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Division of Condensed Matter Physics
Association of Asia-Pacific Physical Societies

Prof. Yaping Chiu (Editor)
Prof. S. M. Yusuf (Editor and Vice Chair)

NEWSLETTER OF THE DCMP (Division of Condensed Matter Physics) AAPPS (Association of Asia-Pacific Physical Societies)

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Chair Message

Dear friends,

First, let me wish you and your nearest family are all ok and well. This almost two-year-long pandemic has put an unbearable strain on all aspects of our life. Unfortunately, we are not spared from this dreadful situation, and much of our scientific activities have been in limbo since.

Given the grave situations we are in, it is remarkable that the DCMP even started in the middle of the pandemic. Not only that, we have been making big and continuous strides along with the plan we put for us early this year.

Among many things we achieved for the last few months, I am proud that we held the 1st Asia-Pacific Conference on Condensed Matter Physics (AC2MP) on 1-3 December. With the final registration of 372, it is no small achievement for us. Another milestone is that the total number of the DCMP membership is close to 300 as of writing this report.

Everything we did this year was the first for the DCMP, and we had to make continuous efforts to make things going. For this, I should express my deepest thanks to my DCMP team: two vice-chairs (Profs. H. Nojiri and S. M. Yusuf), secretary-general (Prof. K. Choi). It was also immense help that I had full supports from all ten members of the DCMP-EXCO members. And, of course, the continuing interests around the region keep us going.

I anticipate the DCMP will be more visible the next year and hold several exciting events like the APPC15 in August and the 2nd AC2MP in November 2022. With this, I wish you all a Merry Christmas and a Happy New Year.

Je-Geun Park
Chair of DCMP
Professor, Dept, Physics & Astronomy, Seoul National University

Vice Chair Message

We reached to the 1st mountain, the road is winding but getting broader.

When we first discussed the plan of DCMP formation in Malaysia in 2019, no one expected international exchange to be so long isolated under covid-19 pandemic. The road to the formation of the DCMP in January 2021 was narrow and winding. However, in 2021, the first event of DCMP, the 1st division international conference, brought the clear milestone of the DCMP. It is like to reach to the top of the 1st mountain in our long way to go. The summit is the good place for us to oversee the future prospects.
The form of international exchange in academia also changes with the times. In the 1980s, when I was a student, if I wanted to read someone else's dissertation or preprint, I used to send the Preprint request by sending a postcard. Subsequent development of electronic journals and the development of preprint servers have significantly changed the way academic exchanges. And now, online conferences are about to change the way academic exchanges in part.
Certainly, online meetings are inferior to on-site meetings in terms of communication quality, interactivity, and effective information exchange. Above all, immersing yourself in extraordinary situations by traveling to a foreign country is an experience that cannot be done online. On the other hand, online meetings are extremely effective in removing space constraints. Also, for researchers with limited resources in Asia-Pacific region, it is meaningful to be able to participate in events that they could not attend before.
In the future, even if international transportation is restored in post-pandemic, it is considered to be important for the DCMP to include a mechanism that allows young students to participate through online to most of international events. As I once experienced, the international conference is one of the great opportunities to establish a solid position as a researcher. Oral presentation and invited talks at international conferences were important steps in gaining recognition in the field. I hope that the DCMP event will be the gateway for young researchers to participate into the global community.
We use currencies for trading and international economic exchange. So what is needed for academic exchange instead of currency? It is a publications, information exchage, and interaction of people. For example, in Asia-Pacific, there are many research opprotinites in large scale facilites and there are many open postions for faculties and exchange students. In the coming year, the DCMP is willing to accelerate to flow these information amoung the communites through the membership system of the division. I hope you and your collaborators participate in the DCMP to catch the academic currency.

Professor Hiroyuki Nojiri (Vice Chair)
Institute for Material Research,
Tohoku University

From Editorial Desk

Dear DCMP members,

We are pleased to present the December-2021 issue of the DCMP Newsletter as the second issue of the Newsletter.

The inaugural issue mainly contained the introduction of the EXCO Members and the reports from the member associations. In the present issue, we have included technical articles covering a wide range in the field of condensed matter physics, including Superconductivity, 2D Materials, Topological Insulators, Multiferroicity, and Colossal Angular Magnetoresistance from young researchers and subject experts. This issue also highlights the activities of the Japan Proton Accelerator Research Complex (J-PARC) and Asia-Pacific Center for Theoretical Physics (APCTP), Pohang, South Korea.

Prof. Yaping Chiu (Editor)
Professor
Department of Physics
National Taiwan University

In the current issue of the Newsletter from DCMP, we have brought to you the review of the scientific works from our invited authors. We hope the readers can get some inspired ideas from the current issue.

The Editorial office of the DCMP Newsletter will continue to devote consistent efforts towards increasing the visibility and scientific impact of the Newsletter. We also look forward to our readers' support and engagement to keep the high scientific standard of the Newsletter in the coming years.

In the end of the 2021, on behalf of the DCMP, we would like to take this opportunity to wish all the DCMP members a happy, healthy and productive year ahead.

Prof. S. M. Yusuf (Editor and Vice Chair)
Director, Physics Group, Bhabha Atomic Research Centre
Senior Professor, Homi Bhabha National Institute

Large facilities/institute/organization reports

Report 1: Neutron and Muon experimental facilities at J-PARC

The J–PARC stands for Japan Proton Accelerator Research Complex. J-PARC will throw light on the mysteries of the creation and structure of our universe by investigating matters at all levels, from quarks to atoms, with using various kinds of particle beams produced in proton-nucleus reactions (nucleus spallation) by MW-class high power proton beams. Three major scientific goals will be attained: materials and life sciences, nuclear particle physics and nuclear transmutation with various secondary particle beams (neutrons, muons, kaons, neutrinos, etc.). Proton is accelerated with three acclerators: 400-MeV linear accelerator (Linac), 3 GeV rapid-cycling synchrotron (RCS) which provides proton beams to Materials and Life Science Experimental Facility (MLF), and 30 GeV rapid-cycling synchrotron (Main Ring, MR) which provides proton beams to Nuclear and Particle Physics Facility. At Nuclear and Particle Physics Facility, nuclear and particle physics experiments are performed using high-intensity beams such as the kaon beam, pion beam, neutrino beam as well as the primary proton beam.

