase sensitive effects in superconductor/ferromagnet/superconductor (SFS) junctions, (iv) Controlled fabrication of s-wave/d-wave/s-wave superconducting junctions and grain boundary junctions, (v) Magnetic shifter for quantum computing.

In task 5: **Fundamentals of fluxonics, superconducting devices**
(i) Guided vortex motion achieved through nanostructuring, (ii) Removal and control of the trapped magnetic flux for noise reduction, (iii) Realization of vortex pumps, diodes and lenses.

2. Facilities and expertise which will be accessible within the ESF NES Programme

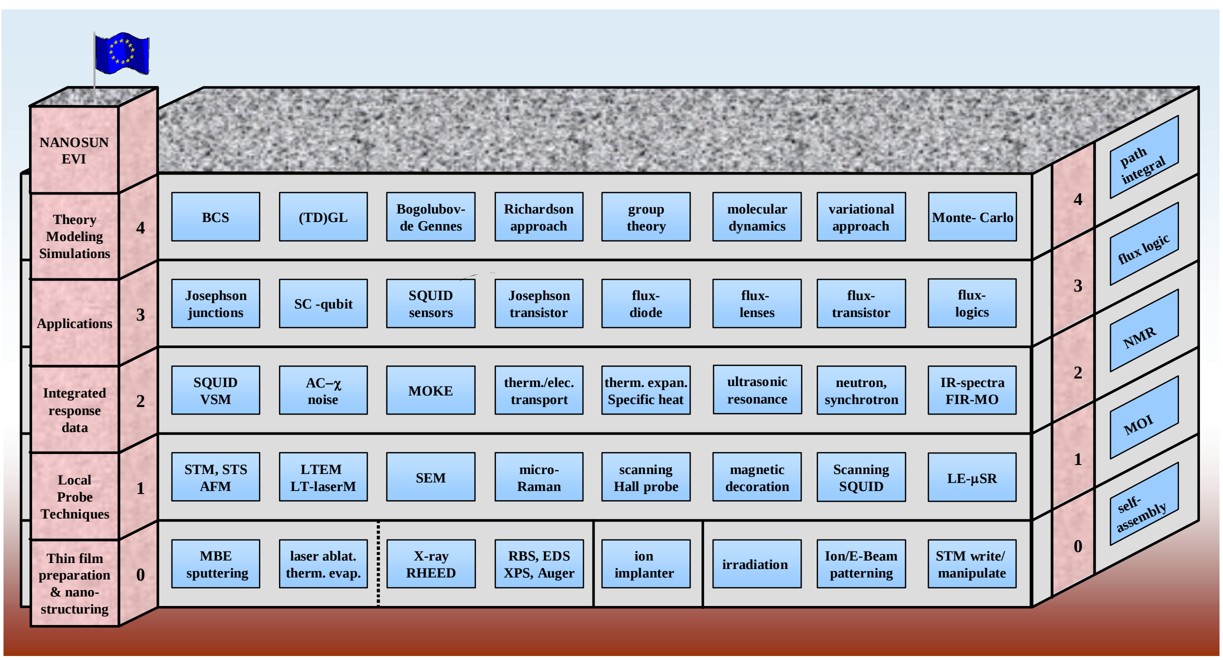


Fig. 1. Schematic illustration of the NES - Integrated Research Facilities

In order to carry out successfully the planned joint research, the ***integration of the research facilities*** of the NES- teams will be achieved at five different levels:

(i) ***Integration of modern sample preparation and nanostructuring techniques (****ground floor in fig. 1)*.
Molecular Beam Epitaxy –MBE, Sputtering, Thermal evaporation, Laser ablation, Clean Room, Reflection High Energy Electron Diffraction –RHEED, Auger spectroscopy, Infrared Spectra, X-ray Photoelectron Spectroscopy –XPS, Energy Dispersive X-Ray Spectroscopy –EDS, Rutherford Backscattering Spectrometry –RBS, E-beam lithography, Ion beam etching, Scanning Tunneling Microscopy –STM writing, Bottom-up methods of self assembly, X-ray diffraction, Ion Implanter, Irradiation.

