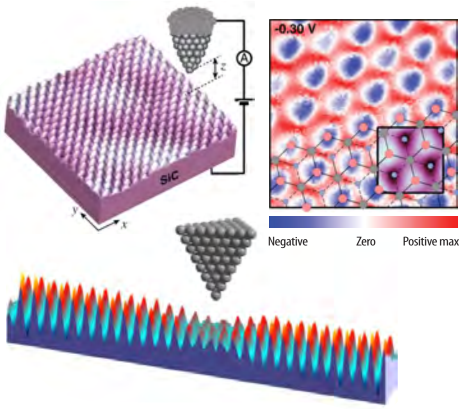
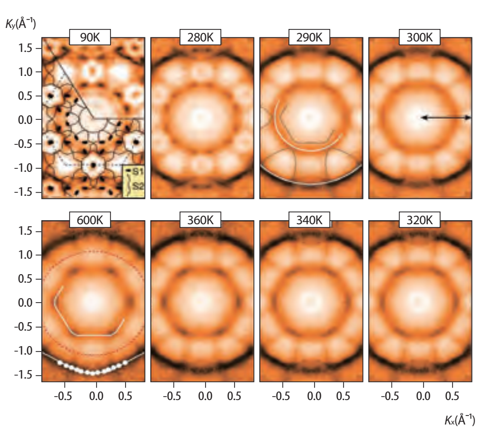
Institute for Basic Science

Center for Artificial Low Dimensional Electronic Systems

CALDES





Center for Artificial Low D Electronic Systems

Center for Artificial Low D Electronic Systems

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Message from Director

CALDES challenges the major physics problems of low dimensional electronic materials that have been the central issues of modern condensed matter physics since 1970's.

In this long pursued discipline with the glory of quantum Hall effects, high temperature superconductors, and graphene, CALDES would pioneer new types of materials with state-of-the-art measurement technologies.

The new materials systems are low dimensional systems controlled and grown in atomic scale precision, such as atomic layers, atomic wires, atomic rods, and their arrays and heterointerfaces. The state-of-the-art measurement technologies include scanning tunneling microscopy below 10 mK and under strong magnetic field, magnetic force and spin-polarized scanning probe microscopy below 500 mK, and untra bright spin- and angle-resolved photoelectron spectroscopy.

These frontier instruments can address the electronic and spintronic properties of atomic-scale low dimensional systems in truly single atom and single spin precision. With the atomically controlled low dimensional materials under atomically-resolved probes, CALDES investigates and manipulates exotic electronic and spin channels and topological excitations such as solitons, quantum spin Hall edge states, non Fermi liquids, skyrmions, quantum magnets and so on. CALDES aims to establish full understanding of these low dimensional electronic phenomena and to discover new physics and new functionality emerging from atomically designed low dimensional electronic materials.

