(Form4-2)

JOINT RESEARCH PROJECT

FINAL REPORT
For Japan-Korea Joint Research Project

AREA	1. Mathematics & Physics 2. Chemistry & Material Science 3. Biology 4. Informatics & Mechatronics 5. Geo-Science & Space Science 6. Medical Science 7. Humanities & Social Sciences

1. Research Title:

Novel Quantum Phenomena in Helium Nanostructures

2. Term of Research: From July 1, 2009 To March 31,2011

3. Total Budget

a. Financial Support by JSPS: Total amount: 2,400 thousand yen

1st Year 1,200 thousand yen 2nd Year 1,200 thousand yen

3rd Year thousand yen

b. Other Financial Support : Total amount: thousand yen

4. Project Organization

a. Japanese Principal Researcher	
Name	Keiya Shirahama
Institution / Department Position	Keio University Department of Physics Professor
b. Korean Principal Researcher	
Name	Eunseong Kim
Institution / Department Position	KAIST (Korean Advanced Institute of Science and Technology) Department of Physics Associate Professor

c. List of Japanese-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Yoshiyuki Shibayama	Keio University, Department of Physics	Assistant Professor (Lecturer)
Mitsunori Hieda	Nagoya University, Department of Physics	Assistant Professor (Lecturer)

d. List of Korean-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Hyungsoon Choi	KAIST, Department of Physics	Postdoctoral associates
Jungil Lee	KAIST, Departement of Physics	Graduate student

5. Number of Exchanges during the Final Fiscal Year*

*Japanese fiscal year begins April 1.

a. from Japan to Korea

Name	Home Institution	Duration	Host Institution
Keiya Shirahama	Keio University	12.18-22, 2010	KAIST
Yoshiyuki Shibayama	Keio University	12.19-22, 2010	
Mitsunori Hieda	Nagoya University	12.18-22, 2010	
Satoshi Murakawa	Keio University	12.19-22, 2010	
Aaron Koga	Keio University	12.19-22, 2010	
Kohta Saitoh	Keio University		
Takayuki Kogure	Keio University	12.19-22, 2010	
Yu Negishi	Keio University	12.19-22, 2010	
Yusuke Chikazawa	Keio University	12.19-22, 2010	

For Final Fiscal Year(FY2010)	For Final Fiscal Year(FY2010)
Total: 9 persons	Total: 34 man-days

Numbers of Exchanges during the past fiscal years

FY2009: Total 7 persons
FY2010: Total 9 persons

b. from Korea to Japan

Name	Home Institution	Duration	Host Institution
Eunseong Kim	KAIST	6.24-27, 2010	Keio University
Hyoungsoon Choi		6.24-27, 2010	
Dukyoung Kim		6.24-27, 2010	
Sangil Kwon		6.24-27, 2010	
Hyunkoo Kang		6.24-27, 2010	
Jungil Lee		6.24-27, 2010	
Sunkyu Park		6.24-27, 2010	
Jaeho Shin		6.24-27, 2010	
Janghee Lee		6.24-27, 2010	
Sung Jang		6.24-27, 2010	
Hyunjoo Ko		6.24-27, 2010	

For Final Fiscal Year(FY2010)	For Final Fiscal Year(FY2010)
Total: 11 persons	Total: 44 man-days

Numbers of Exchanges during the past fiscal years

FY2009: Total 1 persons
FY2010: Total 11 persons

6. Objective of Research

In this collaboration project, we explore novel physics in "Helium Nano-structures", which are formed by confining ^{4}He to various nano-porous materials and flat surfaces. We search for and elucidate novel quantum phases, such as low – dimensional superfluid crystal (supersolid) and nanoscale BEC.

In the last five years, there have been growing interests to new emergent phenomena in liquid and solid helium: Superfluid behaviors in solid ^{4}He ("super-solidity") discovered by Professor Kim have been of particular interest, because it is expected as a new state of matter. Shirahama's group found a new form of Bose-Einstein condensation (BEC) on nano-scale, in liquid ^{4}He confined in nano-porous materials. Since the physics behind both phenomena is closely related, cooperative research of both groups will shed new light on ultimate problems of natural science, such as symmetry breaking and matter formation.

In this project, we cooperate in searching for novel quantum phenomena, such as superfluid, super-solid, Bose glass, Mott insulator, and phase transitions between them, in various helium nano-structures. We will experimentally study the following subjects: (1) Search for novel super-solid states in two-dimensional helium solid formed on graphite and in nanoporous materials. (2) Study of novel quantum phenomena in nano-scale liquid and solid ^{4}He strongly confined in nano-porous media. The research team consists of two representative groups of low temperature physics in Korea and Japan. Dr. Hieda of Nagoya University also joins the project in developing a broad-band oscillating experiment.

These experiments will be done with short-term exchanges of researchers and graduate students between two countries. In both fiscal years, we will hold workshops to discuss and appeal the outcomes and future directions of our projects. This project will lead the frontier research of modern condensed matter physics, and will become a starting point of the Korea-Japan low temperature collaboration.

7. Methodology

We have planned collaboration on several themes of helium nanostructures and supersolid studies, and workshops at Keio University and at KAIST.

Collaboration

(1) Supersolid Helium

(A) Simultaneous measurement of rotational inertia and shear modulus

Unveiling relationship between decrease in the moment of inertia (NCRI) and increase in shear modulus of solid 4He has been the most important issue in supersolid research. We perform measurements of NCRI and shear modulus simultaneously for a single solid 4He sample, by a specially designed torsional oscillator containing annular space surrounded by two piezoelectric ceramic tubes. The experiment is performed in KAIST using piezo devices supplied by Keio group.

(B) Search for superfluidity in two-dimensional (2D) solid ^{4}He formed on Graphite

Thin films of solid 4He formed on some solid substrates may have a novel supersolid phase by quantum mechanically formed vacancies. We search for superfluidity (supersolidity) in 2D ^{4}He solid on Graphite, near its commensurate solid phase (second atom layer) using torsional oscillator technique. The experiment is done mainly by Shibayama at Keio.

(C) Dynamics of solid 4He film adsorbed in nanoporous media

Based on the same motivation as (B), we search for supersolidity in 2D "amorphous" (noncrystalline) solid layer formed in some porous media, such as porous gold and porous glass. The experiments are performed both in KAIST and Keio groups.

(2) Helium Nanostructures (Nanoporous Media)

(A) Quantum phase transition of 4He in nanoporous media

We study the quantum phase transiton of 4He in a nanoporous glass by ultrasound technique. The ultrasound can probe the dynamics of 4He at its superfluid transition with various frequencies. With this technique we search for possible divergence of characteristic time scale in superfluidity near the quantum critical point. This work is performed in Keio Univ. in collaboration mainly with Hieda at Nagoya Univ.

(B) Broadband oscillation experiment for ^{4}He on various substrates

Dynamical responses of helium films are studied in a wide frequency range (10 – 200 MHz) by broadband quartz microbalance technique developed by Hieda. This method will shed new light on supersolidity and superfluidity in 4He films on various substrates.

(C) Development of atomic force microscope for helium study

Scanning probe microscopy can be a powerful probe for superfluidity and supersolidity of helium film. We develop a atomic force microscope working at low temperatures for studying helium films on graphite and other flat substrates.

Workshop

To discuss the achievement of the collaboration, we hold several workshops in KAIST and Keio University.