(ii) ***Integration of local probing techniques enabling vortex visualization and condensate wave function mapping with a nanoscale resolution*** *(first floor in fig. 1)*.
local techniques are a key factor for achieving the scientific objectives, since these technologies provide an important microscopic information:
(Low Temperature) STM, (Low Temperature) Scanning Tunneling Spectroscopy –STS, Force Microscopy – FM, Low Temperature Laser Microscopy –LT laserM, Low Temperature Electron Microscopy –LTEM, Scanning Electron Micropscopy –SEM, Micro-Raman, Scanning Hall Probe or (array) Hall micro-magnetometry, Magnetic decoration, Scanning Superconducting Quantum Interference Device – Scanning SQUID, Magneto-Optical Imaging –MOI, Low energy muon spin rotation (LE-μSR), Transmission Electron Microscopy-TEM.

(iii)The next level of the shared research facilities is ***bulk integrated response***. *(second floor in fig. 1)*. The techniques needed for the experimental studies on nanostructured superconductors are:
SQUID, Vibrating Sample Magnetometry –VSM, Torque Magnetometry, AC-susceptibility, Noise measurements, MOKE, Thermal conductivity, Electrical transport measurements (including high frequency responses), Ultra Low Temperature Systems, Ultrasonic resonance, Specific heat, Neutron scattering, Synchrotron radiation, Far-infrared magnetooptics –FIR-MO, Nuclear Magnetic Resonance –NMR.

(iv) ***A test platform for the development of new applications***. *(third floor in fig. 1)*.
Josephson junctions technology, Ultra sensitive SQUID magnetometers, Superconducting SC – qubits, flux –logics -lenses -diodes –transistors.

(v) ***The theoretical methods and techniques*** will be integrated in order to interact continuously with the experimental NES-teams *(fourth floor in fig. 1)*.. The most important approaches describing the physics of individual nanostructured superconductors are:
Bardeen-Cooper and Schrieffer –BSC, (Time Dependent) Ginzburg-Landau -(TD)GL, Bogolubov-de-Gennes, Richardson's approach to the solution of the BCS Hamiltonian, Molecular dynamics simulations, Group theory and Topology, Monte Carlo simulations, bosonization, renormalization group calculations, Keldysh-formalisms, Sine-Gordon-Equation.

3. Expected benefit from European collaboration in this area

The participating teams will combine their expertise, manpower and available techniques to implement the objectives of this proposal. The European added value is clearly defined since the partners have various complementary unique experimental techniques for sample preparation and characterization, which will be jointly used to resolve the important issues formulated above. This value will be further enhanced by using complementary techniques available at our NES partners in Japan and the USA. Combining these techniques as well as the experimental and theoretical efforts of the European experts in the field of confined quantum condensates will have a pronounced impact upon the progress in this field, thus enhancing the leading role of the European science. ***The European teams will be able to exploit further on a very valuable accumulated joint expertise, thus conserving the important gained momentum. Moreover, joining forces with on-going JSPS core-to-core Programme will certainly create an important added value on a really global scale with a very strong European leading position***. The implementation of the main objectives of the project will create the basis for developing ***fundamentals of fluxonics***, where the manipulation of the confined quantized flux is a crucial issue. ***The understanding of the quantum coherent state and its evolution at nanoscale is an extremely important milestone for developing physical realizations of superconducting qubits and superconducting components needed for quantum computing.***

The advantage of the present NES is that most of the partners know each other very well and they have already established effective pan-European cooperation in the framework of the ESF VORTEX and Pi-shift programmes, which provided the leading position of the European scientists in the field of vortex matter in nanostructured superconductors. Furthermore, the accepted proposal (2004-2006) of the JSPS Core-to-Core programme "Nanoscience and Engineering in Superconductivity" shows a tremendous interest of many Japanese research institutes in these scientific research topics. By joining forces, ESF and JSPS, with support from the NSF, will create a unique global research programme, focussed on a strategically important scientific area.

4. **European context:**

Strong links between different participating research teams already exist due to the ESF Programmes VORTEX and Pi-shift and several previous HCM/TMR networks, INTAS projects, etc. The participating research teams from 15 countries have a recognized longstanding expertise in superconductivity, superfluidity and BEC. ***These teams have a wide variety of unique complementary techniques for the sample preparation and characterization, thus clearly creating an added value. The NES Programme will complement the existing networks and programmes focused on superconducting materials. The proposal, if approved, will further strengthen the European leadership in this important field, now on a really global scale.*** In fact, very spectacular discoveries in the field of the quantum condensates have been made in Europe: superconductivity (1911, H. Kamerlingh Onnes, the Netherlands), the Meissner effect (1933, W. Meissner and R. Ochsenfeld, Germany), the London equations (1935, F. and H. London, U.K.), He4 superfluidity (1938, P.L. Kapitza, Cambridge, U.K.), theory of superfluidity (1941, L.D. Landau, Russia), the vortex state in type-II superconductors (1957, A.A. Abrikosov, Russia), the magnetic decoration of the Abrikosov vortex lattice (1967, U. Essmann and H. Träuble, Germany), Josephson effect (1962, B.D. Josephson, U.K.), high-T_c superconductivity (1987, K.A. Müller and G. Bednorz, Switzerland), phenomenological theories of superconductivity and superfluidity (V.L. Ginzburg, L.D. Landau, L.P. Pitaevskii, Russia), etc. To keep this strong European leadership, the new coordinated research efforts are needed.