Goal of CALDES

In this long-term research project, we aim to

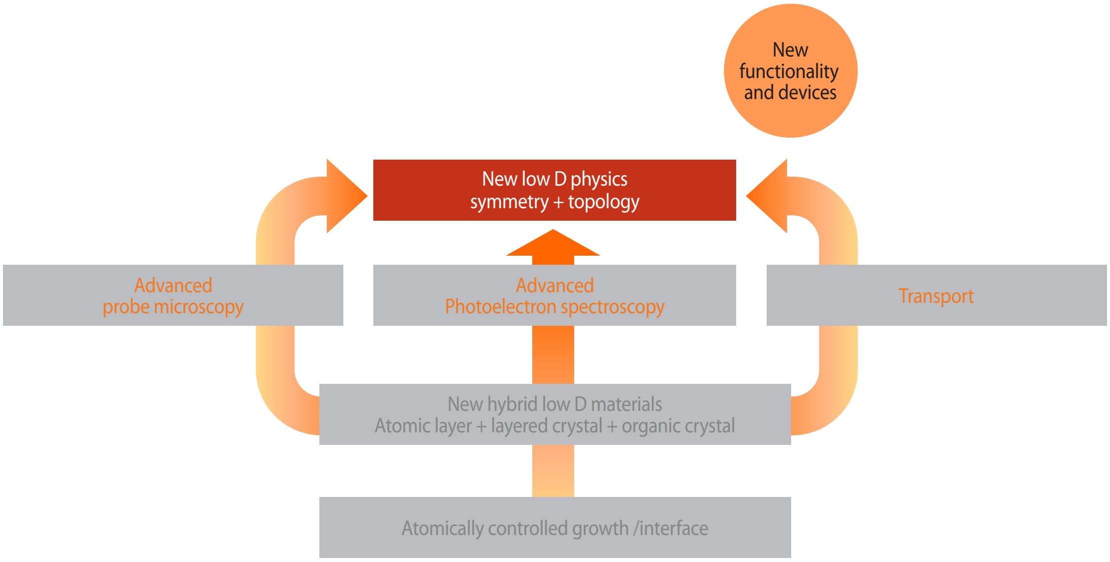
Create atomically controlled artificial materials such as wires, layers, ultrathin films, hetero-interfaces, and multilayers, which can host novel low dimensional electronic systems,
Establish methods for the ultimate atomic scale control over these materials to manipulate their local and global electronic properties,
Discover new types of quantum matter originating from exotic symmetries and orders of low dimensional electrons and challenge the grand problems of the quantum phase fluctuations, competitions, and transitions of low dimensional electrons.

In achieving the above goals, we propose an innovative approach through

The combination of atomically controlled in situ growth of new materials with the advanced spectroscopic and microscopic techniques such as spin-and-angle-resolved photoelectron spectroscopy and ultra-low-temperature-high-magnetic-filed scanning tunneling microscopy.

Finally, we hope to

Pave a way to revolutionary electronic or spintronic devices based on new types of quantum properties of electrons in low dimension.



CALDES Structure

Director : Han Woong Yeom

Physics (Director) Han Woong Yeom

STS	STM	MFM	ARPES	Theory
Research Fellow	Research Fellow	Research Fellow	Research Fellow	Research Fellow
Tae-Hwan Kim	Ungdong Ham	Jeehoon Kim	Keun Su Kim	Sung-Hoon Lee

Materials Physics (Group Leader)
Moon-Ho Jo
Layered Crystals

Theory/Simulation
Participating researchers
Seunghun Ji

Materials Chemistry (Group Leader)
Hee Cheul Choi
Molecular Crystals

Transport
Participating researchers
Jun Sung Kim

Physics (Group Leader)
To be invited
Transport

Director and Group Leaders

Han Woong Yeom
Director & Professor

Ph.D Tohoku University, Japan
E-mail yeom@postech.ac.kr **Tel** +82-54-279-2091

Research Area

- Atomic wires; self-assembled 1D metal and 1D topological insulator
- Atomic layers; epitaxially-grown single atomic layer 2D metals
- Atomic layer 2D topological insulators
- Atomic layer heteroepitaxy on strongly interacting systems

Moon-Ho Jo
Group Leader & Professor

Ph.D University of Cambridge, United Kingdom
E-mail mhjo@postech.ac.kr **Tel** +82-54-279-2158

Research Area

- Atomic heteroepitaxial growth: semiconductors, strongly correalated metals and insulators
- Laser transport Spectroscopy: Photon-Matter interaction at atomically layer materials and complex oxides
- Optoelectronics / Optoplasmonics / Optothermoelectrics: Funda mental energy conversion / Transport processes

Hee Cheul Choi
Group leader & Professor

Ph.D Purdue University, USA
E-mail choihc@postech.edu **Tel** +82-54-279-2130

Research Area

- Synthesis and characterization of low dimensional structures
- Morphology-property correlation of self-assembled crystals
- Molecular crystal electronics
- Organic superconductors, high performance organic semiconductors
- Organic topological insulators, organic superlattice structures