MLF is a user facility for extensive scientific programs covering condensed-matter physics, materials sciences, industrial applications, structural biology and nuclear/particle physics by providing the world's highest flux of neutrons and muons. The proton beam from RCS cascades the graphite target for muons and reaches to the mercury target for neutrons.The proton beam power of MLF, which determines the flux of neutron and muon beam, was ramped up from 600 kW to 700 kW in April 2021. To accept the high power pulsed (microsecond) proton beam, developments of the neutron target system are on-going [Quantum Beam Science, **1**(2) 8 (2017)]: robustness and life span diagnosis should be established for stable operations. It is expecting that the proton beam power will be ramped up to 800 kW next year and 1 MW operation is going to be realized in 2024.

With its more intense, brighter source of neutrons and muons as well as world-class instrumentation, MLF provides the neutron and muon communities with unprecedented research opportunities. MLF allows for measurements of greater sensitivity, higher speed, higher resolution, and in more complex sample environments than have been possible at existing neutron and muon facilities. In the neutron facility [Quantum Beam Science, **1**(3) 9 (2017)], there are 23 beam holes and 21 instruments under operation for user program and one is under commissioning. In the muon facility [Quantum Beam Science, **1**(1) 11 (2017)], 3 beam lines are under operation for user program and one in under commissioning.

Since the neutron has a mass that is similar to that of the hydrogen atom, a magnetic moment but no electric charge, and a high penetrating power, the neutron can sensitively probe spin correlations, and the location and motions of atoms, especially hydrogen atoms, in materials. These characteristics of the neutron make neutrons to play crucial roles in many subjects like studies of the locations and motions of hydrogen atoms in biological cells, which is of particular interest in life science. Recent publications are picked up as follows: Spin texture induced by non-magnetic doping and spin dynamics in 2D triangular lattice antiferromagnet h-Y(Mn,Al)O_3 [Nat, Comm. **12** 2306 (2021)], Crystallization of magnetic skyrmions in MnSi investigated by neutron spin echo spectroscopy [Physical Review Research **2** 43393 (2020)], Development of a new cooling technology using solid refrigerants [Nature **567** 506 (2019)].

The positive muon (μ+) behaves as a light radioisotope of the proton in matter. Because of its large magnetic moment (up to three times that of proton), implanted positive muons have a wide variety of applications to materials science and biology in a fashion similar to nuclear magnetic resonance (μSR). Muonic X-rays are emitted after a negative muon (μ–) is captured by the nucleus of an atom. During this cascading process, characteristic muonic X-rays are emitted depending on the atom that captures the muons and the energy difference among orbits. Recent publications are picked up as follows: Na diffusion in hard carbon studied with positive muon spin rotation and relaxation [ACS Physical Chemistry Au 10.1021/acsphyschemau.1c00036] , Deexcitation Dynamics of Muonic Atoms Revealed by High-Precision Spectroscopy of Electronic K X Rays [Phys. Rev. Lett., **127** 053001 (2021)], Nondestructive High-Sensitivity Detections of Metallic Lithium Deposited on a Battery Anode Using Muonic X-rays [Anal. Chem. **92**, 8194 (2020)].

Promotion of industrial use is also one of the important mission of J-PARC. MLF plays a central role fot the mission. Besides accepting the general proposal from industries, collaborative research agreements are in place to promote research with industries. For example, development of neutron scattering techniques and their application to functional materials with Sumitomo Rubbers Industries, and characterization and evaluation of Fuel cell, Power Control Unit and Li-ion battery with Toyota central Laboratory. Variety of technique are used and developed within collaborations. Also, Functional Polymer Consortium was formed combining 6 academia (universities and institutes) and 5 campanies aiming at understanding the interaction between polymer and water. These activities resulted in scientific papers. To explore new areas of neutron and muon by promoting collaboration between academia and industry, the annual meeting of industrial application at J-PARC MLF was held as an online meeting in 2021. This meeting is be coming an important communication channel between the industrial society and MLF for sharing information and to discuss for practical use of neutron technique in the industry. 352 participants including 150 from industries at tended. Several talks on facility report, status on industrial use and its expectation, and advance d scientific case were presented. Year after year, the presentations from industires refer to the deeper aspects of measurement and analysis methods.

MLF is available to researchers from all over the world with varying degrees of experience. The call for general use proposals is made twice in a year. For the experimental periods from January 2022 to March 2022 (2021B term), we have 411 neutron proposals. The portion of the proposals from foreign countries is 37%. Submitted research proposals are reviewed by international scientists and 169 proposals had been approved for beam time. Operation days in a year is about 160 days and more than 1000 users are performing experiments in our facilities.

Informations of MLF including publication lis t can be found in the home page [https://mlfinfo.jp/en/]. We are looking forward to enjoying research at MLF with you!

Prof. Toshiya Otomo

MLF Division Head, J-PARC center /
KEK IMSS

Report 2: Asia-Pacific Center for Theoretical Physics (APCTP)

First, I would like to congratulate the launching of the Division of Condensed Matter Physics (DCMP) in the AAPPS that has been a long waited homework of the AAPPS. It is also my great pleasure to introduce the APCTP to the members of the newly launched Division of CMP.

I think it will be best to begin this article by telling you the brief history of the Asia-Pacific Center for Theoretical Physics (APCTP) and the Association of the Asia-Pacific Physical Societies (AAPPS), and their relationship. The AAPPS was founded in 1990 with the first president C. N. Yang. Then, in 1994, the AAPPS together with the IUPAP, ICTP supported the establishment of the APCTP in Korea, and two years later in 1996, the APCTP was established in Seoul, Korea, with the first president C. N. Yang.

As you noticed, two organizations share the same founding president, C. N. Yang and we also share several founding members such as Y.M. Cho, K.K. Phua. For the record of history for future generations, I would like to emphasize that the above mentioned three persons, C.N. Yang, Y.M. Cho, and K.K. Phua should be remembered for their far-reaching foresight and pivotal role in establishing the AAPPS and APCTP. Everything has started with their vision and passion to establish the physics community of the Asia-Pacific region as an independent and integrated regional community. Currently, the AAPPS consists of 18 member societies in the AP region and the APCTP consists of 17 member countries. And there is a large overlap of member countries such as Australia, China, India, Japan, Kazakhstan, Korea, Malaysia, Mongolia, Philippines, Singapore, Taipei, Thailand, Uzbekistan, and Vietnam. Naturally, two organizations also share the same mission: namely, the promotion of physics in the AP region through the cooperation of regional physicists and regional societies/institutes. Since 2016, the headquarter of the AAPPS is hosted in the APCTP in Pohang.

The APCTP being a research institute for theoretical physics has more specific missions: (1) play the role as the hub-center for theoretical physicists of the AP-region; (2) pursue the excellence of the in-house research in collaboration with the AP community as well as the International community of physics; (3) play the training center for the young researchers from the AP-region, in particular, from the less-advanced countries.