Relevant R&D networking activities at the European level directly related to the proposal: ***The ongoing JSPS global NES programme***, with a participation of leading European teams will strongly benefit from the proposed ESF – NES programme, since a possible prolongation of the JSPS-NES Programme will depend on the availability of the collaboration within a non-Japanese framework.

5. **Proposed activities, key targets and milestones**

The NES coordination and management will aim at the implementation of all objectives through efficient integration of research infrastructure and human resources of the participating teams. It will be carried out by the coordinator, and the Steering Committee. The latter consists of 16 members, including one representative per each participating country, coordinator and the Programme Secretary. The distribution of the ESF funds allocated to NES will be coupled to the performance, efficiency and integration regularly determined for all types of the NES activities. Dedicated website will be used by all groups to access and share information in the NES Programme.

Integration and efficient use of the NES experimental and theoretical techniques will be achieved through the following activities:

- implementation of coordinated joint scientific research
- sharing complimentary equipment of the participating teams
- joint applications for EU, ESF and other International projects
- joint supervision of the PhD work
- keeping intense electronic exchange of reprints, preprints, data bases, etc
- joint publication of original and review articles
- exchange of lecturers, researchers, samples, software, data bases
- creating and regularly up-dating dedicated NES website

NES consists of 66 leading groups in Nanoscience and Engineering in Superconductivity from 15 European countries. These groups have joined their forces to enhance their excellence and create a European added value through the ***integration of their expertise, research facilities and manpower and focusing their research on strategically important areas in nanoscience***. NES will function as a virtual (or distributed) European Institute, creating an added value in key interdisciplinary fields in Nanoscience and Engineering in Superconductivity and promoting its research level to the highest international standards, which will be reflected in a steady increase of measurable excellence indicators (publications in top 10 % International Journals, citation factors, invited talks, participation in other European projects, etc).

The ***general coordination*** will be carried out by coordinator, who implements the following tasks:

- administering funds, organizing and chairing the work of the Steering Committee
- monitoring the research efficiency and excellence
-representing NES in a global research networking Japan – EU – USA scheme in the field of Nanoscience and Engineering in Superconductivity
- representing NES to external bodies and organizing reporting to the ESF

The Steering Committee (SC) of the NES Programme consists of the representatives of the 15 participating countries. The SC meets at least once per year. ***The SC organizes and monitors:***

-NES Workshops (at least one focused Workshop per year) and Conferences (1st, 3rd and 5th year)
-Organization of several of these Workshops/Conferences in a School format thus giving a possibility to young researchers and PhD students to learn efficiently about the main trends and the latest achievements
-Organization of several Joint ESF-JSPS-USA events with the support from the JSPS and USA for the participation of the scientists from those countries in the NES ESF events
-Organization of short NES expert visits and distribution of the NES grants /fellowships for long term visits (up to 3 months)
- scientific research, research progress, mobility of researchers
- level of the NES Programme performance
- integration activities aimed at the most efficient use of the scientific equipment and the manpower
- inter-group exchange of researchers and joint PhD supervision
- decisions about the distribution of the funds
- enhancing and spreading NES publicity

- functioning of the NES website for electronic exchange of information, preprints, data, etc

For ***Programme publicity*** the following activities are planned:
- publication of the special VORTEX – ESF project Flyer
- creation and permanent maintenance of the dedicated Web page
(ESF, Dedicated website, web sites for all workshops and conferences which will be organized)
- invited lectures will be given by key- NES – scientists
- CDs with oral and poster presentations at NES Conferences and Workshops will be produced and circulated
- proceedings of the Conferences will be published as separate volumes explicitely mentioning the support from the ESF NES Programme

Scientific strategic actions will be undertaken to consolidate the scientists working on Nanoscience and Engineering in Superconductivity worldwide with the strong European leadership in this field. The interdisciplinary research in this area is emerging as a very promising new direction in the future. Taking into account the scale of the research, its importance for our society and a clear interdisciplinary character, the requested ESF support for this strategically important scientific field is truly indispensable.