Research Fellows

Ungdon Ham IBS Faculty

Ph.D University of California, Irvine, USA

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Research Area

- Scanning tunneling microscopy of single atoms and single molecules
- High resolution electron tunneling spectroscopy such as inelastic electron tunneling spectroscopy

Jeehoon Kim Assistant Professor

Ph.D University of Texas at Austin, USA

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Research Area

- Low temperature magnetic force microscopy
- Superconductivity and magnetism
- Quantum materials

Keun Su Kim Assistant Professor

Ph.D Yonsei University, Korea

E-mail keunsukim@postech.ac.kr **Tel** +82-54-279-2073

Research Area

- Artificial design of low-D atomic crystals
- Electronic structures and manybody interactions
- Angle-resolved photoemission spectroscopy

Tae-Hwan Kim Assistant Professor

Ph.D Seoul National University, Korea

E-mail taehwan@postech.edu **Tel** +82-54-279-2084

Research Area

- Scanning tunneling microscopy/spectroscopy of nanostructures
- Scanning tunneling potentiometry of nanostructures
- Microscopic transport of nanostructures

Sung-Hoon Lee IBS Faculty

Ph.D Pohang University of Science and Technology, Korea

E-mail shlee@ibs.re.kr **Tel** +82-54-279-9885

Research Area

- First-principles electronic structure calculations
- Semiconductor surfaces, 2D layered materials, heterostructures
- 1D, 2D, 3D topological materials

Research Groups

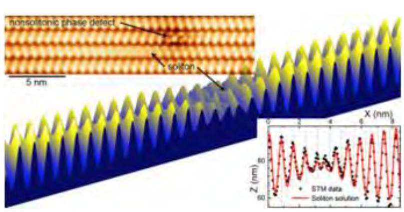
Physics Group

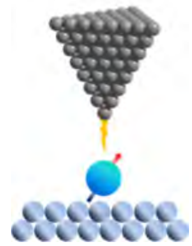
Director : Professor **Han Woong Yeom**

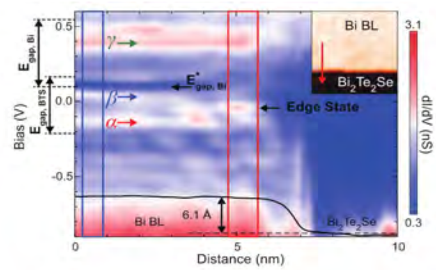
Ultra Low Temperature Scanning Tunneling Microscopy

Probing structural, electronic, and spin information of low-dimensional materials

- Edge states of 1D and 2D topological insulators
- Atomic and electronic structures of hetero-interfaces of layered materials
- Manipulation of spin states of single spins



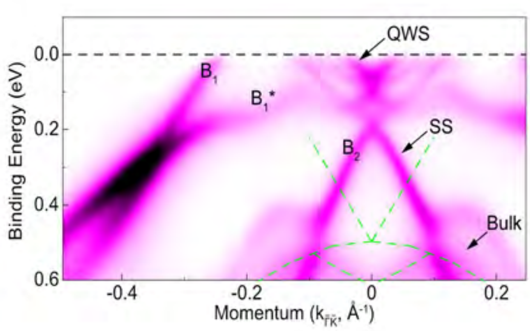


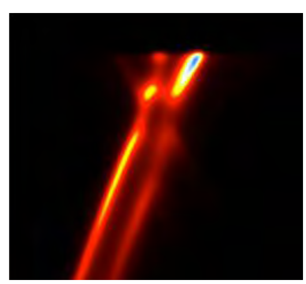


Spin and Angle-Resolved Photoelectron Spectroscopy

Probing spin-resolved band structures of low-dimensional systems

- Band structures of new 1D and 2D topological insulators
- Low-energy excitations of homo- and hetero-interfaces of graphene