To achieve the missions above, we are organizing every year more than 50 conferences and workshops covering all major disciplines of theoretical physics such as high-energy and particle physics, condensed matter physics, nuclear physics and astrophysics, statistical and biophysics, etc. The organizers of these activities are mostly from the physicists of the AP region. On average, about 70 % of these academic activities are held in Korea and about 30% of them are held abroad in the AP countries. Needless to say, the invited speakers and participants of these activities are not limited to the AP-region but from all over the world. Every year, more than 4,000 physicists participate in these conferences and WSs. For mission (2) above, we are running 10 research groups, called the Junior Research Group (JRG), covering the wide range of theoretical physics listed above. For mission (3) above, we have the young postdoc fellow positions called YST (Young Scientists Training) program with which we attract talented young physicists from the AP region. Currently, this program is supporting 12 fellows. Over the last 26 years since 1996, the APCTP has been well established in the international physics community and is being recognized as an indispensable institute representing the Asia-pacific physics community.

More relevant for the DCMP are our cooperation activities with the AAPPS. Among others, since 2017, the APCTP has directly supported the building up of the Division structure in the AAPPS. As a result, until last year we have helped to build three divisions such as DPP (Division of Plasma Physics), DNP (Division of Nuclear Physics), and DACG (Division of Astrophysics, Cosmology, and Gravitation). And the DCMP is the fourth Division in the AAPPS and this is indeed the long-waited division because Condensed matter physics forms the largest community in any physics community. I think that the launching of the DCMP is truly a great event in the history of the AAPPS, if you remember the short history that I have described above. With the DCMP, the AAPPS will make one more great jump toward its founding mission. I am sure that already many of the DCMP members have participated in many of the Conferences and WSs organized by the APCTP. In the future, I expect more active participation and leading role of the DCMP in AAPPS with the APCTP.

Another very important cooperation between the APCTP and AAPPS is the publication of the AAPPS bulletin journal. The AAPPS Bulletin was launched in 1991 and since 2011 the APCTP is managing its publication process. The main function of the Bulletin has been to deliver newsletters of the AP community and some review articles. However, since 2019, the editorial board of the Bulletin and the APCTP have agreed to upgrade and transform the Bulletin as a scientific journal representing the Asia-Pacific Physics community, while keeping the newsletter function together. To speed up this transformation, since 2021 we have hired the commercial publisher, Springer-Nature, to use their professional services for publication process, distribution network, and journal indexing management, etc. The visibility of the Bulletin journal is rapidly increasing as a science journal and we are now soliciting high-quality review papers and research papers. I hope that the members of the DCMP contribute your papers to the AAPPS bulletin and let us work together to make a representative physics journal of the AP physics community.

Finally, I would like to express my gratitude to the members of the DCMP for your effort and efficient leadership for successfully launching the DCMP, which has all started only two years ago at the APPC14 conference in Kuching, Malaysia in 2019. I have no doubt that the DCMP will grow rapidly to be an important player in the international condensed matter physics community, and I hope you remember the founding vision and missions of the AAPPS and the APCTP during the journey of making your own history.

Prof. Yunkyu Bang
Asia Pacific Center for Theoretical Physics (APCTP)

Topical research issues

Superconductivity at a new oxide interface

Subtilte: *The (EuO or $LaAlO_3$)/$KTaO_3$ interface is alike the seminal $LaAlO_3$/$SrTiO_3$ interface, but not the same.*

Oxide interface superconductor, represented by the seminal $LaAlO_3$/$SrTiO_3$ interface, was discovered fourteen years ago(*1–3*). Very recently, a new family of oxide-interface superconductors were found at the interfaces between $KTaO_3$ and other oxides (EuO or $LaAlO_3$)(*4–8*). These new oxide interfaces are alike the $LaAlO_3$/$SrTiO_3$ interface. For example, in all of them the conduction, and thus the superconductivity, is formed between two oxide insulators. Both of the mother materials, $SrTiO_3$ and $KTaO_3$, are widely used as substrates in growing oxide films, and share many common features such as the crystalline and electronic band structures. However, the (EuO or $LaAlO_3$)/$KTaO_3$ interface indeed shows a few unusual features that make it distinct from $LaAlO_3$/$SrTiO_3$. Thus one may call it the second generation oxide interface superconductor. In the past nearly two years we have been endeavoring to unveil its mystery.

1. Strong dependence on the crystalline orientation of $KTaO_3$

In 2011 Iwasa and Kawasa groups(*9*) made the first report of superconductivity in $KTaO_3$. They gated the surface of $KTaO_3$(001) surface using ionic liquid, and found a T_c ~50 mK superconductivity. After that, there was a decade of silence until very recently Bhattacharya group(*4*) discovered superconductivity at the $KTaO_3$(111) interface, with an optimal T_c ~2.2 K, a big leap from the aforementioned 50 mK. In contrast, they detected no superconductivity at the $KTaO_3$(001) interface down to 25 mK. At almost the same time, our group(*6*) found a T_c ~0.9 K superconductivity at the $LaAlO_3$/$KTaO_3$(110) interface. It is worthy to point out that the sheet carrier densities of the interfaces of the three different orientations are actually comparable. Note that the (001), (110), and (111) are the three principal crystalline orientations of $KTaO_3$. This unusual strong dependence of superconductivity on the orientation of $KTaO_3$ is quite interesting, but its origin is still unclear. Moreover, this dependence, together with the fact that the superconductivity was detected only at surface and interface of $KTaO_3$, leads to a speculation that in this new family the surface and interface play a more intrinsic effect than that in the $LaAlO_3$/$SrTiO_3$ interface.

2. Origin of the interfacial conduction

It is interesting to ask what accounts for the conducting electrons at the interface. In the seminal $LaAlO_3$/$SrTiO_3$ interface the answer of this question is still under hot debate. But it seems to be simpler for the $KTaO_3$ interfaces. Because neither EuO or $LaAlO_3$ are epitaxially grown on $KTaO_3$, one can safely exclude the polar discontinuity and electronic reconstruction

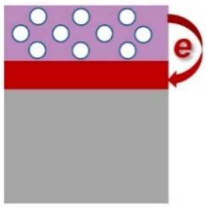

Fig. 1. Schematic of electron transfer.

model. From experiments one can easily see that oxygen vacancies play a key role. The remaining question is which oxygen vacanices, the ones in film and in $KTaO_3$, are crucial. By in-situ transport measurements during growth, we found that, at least for the $LaAlO_3$/$KTaO_3$ interfaces, the crucial ones are these in the $LaAlO_3$ film(*8*). As schemed in Fig. 1, the conduction electrons are controlled by the electron transfer from the oxygen vacancies in the $LaAlO_3$ film to the $KTaO_3$ layer near the interface.