6. **Duration:** 60 months

7. Budget estimate (in €) by type of activities and per year of the Programme.

Individual short scientific visits (8 visits @ about € 800 each)	€ 6.400
Three-month fellowships for young researchers @ € 1600/month	€ 19.200
Workshops	€ 18.000
Conferences / Schools	€ 50.000
Publications under the program	€ 3.000
Other expenses (Rent of multimedia equipment for conferences and workshops, administration and shipment cost of samples)	€ 3.000
Total budget per year	€ 99.600

ESF administrative fee (7.5%): € 7.470

Total annual budget all included € **107.070**

1. Full coordinates and curriculum vitae of the applicant(s). The list of the five most recent relevant publications.

Prof. Dr. V.V. Moshchalkov *(Belgium)*
INPAC – Institute for Nanoscale Physics and Chemistry
Katholieke Universiteit Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium
Phone: + 32 16 32 76 18, Fax: + 32 16 32 79 83, Email: victor.moshchalkov@fys.kuleuven.be

CURRICULUM VITAE

Born:	12 June, 1952, Tambov, Russia
Nationality:	Belgian

Honors
Laureate of the USSR State Prize for Young Researchers, 1986
Laureate of the USSR Ministry of High Education Scientific Prize, 1988
ISI Thomson Scientific Award "Top Cited Paper in Flanders", 2000
Laureate of the Belgian "De Leeuw-Damry-Bourlart" Prize for Exact Sciences, 2005

Education:

Ph.D in Physics	Lomonosov Moscow State University, 1978
"Habilitation"	Lomonosov Moscow State University, 1985

Positions:

1978-1988:	Research Physicist, Assistant Professor, Professor at Lomonosov Moscow State University
1988-1991:	Head of the Laboratory of High Temperature Superconductivity, Lomonosov MSU
1986-1991:	Visiting Professor at Toronto University (Canada); TH Darmstadt, Marburg University, RWTH Aachen, Germany
1990:	Visiting Scientist at Centre d'Etudes Nucléaires de Grenoble, France
1991-1993:	Visiting Professor at the Katholieke Universiteit Leuven, Belgium
1993-…	Professor of Physics at the K.U.Leuven, Leuven, Belgium
1999-2004:	Chairman of the European Science Foundation Programme "VORTEX"
2004-…	Co-chairman of the global Core-to-Core Programme "Nanoscience and Engineering in Superconductivity -NES" (Japan-EU-USA)

Research
Over 590 publications in international journals with referee system - more than 3300 SCI citations
Invited speaker at 80 international conferences
Member of an international advisory committee of 20 international conferences
Promoter of 36 PhD theses

5 MOST RELEVANT PUBLICATIONS (in the last 5 years)

- **Vortex rectification effects in films with periodic asymmetric pinning**
  J. Van de Vondel, C. C. de Souza Silva, B. Y. Zhu, M. Morelle, and V. V. Moshchalkov
  Phys. Rev. Lett. 94, 057003 (2005)
- **Domain-wall superconductivity in superconductor-ferromagnet hybrids**
  Z.R. Yang, M. Lange, A. Volodin, R. Szymczak, V.V. Moshchalkov
  Nature Materials, 3 (11): 793 (2004)
- **Magnetic phase shifter for superconducting qubit**
  D.S. Golubovic, W.V. Pogosov, M. Morelle, V.V. Moshchalkov
  Phys. Rev. Lett., 92, 177904 (2004)
- **Nanoengineered magnetic-field-induced superconductivity**
  M. Lange, M.J. Van Bael, Y. Bruynseraede, V.V. Moshchalkov
  Phys. Rev. Lett., 90, 197006 (2003)
- **Symmetry-induced antivortices in mesoscopic superconducting squares**
  L.F. Chibotaru, A. Ceulemans, V. Bruyndoncx, V.V. Moshchalkov
  Nature 408, 833 (2000)

2. Envisaged Steering Committee members

Prof. V.V. Moshchalkov *(Belgium)*
[Applicant]
INPAC – Institute for Nanoscale Physics and Chemistry, Katholieke Universiteit Leuven,
Celestijnenlaan 200 D
B-3001 Leuven, Belgium
Phone: + 32 16 32 76 18, Fax: + 32 16 32 79 83
Email: victor.moshchalkov@fys.kuleuven.ac.be