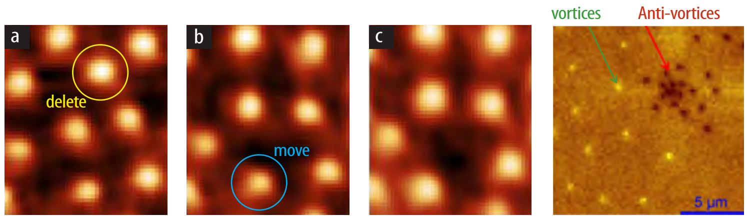


Research Groups

Low Temperature Magnetic Force Microscopy

Superconductivity and magnetism at the nanoscale

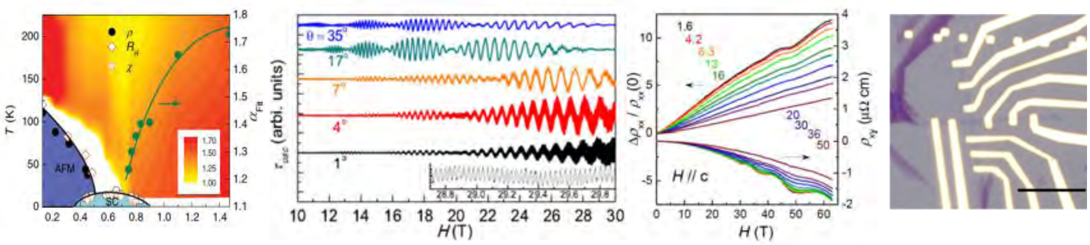
- Iron based superconductors, high-T_c cuprates, and heavy fermion superconductors
- Skyrmions, magnetic monopole system, magnetic metastable domains
- Heterostructure of superconductor and magnet



Quantum Phenomena under Extreme Conditions

Physical properties of correlated/chiral electronic system under extreme conditions

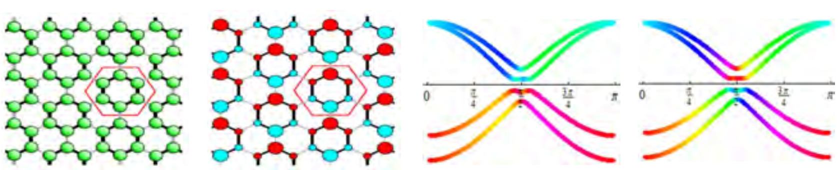
- Quantum phase transition in low dimensional materials and their heterostructures
- Quantum oscillations and transport under extreme conditions



Theory and Computation

First-principles electronic structure calculations and tight-binding analysis

- Semiconductor surfaces, 2D materials, heterostructures
- Topological nature of electronic structures of 1D, 2D, 3D topological materials