3. Controlling the superconductivity with electric field

Controlling superconductivity with an electric field is very appealing but also a long-standing challenge. So far successful tunings (fully suppressing superconductivity) have been achieved only in a few systems and all of them, including $LaAlO_3/SrTiO_3$, tuned the superconductivity by changing carrier density. We have demonstrated a surprisingly prominent control of the newly discovered $LaAlO_3/KTaO_3$(111) interface, and found that the tuning

mechanism is the effective disorders felt by the carriers, rather than the carrier density(*7*).

3.1 A new tuning mechanism

Our device configuration apparently looks the same as a conventional field-effect device. With varying gating bias V_g, the interface can be tuned continuously from a superconducting state to an insulating one. However, the conventional field effect is not expected to largely change the conductance of the present interface because its carrier density is high, and the dielectric constant of $KTaO_3$ is not large enough. Indeed we found that in our study the electric gating has only a minor effect on carrier density, but a strong one on mobility. As schemed in Fig. 2, we interpret the result in terms of change in the spatial profile of the carriers in the interface and hence, effective disorder. There are more disorders in the region where is closer to the interface. In this viewpoint, the tuning effect is achieved by the interplay between carriers (electrons and Cooper pairs) and disorders.

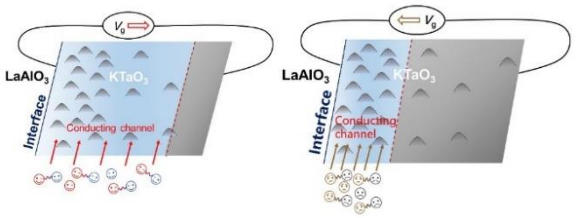

Fig. 2. Schematic of electric field effect on the $LaAlO_3/KTaO_3$(111) interface.

3.2 Quantum metal

Due to the nature of this tuning, a few exciting phenomena associated with disordered two-dimensional superconductors were revealed. A true superconducting ground state is absent. Below the superconducting T_c, a residual saturating resistance, which varies with V_g in orders of magnitudes, emerges in both superconducting and insulating sides. That residual resistance, often called quantum metal, has been observed in many systems, but rarely seen to be largely tuned as in the present $LaAlO_3/KTaO_3$(111) interface.

4. Outlook

Given its similarity and dissimilarity with the classic $LaAlO_3/SrTiO_3$ interface, one may directly extend many previous critical studies in $LaAlO_3/SrTiO_3$ to the present new oxide interface, still with a large advantage to gain new insights and applications. The new interface also provides a unqiue platform to study the rich physics involving the interplay between disorders and cooper pairs. The lack of superconductivity in bulk electron-doped $KTaO_3$ indicates that the surface and interface have a vital effect on the occurrence of superconductivity. However, shall we regard them as indispensable? A simple estimation shows that the three-dimensional carrier concentration at the interface is considerably higher than that had been achieved in the doped bulk $KTaO_3$(*10*). It would be very interesting to see if superconductivity can occur or not when more electrons are doped to the bulk $KTaO_3$.

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DCMP
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Reports on new results/important discoveries

Report 1: Colossal angular magnetoresistance in a new topological magnet

Topological magnets, where both magnetism and topological electronic states coexist, have emerged as a new class of materials for next-generation spintronic applications. In topological magnets, their symmetry-protected band degeneracy can be readily controlled by modulating spin configurations or orientation. This unique character endows topological magnets with a promising material platform to realize efficient magnetic control of electronic conduction, useful for electronic and spintronic applications.

A research team led by Prof. Jun Sung Kim (Center for Artificial Low Dimensional Electron Systems within the Institute for Basic Science (IBS), South Korea; Physics Department at Pohang University of Science and Technology (POSTECH), South Korea) discovered a new magneto-transport phenomenon, named as colossal angular magnetoresistance (CAMR), in a ferrimagnetic nodal-line semiconductor $Mn_3Si_2Te_6$ [1]. Unlike the large angular magnetoresistance, previously reported in various magnetic materials, a huge change in resistivity is induced by rotating the net magnetic moment, while keeping the magnetic phase intact. This unprecedented transport property is due to the nodal-line band degeneracy of spin-polarized bands, together with the spin-orbit coupling effect, in magnetic semiconductors.

This research has started from the idea based on their previous report on magnetic nodal-line semimetal Fe_3GeTe_2, in which the lifting of the nodal-line degeneracy of spin-polarized bands depends on the spin orientation [2]. Exploiting this characteristics of nodal-line band degeneracy, the research team has proposed the concept of magnetic nodal-line semiconductors, which

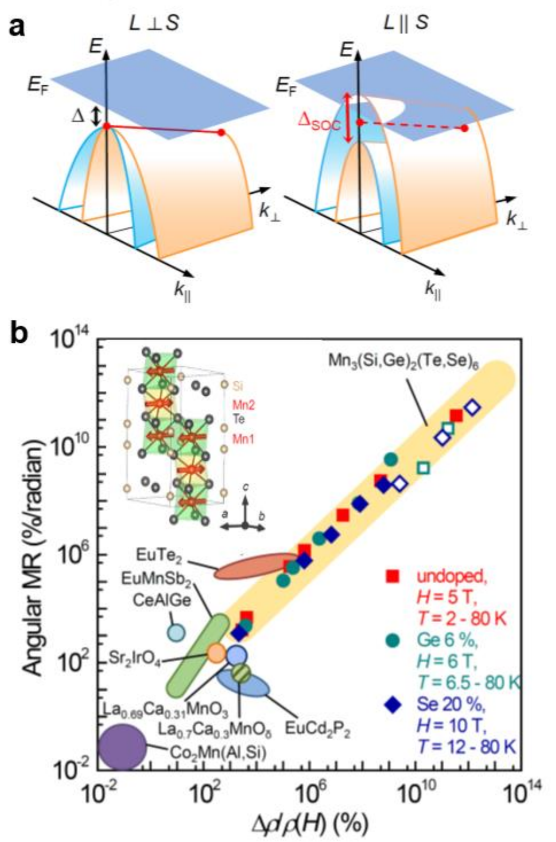

Fig. 1. (a) Schematic illustration of insulator-to-metal transition by lifting the nodal-line degeneracy with spin rotation. (b) Angular magnetoresistance and magnetoresistance for various magnets.

possess the nodal-line band degeneracy in conduction or valence bands. In this case, the lifting of band degeneracy by spin rotation can close the band gap and induce an insulator-to-metal transition with a huge change in magnetoresistance.