Prof. A. Barone *(Italy)*
University of Naples "Frederico II",
Department of Physical Sciences
Piazzale Tecchio 80,
I-80125 Naples, Italy
Phone: + 390 81 76 84 416, Fax: + 390 81 23 91 821
Email: barone@axpna1.na.infn.it

Prof. S. Bending *(UK)*
Department of Physics
University of Bath
Claverton Down
UK-BA2 7AY Bath
U.K.
Phone: + Fax: + 1225 826 110
E-mail: pyssb@bath.ac.uk

Prof. Ø. Fischer *(Switzerland)*
Département de Physique de la Matière Condensée,
Université de Genève
CH-1211 Genève, Switzerland
Phone: + 41 22 702 62 70 Fax: +41 22 702 68 69
Email: fischer@sc2a.unige.ch

Prof. A. Sudbo *(Norway)*
Norwegian University of Science and Technology
Department of physics
N-7034 Trondheim, Norway
Phone +47 73 59 34 03 Fax +47 73 59 36 28
E-mail asudbo@phys.unit.no

Prof. P.H. Kes *(The Netherlands)*
Kamerlingh Onnes Laboratorium
POB 9504
Niels Bohrweg 2
NL-2300 RA Leiden
The Netherlands
Phone: +31-71-527-5472 Fax: +31-71-527-5404
Email: kes@physics.leidenuniv.nl

Prof. J. Kolacek *(Czech Republic)*
Institute of Physics
ASCR
Cukrovarnicka 10
162 53 Prague 6
Czech Republic
E-mail: kolacek@fzu.cz

Prof. S. Lewandowski *(Poland)*
Instytut Fizyki PAN
Al. Lotnikow 32/46
PL-02-668 Warsaw, Poland
Phone: +48 22 843 73 86 Fax: +48 22 843 09 26
Email: lewan@ifpan.edu.pl

Prof. B. Pannetier *(France)*
CNRS-CRTBT, BP166
25 avenue des Martyrs
F-38042 Grenoble Cedex 9, France
Phone: + 33 476 88 11 51 Fax: + 33 476 87 50 60
Email: pannetie@labs.polycnrs-gre.fr

Prof. N.F. Pedersen *(Denmark)*
Department of Physics, Build 309,
Technical University of Denmark
DK-2800 Lyngby, Denmark
Phone: +45 45253297, Fax: + 45 45886111
Email: nfp@oersted.dtu.dk

Prof. M. Saarela *(Finland)*
Department of Physical Sciences
Division of Theoretical Physics
University of Oulu
P.O.Box 333
90571 Oulu, Finland
Phone: +358 8 553 1877 Fax: +358 8 553 1884
E-mail: mikko.saarela@oulu.fi

Prof. P. Samuely *(Slovakia)*
Institute of Experimental Physics
Slovak Academy of Sciences
Department of Low Temperature Physics
Park Angelinum 9
04154 Kosice, Slovakia
Phone: + 421 95 6228158 Fax: + 421 95 6228158
E-mail: samuely@saske.sk

Prof. S. Vieira *(Spain)*
Laboratorio de Bajas Temperaturas
Instituto Nicolas Cabrera
Universidad Autonoma de Madrid
E-28049 Madrid, Spain
Phone: + 34 1 39 74 735 Fax: + 34 1 39 73 961
Email: sebastian.vieira@uam.es

Prof. R. Wördenweber *(Germany)*
Forschungzentrum Jülich
D-52425 Jülich
Germany
Phone: +49 2461 61 2365, Fax: +49 2461 61 2940
Email: r.woerdenweber@FZ-juelich.de

Prof. S.S. Tinchev *(Bulgaria)*
Head of Laboratory "Physical Problems of Ion Technologies"
Institute of Electronics, Bulgarian Academy of Sciences,
Tzarigradsko Chaussee 72,
Sofia 1784, Bulgaria
Phone: +3592-7144-678 Fax: +3592-9753201
e-mail: stinchev@ie.bas.bg

Prof. J. Vanacken *(Belgium)*
[Scientific secretary]
Laboratorium voor Vaste-Stoffysica en Magnetisme,
K.U.Leuven
Celestijnenlaan 200 D, B-3001 Leuven, Belgium
Phone: + 32 16 32 71 98, Fax: + 32 16 32 79 83
Email: johan.vanacken@fys.kuleuven.ac.be