Research Groups

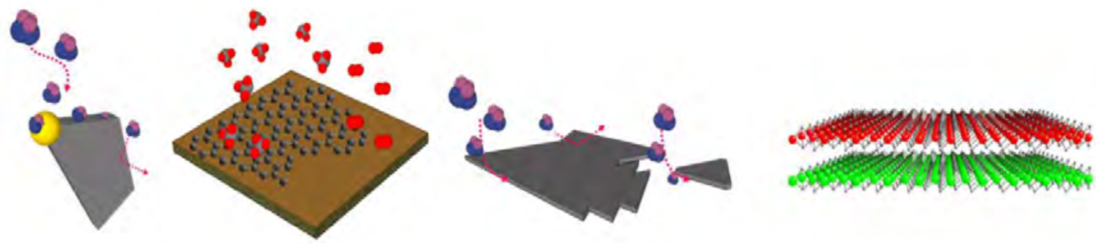
Materials Physics Group

Group Leader : Professor **Moon-Ho Jo**

Atomic Heteroepitaxial Growth of 2D Layered Materials

Gas-phase epitaxial growth of low-D materials and their heterostructures

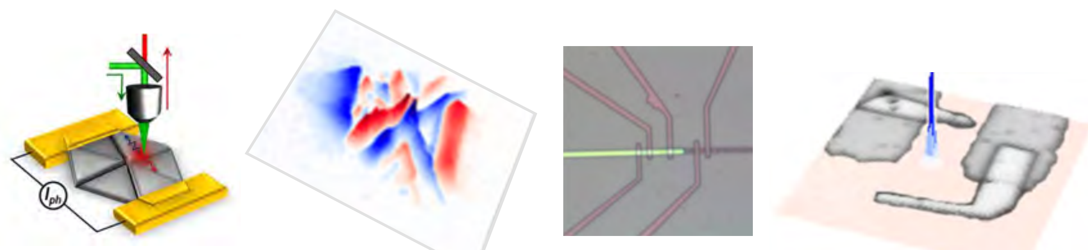
- Large Band-gap Layered Dichalcogenides : 2D Semiconductors
- Small Band-gap Layered Dichalcogenides : Topological Insulators and Superconductors



Laser Transport Spectroscopy

Spatially, spectrally, temporally resolved photonic/optoelectronic probes

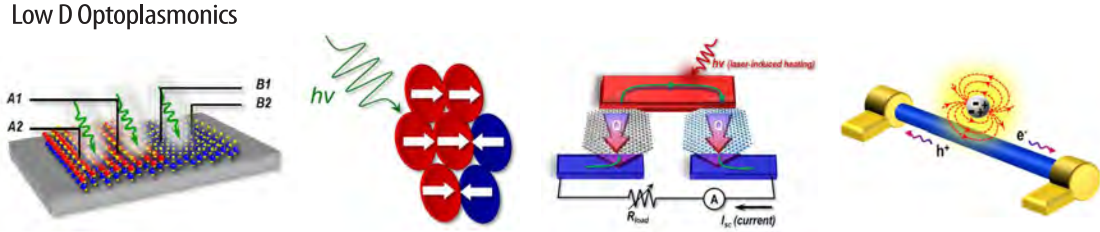
- Local Photo-induced Phenomena in Strongly Correlated Electronic Systems
- Optical/Electronic 2D Interlayer Transitions and Their Dynamics
- Nonlinear 2D Photonic Processes



Fundamental Energy Transfer/Conversion Devices

Near-future device application platforms

- Atomic 2D Photovoltaics
- 2D Thermophysical Devices and Photo-induced Thermoelectrics
- Low D Optoplasmonics



Research Groups

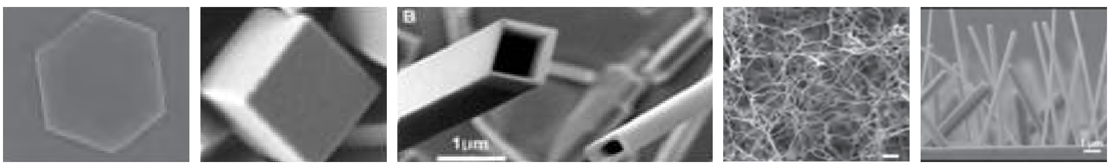
Materials Chemistry Group

Group Leader : Professor **Hee Cheul Choi**

Self-Assembled Molecular Crystals

Design and synthesis of geometrically well-defined molecular crystals

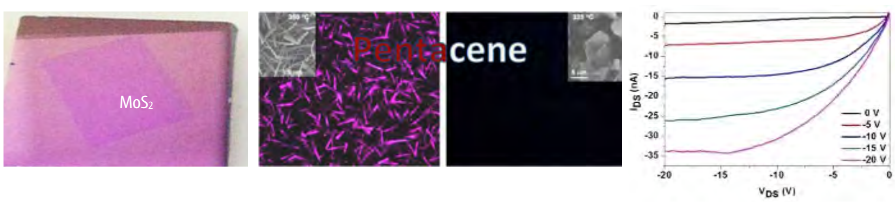
- Development of synthetic methodologies in vapor and solution phase through non-equilibrium crystallization
- Structure analysis using synchrotron light source



Morphology-Property Correlation Study

Electrical, optical and magnetic property changes depending on crystal facets within a crystal