Such a proposal is realized in a layered ferrimagnet $Mn_3Si_2Te_6$. Based on first-principles calculations and symmetry analysis, the research team identified the nodal-line band degeneracy in a valence band of $Mn_3Si_2Te_6$. Using high-quality single crystals of $Mn_3Si_2Te_6$, they experiemetally observed a huge variation of magnetoresistance with rotating magnetic field, reaching a billion times difference. The opening or closing of the electronic gap by spin rotation has been further confirmed by terahertz absorption spectroscopy. These results provide compelling evidence that the nodal-line band degeneracy is responsible for inducing CAMR in $Mn_3Si_2Te_6$.

The newly discovered CAMR is expected to be used in extremely sensitive vector magnetic sensing or efficient electrical readout of spin information. Moremore, the CAMR is considered a common transport property of magnetic nodal-line semiconductors. These unique characteristics establish magnetic nodal-line semiconductors to be a promising platform to realize extremely sensitive spin- or orbital-dependent functionalities.

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Prof. Jun Sung Kim
Pohang University of Science and Technology, Center for Artificial Low Dimensional Electron System, Institute for Basic Science

Report 2: Giorgio Parisi: Physics Nobel Laureate 2021

Giorgio Parisi is one of the pioneers in the field of statistical mechanics. He is also probably one of the most versatile living physicists who has worked in the areas, ranging from physics of sub-atomic particles to molecules, animal migratory behavior to climate science, computer sciences, etc. Parisi made seminal contributions in all the above-mentioned fields with a very high degree of innovation. His contributions in these different areas had an overarching effect on the future development of science in general. This year he has been awarded the most prestigious Nobel prize for his "discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales"[1].

In this short article, I want to highlight some of the seminal works that he has done and their implications in the field. His works on disorder systems, particularly the spin-glass problem and his famous replica symmetry breaking ansatz[2] are probably one his most influential works. Spin glasses are magnetic systems with local static impurities (quenched disorder) together with disorder coming in terms of frustrations in the ferromagnetic and anti-ferromagnetic interactions between interacting spins in the crystal. These systems show a sudden freezing of the spin directions below a critical temperature (Tc) with no detectable long-range order in the spin orientation. This led to the discovery of a new type of phase transition in magnetic materials whose physics are very non-trivial to understand using the standard statistical mechanics frameworks and the famous Landau-Ginzberg theory of phase transition. As quenched disorder plays an essential role in these systems, a new method was devised (known as the replica trick) to compute the free energy of the system. It turns out that if one considers replica symmetric solutions for a model of spin glass (e.g. the well-known Sherington-Kirkpatrick model [3]), then one indeed observes an emergence of spin-glass phase with non-zero value of the Edward-Anderson order parameter [4] below Tc, and zero above. But one of the major problems of this solution is that the entropy of the spin-glass phase becomes negative at lower temperatures, and the whole spin-glass phase becomes unstable. This is when Parisi's work [2] came to the rescue and solved the abovementioned issues. He proposed breaking the replica symmetry and considering the spin-glass phase to be a replica symmetry broken state, signaling a major change in the physics concept. He then offered how to correctly perform the replica symmetry breaking calculations leading to the correct free energy of the system. Later this was shown mathematically to be the exact procedure for the SK spin-glass model [5]. Thus replica symmetry breaking ansatz of Parisi is still the only method to obtain the essential physics of various spin-glass model systems. However, a rigorous proof for general model systems is still lacking. It is important to mention that there are many competing theories for the spin-glass transition – the most famous being the Droplet theory [6]. This theory suggests that the spin-glass phase is a unique ground state of the problem in short-range models, and the phase completely disappears even under a small magnetic field. Some of these controversies remain unresolved to date, although there are big computational efforts to resolve them in the near future, the most talked-about one being the Janus project [7].

Next, I want to briefly discuss yet another seminal work of Parisi that played an important role in climate modeling, for which Syukuro Manabe and Klaus Hasslemann got the other half of the Nobel prize. This suggests that Parisi's work indeed encompasses a broad spectrum of complex systems. The title of the work is

"*Stochastic resonance in climate change* [8]". The main achievement of this work is that this work, for the first time, predicted a plausible answer for the periodic appearance of an ice age in the earth with a periodicity of 10^5 years as time series of continental ice volume variation over last 10^6 years shows that glaciation sequence has a periodicity of about 10^5 on average. Now the question is, what is this astronomically long timescale? The answer turns out to be the modulation period of the earth's orbital eccentricity primarily caused by the planetary gravitational perturbations. This modulation of earth's orbital eccentricity results in variations of total solar energy flux that incident on earth at about 0.1%. Then the question is whether enhancement of climate sensitivity to such a small external periodic perturbation is possible or not? Parisi and collaborators were able to show that a stochastic process coupled to a small periodic perturbation can lead to resonance-like phenomena where the system flips back and forth between two stable states under the stochastic noise with the same periodicity of the small external periodic perturbation. The phenomenon later turned out to be ubiquitous in nature and plays an important role in various complex systems, including many biological processes in our body.

This article will not be complete if the famous Kardar-Parisi-Zhang (KPZ) equation for the growth of an interface is not discussed, at least briefly. In short, the KPZ equation teaches us about the static and dynamic properties of growing interfaces, which can occur in various situations like the growth of smoke and colloid aggregates, flame fronts, tumors, bacterial colony etc. [9]. This phenomenon is so general that many growth processes in nature can be mapped back to the KPZ model leading to the categorization of the KPZ universality class in the Renormalization Group sense.

Finally, I want to end this article by sharing some of my personal interactions with him as my postdoctoral mentor. Giorgio is probably one of the smartest (scientifically) persons I have ever interacted with until now. Just to highlight one occasion, when Prof. G Szamel from Colorado university was visiting Giorgio, we had a joint discussion. Then Giorgio wrote down a differential equation that both Szamel and I had not seen before, and he then explained the origin of this equation. Near the end of the discussion, Giorgio thought for some time and suddenly wrote down the possible form of the solution of this complicated differential equation. We then worked through the night to see whether the proposed solution of Giorgio satisfies the differential equation. We were amazed that it did. The next day, Prof. Szamel said that either Giorgio is a genius or knew the solution beforehand. My take will be that he is a genius; otherwise, it will be tough to explain how he managed to finish his doctoral thesis with Prof. Nicola Cabibbo at the age of 22 years. Despite being one of the best scientists, he is a very down-to-earth person and very affectionate. I have not ever seen him becoming angry on anything; he is undoubtedly a noble human being.