3. Programme Collaborations

Country Research Institutes	**Team members (professor or post-doctoral fellow, member of the Steering Committee)**
Belgium (.Be) [1] K.U.Leuven [2] IMEC – Leuven [3] Universiteit Antwerpen	**V.V. Moshchalkov[1], A. Silhanek[1], M. Van Bael[1], J. Vanacken[1], A. Ceulemans[1], L. Chibotaru[1], J.P. Celis[1], R. Jonckheere[2], W. Schoenmaker[2], W. Magnus[2], M. Van Rossum[2], J.T. Devreese[3] , F. Brosens[3], V.M. Fomin[3], V.R. Misko[3], V.N. Gladilin[3], J. Tempere[3], L. Lemmens[3], F. Peeters[3], S. Yampolskii[3], D. Vodolazov[3], B. Baelus[3]**
Czech Repulic (.Cz) Institute of Physics - Prague	**J. Kolacek, P. Lipavsky, P. Vasek, M. Jirsa, Z. Janu, Z. Simsa, R. Tesar, V. Zelezny, M. Marysko, M. Novak, L. Skrbek**
Denmark (.Dk) [1] Techn. Univ. of Denmark – Electro [2] Risoe National Laboratory [3] Techn. Univ. of Denmark - Physics	**N.F. Pedersen[1] N.H. Andersen[2], J. Mygind[3], J.L. Skov[3], J.B. Hansen[3], C.S. Jacobsen[3]**
Finland (.Fi) [1]University of Oulu [2]Helsinki University of Technology	**M. Saarela[1], E. Thuneberg[1], P. Pietiläinen[1], K. Alekseev[1], J. Viljas[2], M. Krusius[2], G. Volovik[2], R. Blaauwgeers[2]**
France (.Fr) [1] CRTBT – Grenoble [2] Universite Bordeaux I [3] Université Paris 12 [4] Ecole Polytechn.–Palaiseau [5] ISMRA – Caen [6] Universite de Nice [7] LEPES – Grenoble [8]Ecole Normale Superieure, Paris [9]CEA-Saclay [10]CEA-Grenoble	**B. Pannetier[1], O. Buisson[1], K. Hasselbach[1], P.Gandit[1], A. Buzdin[2], M. Daumens[2], J.-P. Ader[2], Ch. Meyers[2], I. Baladie[2], C. Deville-Cavellin[3], M. Laguës[3], X. Z. Xu[3], C.F. Beuran[3], M. Konczykowski[4], D. Robbes[5], A. Gilabert[6], Th. Klein[7], J. Dalibard[8], V. Bretin[8], P. Rosenbusch[8], C. Cohen-Tannoudji[8], O. Avenel[9], J.-C. Villegier[10]**
Germany (.De) 1 Forschungszentrum Jülich 2 MPI Stuttgart 3 Techn. Univ. Muenchen 4 University of Tuebingen 5 Univ. Erlangen-Nuernberg 6 University of Ulm 7 Universität Tübingen 8 Universität Hamburg 9 Universität Heidelberg 10 Universität Karlsruhe	**R. Wördenweber[1], P. Lahl[1], W. Hofer[1], E. Hollmann[1], E.H. Brandt[2], R. Gross[3], A. Marx3, Ch. Probst[3], L. Alff[3], D. Koelle[4], R. Kleiner[4], E. Goldobin[4], B. Chesca[4], M. Mößle[4], E. Sassier[4], P. Mueller[5], A.V. Ustinov[5], A. Wallraff[5], A. Lukashenko[5], D. Abraimov[5], Yu. Koval[5], V. Dremov[5], P. Ziemann[6], H.-G. Boyen[6], A. Plettl[6], J. Eisenmenger[6], C. Zimmermann[7], K. Sengstock[8], J. Schmiedmayer[9], G. Schön[10],**