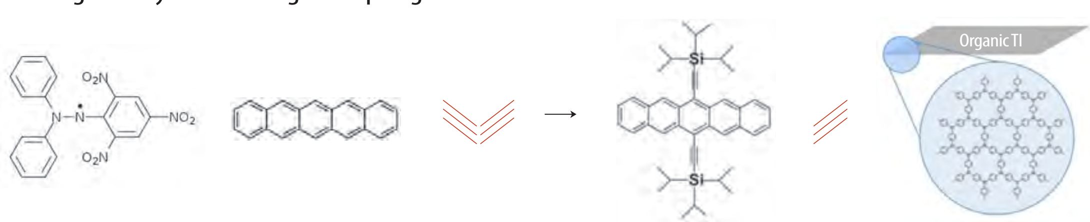
- Synthesis of quantum 2D crystals
- Crystallization-induced property change
- Evaluation of molecular orientation-dependent light-molecule interaction
- Development of highly efficient organic optoelectric devices



Organic Superconductors, Semiconductors, and Topological Insulators

New functional materials based on organic and inorganic molecules

- Design and synthesis of new organic superconductors
- High-performance molecular semiconductors
- Design and synthesis of organic topological insulators in various dimension



CALDES Research Highlight

Physics Group

- Valley spin polarization by using the extraordinary Rashba effect on silicon, K. Sakamoto, H. W. Yeom et al. Nature Comm. 4, 2073 (2013).
- Visualizing Atomic-Scale Negative Differential Resistance in Bilayer Graphene, K. S. Kim, T.-H. Kim, A. L. Walter, T. Seyller, H. W. Yeom, E. Rotenberg, A. Bostwick, Phys. Rev. Lett. 110 (2013).
- Self-Assembled Nanowires with Giant Rashba Split Bands, J. Park, S. W. Jung, M.-C. Jung, H. Yamane, N. Kosugi, H. W. Yeom, Phys. Rev. Lett. 110, 036801 (2013).
- Topological Solitons versus Nonsolitonic Phase Defects in a Quasi-One-Dimensional Charge-Density Wave, T.-H. Kim, H. W. Yeom, Phys. Rev. Lett. 109, 246802 (2012).
- Radial band structure of electrons in liquid metals, K. S. Kim, H. W. Yeom, Phys. Rev. Lett. 107, 136402 (2011).
- Nearly Massless Electrons in the Silicon Interface with a Metal Film, K. S. Kim, S. C. Jung, M. H. Kang, H. W. Yeom, Phys. Rev. Lett. 104, 246803 (2010).

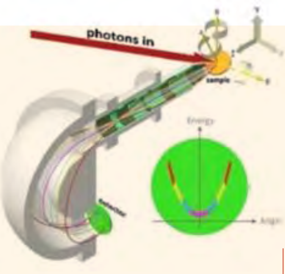
Materials Physics Group

- Large electroabsorption susceptability mediated by internal photoconductive gain in Ge nanowires, H.-S. Lee, C.-J. Kim, D. Lee, R. R. Lee, K. Kang, I. Hwang, M.-H. Jo, Nano Lett., 12, 5913 (2012).
- Tunable catalytic alloying eliminates stacking-faults in compound semiconductor nanowires, H. Heo, K. Kang, D. Lee, L-H. Jin, H.-J. Baek, I. Hwang, M. Kim, H.-S. Lee, B.-J. Lee, G.-C. Yi, Y.-H. Cho, M.-H. Jo, Nano Lett. 12, 855 (2012).
- Spatially resolved photodetection in leaky ferroelectric BiFe03, W.-M. Lee, J. H. Sung, K. Chu, X. Moya, D. Lee, C.-J. Kim, N. D. Mathur, S.-W. Cheong, C.-H. Yang, M.-H. Jo, Adv. Mater. 24 0P49 (2012).
- On-Nanowire band-graded Si:Ge photodetectors, C.-J. Kim, Y.-J. Cho, J.-E. Yang, H.-S. Lee, R. R. Lee, J. K. Lee, M.-H. Jo, Adv. Mater. 23, 1025 (2011).
- Diameter-dependent internal gain in ohmic Ge nanowire photodetectors, C.-J. Kim, H.-S. Lee, Y.-J. Cho, K. Kang, M.-H. Jo, Nano Lett., 10, 2043 (2010).