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Report 1: Non-volatile and Reversible Optical Control of Multiferroicity at Ambient Temperature

Optical control of multifunctionalities is the cornerstone towards modern technology and beyond. However, controlling multiple ferroic orders (ferroelectricity, ferroelasticity and ferromagnetism) via optical method is always challenging, since the correlation between light stimulus and the order parameters is "loose". Thus, controlling of ferroic orders and phase stability in ferroic/multiferroic materials is of significant importance not only for fundamental scientific research but also for development of next-generation nanoelectronics. In this report, we review our recent achievement upon deterministic and reversible optical control of multiferroic $BiFeO_3$ *thin films using continuous-wave and pulsed lasers, via which all-optical non-volatile control of phase and ferroic orderings at room temperature is successfully demonstrated.*

The past decade has witnessed the prosperity of optoelectronics. The utilization of opto-electronic devices has shown its impact in photodetector, energy harvesting, display, catalytic applications and so on. Additionally, the opto-magnetism has exhibited significant potential with respect to data storage and information technology. Nevertheless, given that the reversible and non-volatile modulations to the interaction of photons with charge, spin, orbital, and lattice degrees of freedom are often elusive, deterministic control of electric, magnetic, and elastic ordering by means of light has never been an easy task. From energy point of view, the energy scales for exchange coupling, spin-spin and spin-orbital interactions, ranging from a few μeV to meV, are always significantly lower than the energy of a single photon in visible spectrum, which is usually about a few electron volts. In such a scenario, the huge discrepancy in required energy makes the reversible and non-volatile switching too subtle to be directly manipulated by external light stimulus, and thus usually gives rise to the major consequence of local heating or electronic excitation caused by the absorption of photons. As a result, the mismatched requirement in energy has hindered relevant development of optically-controllable non-volatile applications such as logic and memory devices.

To overcome aforementioned obstacles, optical modulation through tuning complex interactions such as the delicate combinations of thermal effect, electronic excitation, electric field, polarity of light and ultrashort laser pulse have been exploited.[1-5] For example, all-optical magnetic recording based on GdFeCo amorphous alloy can be achieved via the combination of circular polarity and laser pulse.[1] Control of antiferromagnetic domain distributions in MnF_2 has been accomplished by polarization-dependent optical annealing.[6] Taking advantages of the transfer of angular momentum from the light to the magnetic materials and the effective field created by the polarized laser pulse via inverse Faraday effect, interaction between magnetic systems and light has led to helicity-dependent magnetization switching.[3] Using light pulses with different colours, the antiferromagnetic order parameter in $TbMnO_3$ can be reversibly altered at low temperature.[2] Extension of the similar concept to multiferroic materials that possess coupled order parameters is remarkably appealing, given that the deterministic optical control of multiferroicity could lead to the modulation of multiple functionalities driven by the electric or magnetic orderings. Nevertheless, all-optical control of multiferroicity has rarely been reported.

In our previous work published in *Nat. Mater.* **18**, 580-587 (2019),[7] we chose multiferroic $BiFeO_3$ (BFO) thin film as a model system to demonstrate the all-optical control of room temperature multiferroicity. BFO possesses both ferroelectric and antiferromagnetic properties at room temperature (the Curie temperature is ~1,103 K, and the Néel temperature is ~673 K), which has long been widely studied as a promising candidate for next-generation nanoelectronics.[8] The <111>-oriented ferroelectric polarization in BFO directly correlates with the G-type antiferromagnetism as well as a weak ferromagnetic moment resulting from Dzyaloshinskii–Moriya interaction. Namely, the rotation of the ferroelectric polarization in BFO would give rise to corresponding alteration of the (anti)ferromagnetism at room temperature. Additionally, the strong magnetoelectric coupling in BFO has promised the potential application towards low-electric-field control of magnetism.

When significant compressive strain is applied on BFO, it becomes a mixed-phase system composed of tetragonal-like (T-BFO) and rhombohedral-like (R-BFO) BFO phases (see Fig. 1). The mixed-phase BFO shows significant piezoelectricity and enhanced magnetism that are proved to be controllable via various external stimuli.[9] The phase transition energy

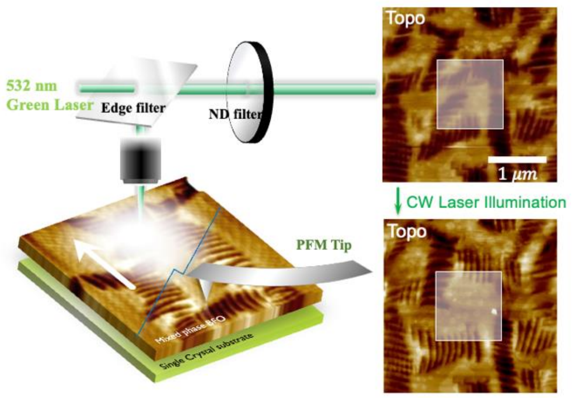

Fig. 1 Optical modulation of the highly-strained mixed-phase BFO thin film. Adapted from Ref. 7.

in such a mixed-phase system is relatively low so that one can alter the phase stability by applying an electric field or stress, as reported by previous publications.[9] As a result, it is straightforward that the direct manipulation of the polarization and domain structures in BFO by means of light could lead to the non-volatile optical control of ferroelectricity, antiferromagnetism as well as the correlated ferromagnetism, i.e. multiferroicity.

The left panel shown in Fig.1 shows the schematic of the experiment setup: a 532 nm solid-state continuous—wave (CW) laser is adopted as the light source, while the linearly polarized laser spot is focused into a size of 2 μm by 2 μm. After the illumination of CW laser, the resulting area eventually becomes a squared-like topography composed of flat T-BFO region inside the illuminated area and mixed-phase stripes at the edge of illuminated area. The light illumination effectively results in the reconstruction of the as-grown mixed-phase structure of BFO thin films, turning the originally random distribution of T-BFO and R-BFO into a well-ordered configuration.

After careful examination, the consequence is attributed to a combination of flexoelectric and thermal effects under laser illumination, as revealed by Raman spectroscopy and scanning probe microscopy. Additionally, phase field simulation also suggests that the flexoelectric field resulting from laser illumination dominates the nucleation of the rearranged ferroelectric domains in mixed-phase BFO. The experimental and simulated results are shown in Fig. 2.

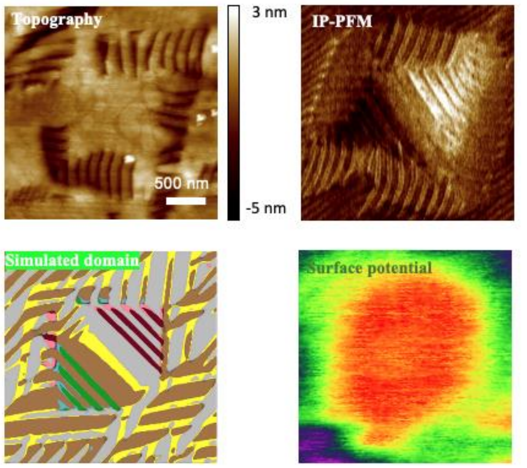

Fig. 2 Topography, IP PFM, phase field simulation and surface potential images of the light induced domain structure. Adapted from Ref. 7.