Country Research Institutes	**Team members (professor or post-doctoral fellow, member of the Steering Committee)**
Italy (.It) [1] Univ.of Naples Federico II [2] Politecnico di Torino [3] Università di Roma [4] CNR-Ist. di Cibernetica, Pozzuoli [5] Universita di Catania [6] CNR Univ. of Salerno	**A. Barone[1], F. Tafuri[1], F.M. Granozio[1], U.S. di Uccio[1], L.Maritato[1], A.Tagliacozzo[1], G.Testa[1], E.Sarnelli[1], E. Mezzetti[2], B.Minetti[2], R.Gerbaldo[2], G.Ghigo[2], L.Gozzelino[2] , A. Montuorsi[2], A. Varlamov[3], G. Savona[3], F. Federici[3], M. Giura[3], C. Camerlingo[4], R. Cristiano[4], L. Frunzio[4], C. Granata[4], M. Lisitskii[4], C.Nappi[4], B. Ruggiero[4], M. Russo[4], E. Sarnelli[4], G.Testa[4], G. Falci[5], A.M. Cucolo[6]**
Norway (.No) [1] Univ. Sci.& Techn. -Trondheim [2] University of Oslo	**A. Sudbø[1], K. Fossheim[1], Th. Tybell[1], I. Zhilyaev[1], J. Grepstad[1], A.Brataas[1], T. Johansen[2], M. Baziljevich[2], Y.M. Galperin[2]**
Poland (.Pl) Instytut Fizyki PAN – Warszawa	**S.J. Lewandowski, A. Abal’oshev, I. Abal’osheva, M. Cieplak, P. Gierłowski, H. Szymczak, M. Baran, M. Borowiec, V. Dyakonov, A. Nabialek, M. Gutowska, R. Szymczak, R. Puzniak, A.Wisniewski, M. Berkowski, J. Fink-Finowicki, Mai Suan Li**
Slovakia (.Sk) [1] Slovak Acad. of Sci. –Kosice [2] Slovak Acad. of Sci. –Bratislava	**P. Samuelly[1], P.Szabo[1], K. Flachbart[1], P. Skyba[1], S. Benacka[2], S. Chromik[2] V. Strbik[2], M. Spankova[2], I. Kostic[2], P. Hrkut[2],**
Spain (.Es) [1] Univ. Autonoma de Madrid [2] Univ. Complutense -Madrid [3] Universidad de Santiago [4] University of Alicante [5] Inst. de Ciencia de Mat. -Madrid	**S. Vieira[1], N. Agraït[1], F. Aliev[1], A. Levanyuk[1], G. Rubio-Bollinger[1], J.G.Rodrigo[1], H. Suderow[1], R. Villar[1], F. Sols[1], J.L. Vicent[2], A. Asenjo[2] , E. M. Gonzalez,[2], J. I. Martín[2], E. Navarro[2], M. Velez [2], F. Vidal[3], J. M.aza[3], J.A. Veira[3], C. Torrón[3], J. Mosqueira[3], M.V. Ramallo[3], C. Carballeira[3], J.J. Palacios[4], F. Guinea[5],**
Switzerland (.Ch) 1 Univ. De Genève 2 ETH Honggerberg 3 University of of Neuchâtel 4 IBM Research Laboratory, Zurich	**Ø. Fischer[1], J.-M. Triscone[1], A. Manuel[1], M. Decroux[1], L. Antognazza[1], I. Maggio-Aprile[1], M. Kugler[1], O. Kuffer[1], M. Eskildsen1, I. Joumard1, S. Reymond1, J. Blatter2, V. Geskenbein2, P. Martinoli3, H. Beck3, Ch. Leemann3, G.E. Tsydynjapov3, R. Théron3, J.-P. Locquet4**
The Netherlands (.Nl) 1 Leiden University 2 Free University of Amsterdam 3 Technische Universiteit Delft 4 Universiteit Twente	**P. Kes[1], J. Aarts[1], T. Sorop[1], R. Wijngaarden[2], Y. Nazarov[3], H. Hilgenkamp[4] , A. Brinkman[4] , A. Golubov[4]**
United Kingdom (.UK) 1 University of Bath 2 University of Birmingham 3 University of Bristol 4 University of Cambridge 5 Imperial College – London 6 Royal Holloway College – London 7 University College – London 8 Loughborough University 9 Lancaster University 10 Oxford University 11 University of St. Andrews 12 University of Southampton	**S. Bending[1], S. Gordeev[1], A.R. Nogaret[1], E.M. Forgan[2], C.M. Muirhead[2], E. Tarte[2], J. Annett[3], B.L. Gyorffy[3], M. Blamire[4], Z. Barber[4], N. Mathur[4], A.D. Caplin[5], G. Perkins[5], V. Petrashov[6], I. Sosnin[6], P. Meeson[6], M. Dodgson[7], P. Warburton[7], F.V. Kusmartsev[8], D. Khomskii[8], J.H. Samson[8], M.B. Sobnack[8], R.T. Giles[8], C.J. Lambert[9], P.V.E. McClintock[9], R. Roth[10], J. Dunningham[10], C. Stevens[10], S.L. Lee[11], P. De Groot[12], A. Zhukov[12], H. Fangohr[12], D. Bagnall[12].**
Bulgaria (.Bg) 1 Bulgarian Academy of Sciences	**S.S. Tinchev[1], P.I. Nikolova[1], J.T. Dyulgerska[1]**