Materials Chemistry Group

- Patternable large-scale molybdenium disulfide atomic layers grown by gold-assisted chemical vapor deposition, I. Song, C. Park, M. Hong, J. Baik, H.-J.Shin, H. C. Choi, Angew. Chem. Int. Ed., 53, 1266 (2014). (Inside Back Cover)
- Catalyst-free direct growth of a single to a few layers of graphene on a germanium nanowire for the anode material of a lithium battery,H. Kim, Y. Son, C. Park, J. Cho, H. C. Choi, Angew. Chem. Int. Ed., 52, 5997 (2013). (Hot paper)
- Crystal Plane-Dependent Photoluminescence Activity of Pentacene 1D Wire and 2D Disk Crystals, J. E. Park, M. Son, M. Hong, G. Lee, H. C. Choi, Angew. Chem. Int. Ed., 51, 6383 (2012).
- Significant increase in the water dispersibility of zinc phthalocyanine nanowires and its application in cancer phototherapy, H. K. Moon, M. Son, J. E. Park, S. M. Yoon, S. H. Lee, H. C. Choi, NPG Asia Mater., 4, e12 (2012).
- Self-crystallization of C70 cubes and remarkable enhancement of photoluminescence, C. Park, E. Yoon, M. Kawano, T. Joo, H. C. Choi, Angew. Chem. Int. Ed., 49, 9670 (2010). (Hot Paper, Highlighted in NPG Asia Materials)

Equipment



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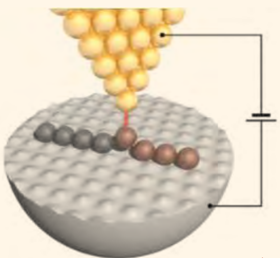
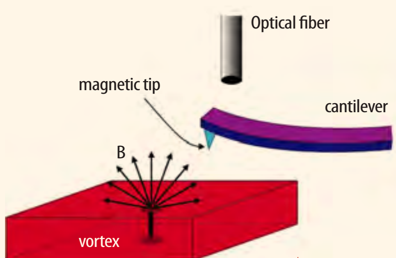
02



03



04

05

Spin and Angle Resolved Photoemission Beamline 01

Angle-resolved photoelectron spectroscopy is a powerful technique that measures the electronic structure of low D atomic crystals. We are constructing a spin and angle resolved photoemission beamline in collaboration with Pohang Light Source, which is based on new type of spin detector to achieve world top level performance in mapping out spin resolved band structures.

Dilution Refrigerator with High Field Magnet 02

The dilution refrigerator combined with high field magnet provides extremely low temperature (~10mK) and high magnetic field (~20 T) conditions for investigating various interesting quantum phenomena in low dimensional materials

Scanning Tunneling Microscope space (10 mK, 9-2-2 T) 03

Scanning tunneling microscope is a powerful tool that images surfaces at the atomic level as well as can manipulate atoms on surfaces.

Low-Temperature Magnetic Force Microscope 04

Low temperature magnetic force microscope images magnetic domains and force distribution at the nanoscale to investigate low temperature phase transition such as superconductivity and magnetism. Our MFM specification is as follows: base temperature of T=0.3 K and vector field of H = 9T-2T-2T.

Electron-Ion Dual Beam Lithography 05

The electron-ion dual beam lithography machine is combined with Nanopattern Generation System (NPGS) and enables high resolution device fabrication of various low dimensional materials. A clean room facility equipped with a micro-contact aligner (MIDAS) and e-beam/thermal metal evaporator is also available.