Through the precise control of illumination process, formation and erasure of the different domain structures have been accomplished. Additionally, we further demonstrate the non-volatile and deterministic control on the piezoelectricity and conductivity.[7] This work establishes an efficient optical method to control the ferroelectricity and magnetism of complex materials at ambient temperature, without any aid of external electric and magnetic fields.

In contrast to our previous work based on the adoption of CW-laser, our work published this year, *Adv. Mater.* **33**, 2007264 (2021),[10] has further developed a highly distinctive scenario: using ultrafast and nanosecond laser "pulse" to fulfill non-volatile control on extremely fast timescale. As shown in Fig. 3, we demonstrate all-optical manipulation of the complex phases and domain structures in mixed-phase BFO thin films by the illumination of extremely-short light pulses. The underlying mechanism of fast phase transformation is ascribed to the

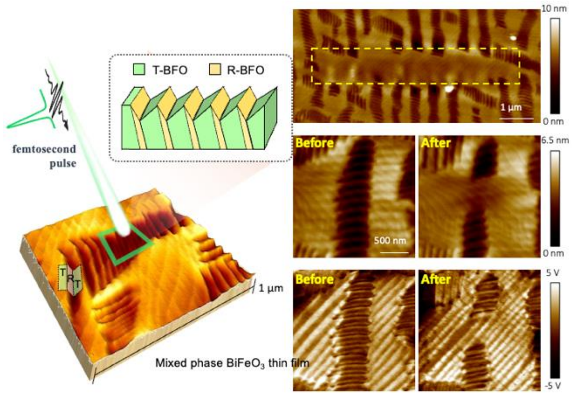

Fig. 3 Laser pulse induced changes in mixed-phase BFO. Adapted from Ref. 10.

instantaneous strain perturbation induced by light stimulus, as revealed by dynamic studies of scanning probe microscopy, thermal transport simulation and ultrafast optical pump-probe spectroscopy. The scanning transmission electron microscopy observation combined with density function theory results suggest that the capability of rapid transformation is endowed by the martensitic phase transition in mixed-phase BFO. Moreover, the configuration of optically written ferroelectric domains can be further manipulated by tuning the competing elastic and electrostatic energies, as shown in Fig. 4.

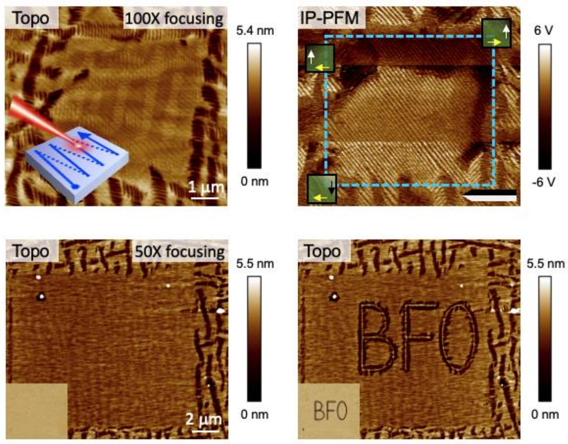

Fig. 4 Large-area ferroelectric domain manipulation via sequential pulse laser illumination. Adapted from Ref. 10.

In short, our recent works demonstrate that the illumination of CW and pulse lasers can be adopted to fulfill deterministic optical control of phase and the corresponding ferroic orders in multiferroics over a wide timescale range. Specific descriptions of relevant experimental and theoretical data are detailed in Ref. 7 and 10. Through this highlight report, we offer a brief overview of our recent works on optical control of multiferroicity. We hope the discoveries would not only trigger new inspiration for all-optical switchable devices, but also offer novel routes for development of high-speed multifunctional optoelectronics.

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Report 2: High-order topological insulators

The discovery of topological insulators shows that time-reversal symmetry protects a new type of band topology, urging scientists to reveal further connections between symmetry, dimensionality, and topology in band structures. Recent theoretical works have suggested that in insulators, topology protected by lattice symmetries can be understood in a hierarchy of orders: the n-th order topological insulator in d dimensions has topological gapless modes localized at $(d-n)$-dimensional edges. On this hierarchy, the time-reversal Z_2 topological insulators belong to the 1st-order. In 3D, a 2nd-order topological insulator has gapped surfaces, but along certain "hinges", where two crystalline surfaces meet each other, there run a pair of helical edge modes.

Physicists had known, before the discovery of topological insulators, that certain insulating states can have nontrivial "band topology", indicated by a particular number called the topological invariant. A topological invariant is similar to an order parameter in the sense that its nonzero/zero value indicates the nontrivial/trivial topology of given states. It is, however, drastically different from the order parameter in that (i) it does not change under symmetry operations or associate with spontaneous symmetry breaking, and (ii) it takes quantized values such as integers and Boolean numbers. The most prominent example of topological invariant is the Chern number C, also known as the TKNN number, expressed in terms of the Berry curvature [1-2].

Thouless *et al* [1] showed that this topological invariant is directly related to the Hall conductance in a quantum Hall state

$$\sigma_{xy} = Ce^2/h,$$

where e is the electron charge and h the Planck's constant. This was later extended to quantum anomalous Hall states by Haldane in a famous paper [2].

Besides this striking equality between a topological number and a physical observable, another essential implication of nontrivial topology is the presence of edge modes. In the case of Chern numbers, there are exactly $|C|$ gapless modes localized at the edges, and they propagate along the same direction. This correspondence between a bulk topological invariant and gapless edge modes is called the bulk-edge correspondence, playing a central role in the study of topological states of matter.

For many years, Chern insulators and topological states of matter in general have been considered applicable only to a limited number of systems. This is because a nonzero Chern number implies that time-reversal symmetry be severely broken, either by a strong magnetic field or complex hopping parameters. Nonetheless, in three papers in 2005 and 2006 [3-5], theorists have proposed an entirely different topological state in 2D. This state is now termed a topological insulator (TI), and it is indicated by a new topological invariant called the Z_2 index, ζ_{2D}. "Z_2" means that, unlike the Chern number, ζ_{2D} is Boolean, takeing 0 for trivial and 1 for nontrivial band topology, respectively. The essential feature of this new invariant is that it is not only *compatible* with time reversal, but also *requires* the presence of time reversal (TR) for definition. This topological invariant, and the topological state thereof, is called *symmetry-protected*, and in this particular case, TR-protected. In physical terms, this new topological state exists in the absence of magnetic field and in nonmagnetic materials. When $\zeta_{2D} = 1$, the edge states consist of two counterpropagating modes. The two modes are related to each other by time reversal, forming a Kramers' pair that are always twofold degenerate, so that the two cannot backscatter to open an edge gap. This pair of modes is called the helical edge modes, a hallmark of 2D TI. A 2D TI was proposed and realized in HgTe/CdTe quantum wells [6].