4. ‘International’ dimension

Recently Prof. V.V. Moshchalkov has been approached by the Japanese colleagues and JSPS to coordinate the European teams, which have been invited to participate in the Japan Society for Promotion of Science (JSPS) Core-to-Core (CTC) Programmes aimed at International Strategic Research Networking. The key European research groups(Prof. V.V. Moshchalkov and Prof. F. Peeters (Belgium), Prof. B. Pannetier en Prof. A. Buzdin (France), Prof. R. Woerdenweber, Prof. R. Kleiner, Prof. P. Müller, Prof. R. Gross (Germany) Prof. A. Barone (Italy), Prof. P.H. Kes and Prof. H. Hilgenkamp (The Netherlands), Prof. S. Vieira (Spain), Prof. Ø. Fischer and Prof. J.W. Blatter (Switzerland), Prof. T. Claeson (Sweden), Prof. S.J. Bending and Prof. M. Blamire (UK)), which also participate in the current NES proposal for the ESF Programme, are involved in this JSPS CTC Programme. The JSPS CTC proposal “Nano-Science and Engineering in Superconductivity” (Main applicant: Prof. K. Kadowaki, University of Tsukuba, Japan; EU coordinator: Prof. V.V. Moshchalkov, University of Leuven, Belgium; USA coordinator: Dr. K. Kwok, Argonne National Laboratory) has been selected by the JSPS as a result of a very tough competition – only 12 proposals, NES including, were selected from 119 applications. The existing format of the CTC programmes supports a few carefully selected scientific domains where international collaboration can strongly enhance the impact of the research on the technological progress. The total budget of this JSPS NES Proposal is 40,000,000¥ (for two years)

The basic idea of the CTC programmes is to give the JSPS support for two years (April 2005- April 2006, with possible prolongation for another 3 years) to the leading Japanese teams and also to key partners from Europe and the USA to establish direct contacts, exchange of the ideas and researchers, thus creating an important added value for the scientific domains of strategic importance. The JSPS support ()is already available now for Japanese and key European and American participants for two years but if the ESF and NSF are joining this CTC programme, then the JSPS support for the CTC will be extended for another three years.

The selection of our CTC programme for financing for two years starting from April 01, 2004 clearly underlines the strategic importance of the research in the field of Nanoscience and Technology in Superconductivity. This programme is based on recent spectacular results in the field of vortex physics in nanostructured superconductors achieved by the European researchers working in the framework of the ESF VORTEX and PI-SHIFT programmes, which is explicitly acknowledged in this CTC proposal. To maintain this important momentum and the leading ESF impact on the worldwide research in this field, the participation of the ESF in this CTC programme is crucial. By joining forces ESF, JSPS and NSF can create in this case a unique global international programme supporting the strategically important scientific areas.

The US Institutions (ITS-University of Notre Dame, MTI, Argonne National Laboratory) and the CTC programme have recently expressed their firm commitment to establish close collaborative ties with the activities of the Japan – EU –USA NES Core-to-Core (CTC) programme. It has been agreed to develop a collaborative scheme between the CTC program, the Institute for Theoretical Sciences (ITS) – a joint University of Notre Dame and Argonne venture, Argonne's Materials Theory Institute (MTI) and the Superconducting and Magnetism Group in the Materials Science Division at Argonne National Laboratory. On the US side, the participating teams represent a total funding of $1.3M of which at least $400K is currently committed to visitor/information exchange programs.

Needless to say that taking into account the existence of these programmes in Japan and USA, an urgent European concerted action is required. To match adequately these initiatives in Japan and the USA on a European scale and to strengthen the European leadership in the field of Nanoscience and Engineering in Superconductivity is strategically important issue clearly defining an international dimension of the proposed NES ESF Programme.

Coordinators of the NES Programmes in Japan and the USA:

Chairman of the JSPS NES Core-to-core Programme (Japan):

Prof. Kazuo Kadowaki
University of Tsukuba
Institute of Materials Science

1-1-1, Termodai,
Tsukuba, Ibaraki 305-8573, Japan
Tf: (+81)-(0)29-853-5291
Fax: (+81)-(0)29-855-7440

E-mail address: kadowaki@ims.tsukuba.ac.ip

Coordinator of the NES activities in the USA:

Prof. Wai K. Kwok
Argonne National Laboratory
Materials Science Division

9700 South Cass Avenue, Argonne,
IL60439, USA
Tf: (+001) 630-252-5539
Fax: (+001) 630-252-4748

E- mail address: wkwok@anl.gov