Activities

a

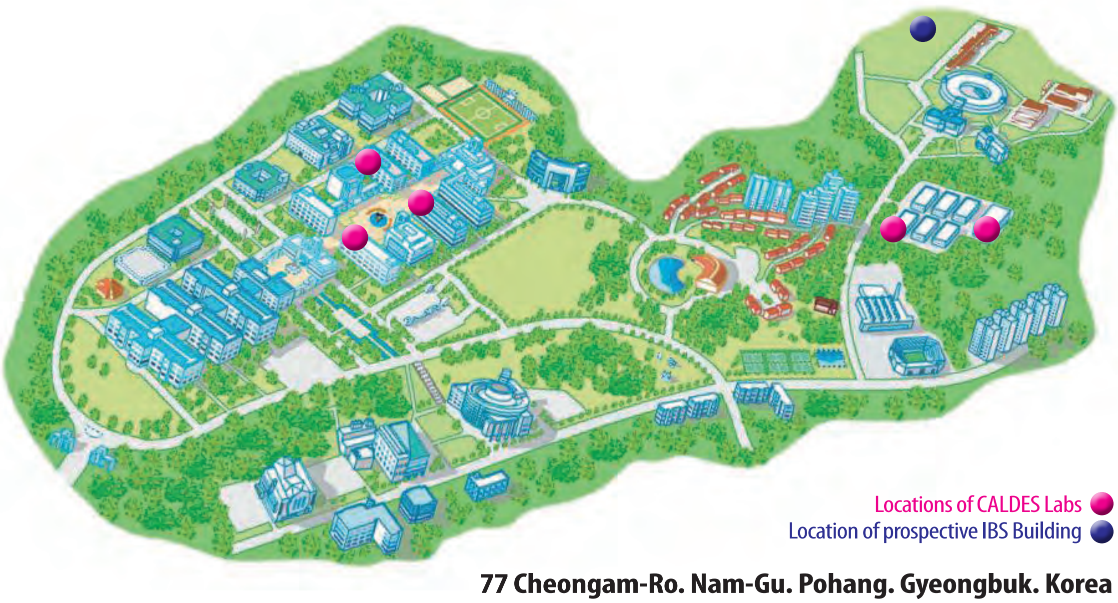
b


c

a Gyeongju, Korea
b Geoje, Korea
c Yongpyeong, Korea

- The 14th International Conference on the Formation of Semiconductor Interfaces (2013 6.30~7.5, Gyeongju)
- The 1st CALDES Annual Internal Workshop (2013. 11. 29~30, Geoje)
- The 10th Workshop on Surface Nano-Science (2014. 2. 6~8, Yongpyong)

Location & Direction



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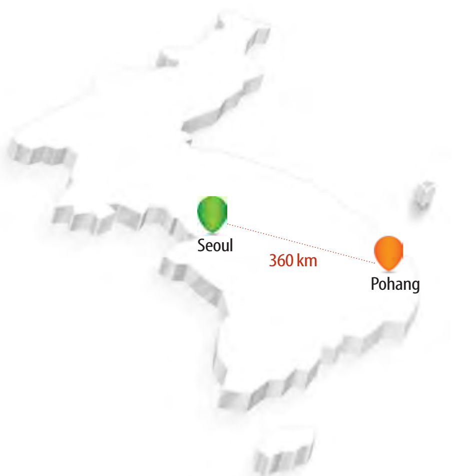

Coming to POSTECH

The most convenient way to reach POSTECH from Seoul is either via Air (from Gimpo International Airport to Pohang Airport) or KTX fast train (from Seoul KTX Station to Singyeongju KTX Station). Note that direct KTX train service from Seoul to Pohang will be available on January 2015.

From Pohang Airport (KPO) to campus

POSTECH is located about 30 minutes away from Pohang Airport by car. Taxi service will charge about KRW 15,000.

From Singyeongju KTX Train Station to campus

There is a Limousine Bus service from KTX station to Pohang Intercity Bus Terminal, which takes about 40 min. A one-way ticket costs KRW 5,000. Another option is InterCity Taxi that can be found in front of the main gate of the station. The InterCity Taxi will cost about KRW 50,000.

From Pohang KTX Train Station to campus (available on January, 2015)

The Pohang KTX Station is about 20 minutes away from the campus by car and Taxi service will cost about KRW 10,000.

Institute for Basic Science

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