Soon after, three independent groups theoretically discovered another topological invariant ζ_{3D}, also Boolean, in 3D systems having time reversal [7-9]. The state hosting $\zeta_{3D} = 1$ is called a 3D topological insulator. The bulk-edge correspondence in a 3D TI is manifested as follows. Suppose we have a sample of 3D TI, then every termination of the sample has on any open surface a single, or an odd number of, Dirac cones. This Dirac cone is similar to the one in graphene, but spin non-degenerate due to the strong spin-orbit coupling.

This was the first time any 3D topological state was proposed, giving the field a great boost on the experimental front. This is because the Dirac-cone surface states of 3D TI are considered more readily observable than the helical edge modes of 2D TI. Well studied thermalelectrics Bi_xSb_{1-x} [10], Bi_2Te_3 [11] and Bi_2Se_3 [12] were predicted to be 3D TI, and their Dirac cones surface states were then confirmed in ARPES experiments [13-15].

On the theoretical frontier, more attention was then shifted to the topological states that are protected by symmetries other than TRS. These include the states protected by particle-hole symmetry, better known as topological superconductors [16], and also the states protected by lattice symmetries. The latter type are called the topological crystalline inisulators (TCI) [17]. Mirror-plane symmetry [18] and glide-plane symmetry [19, 20] were shown to protect two new topological invariants, namely the mirror Chern number and the hourglass-Z_2 number. Unlike in Chern insulators or TI, where the surface modes appear on each surface of the sample, for TCI, only terminations preserving the *same* crystalline symmetry exhibit gapless surface modes, while terminations having generic normal vectors are gapped (having no surface states). In Figure 1, a TCI with mirror Chern number $C_m = 2$ is shown with its surface states. The top/bottom surface has two Dirac cones, while the side surfaces are gapped. This seemingly consistent picture for the surface states of TCI has one sutble but crucial flaw: how are the top and the bottom surface states connected? If all the sides are fully gapped, the top-surface states are confiined to the top surface and similar are the bottom-surface states. But this is in direct contradiction to the bulk-edge correspondence, which states that all topological surface states (1D and higher) are *anomalous*, and as such cannot be confined to a single termination. This inquiry, in hindsight, was awaiting a new perspective.

In 2017, Benalcazar *et al* proposed that a 2D system with a "special symmetry", neither TR nor crystalline symmetry, may host a new topological state [21]. Suppose the state be cut into square geometry preserving two mirror reflections, then all four sides can be gapped without breaking the symmetry, while at the four corners where the sides meet, there are localized four modes of zero energy. Although the special symmetry makes that state difficult to realize in condensed matter, this work pointed out a new possibility for topological insulators, that the topological edge modes may reside, not on the $(d-1)$-edges, but on the $(d-2)$-edges, where d is the spatial dimension.

Later in 2017, Song *et al*, Schindler *et al*, and Langbehn *et al* independently proposed the theory for second-order topological insulators, realizable in 3D lattice and protected by crystalline symmetries [22-25]. In these papers, the side surfaces of a 3D state are considered, and a spatial symmetry (a fourfold axis plus TR $C_4 + T$ [22], the composition of fourfold axis and TR C_4T [23], or a mirror plane [24] sends one side surface to an adjacent side surface (Figure 1). Each side surface is gapped by itself, but there is relative "minus sign" between the gaps on surfaces related by the spatial symmetry. This makes the edge where the two surfaces meet gapless. Calculation shows that along the gapless edge run a pair of helical edge modes or one chiral edge mode, depending on the spatial symmetry. This picture completes the story of the previously mentioned mirror-protected TCI: on the side of the sample, there are two hinges connecting the top and the bottom, and along the hinges run the helical edge modes (Figure 1). A similar picture can be obtained for the cases of TCI protected by $C_4 + T$ and C_4T. The name "high-order TI", and in this case "2nd-order TI", was then coined to describe topological states having gapless modes localized at $(d-2)$-dimensional edges. The 1st-order TI then refers to topological states where each $(d-1)$-dimensional edge has gapless modes.

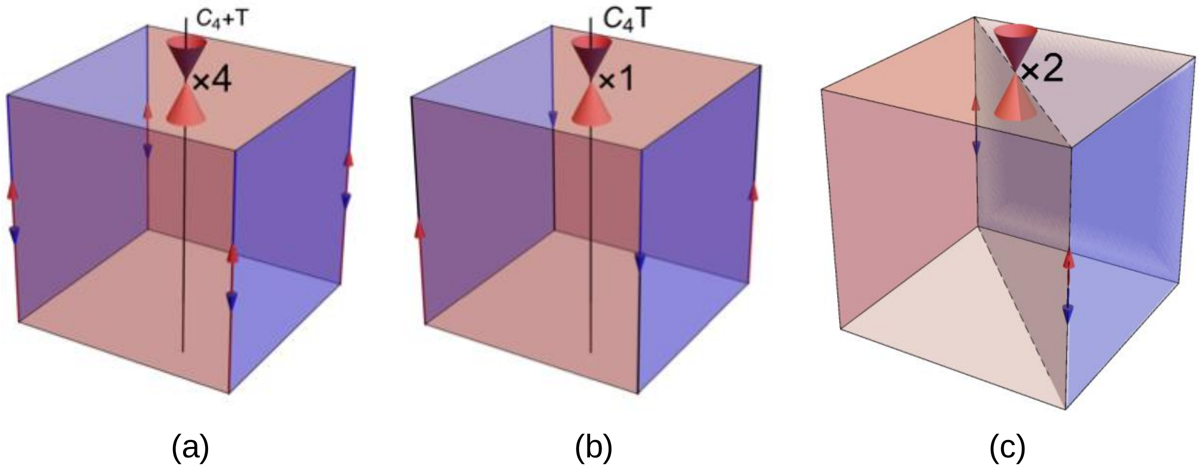

Figure 2: Topological edge states of 2nd order TI protected by (a) Fourfold axis and time reversal, (b) fourfold-axis composed with time reversal, and (c) mirror plane (a diagonal, colored plane.

What is the topological invariant describing a 2nd-order TCI? The answer depends on the symmetry that protects it. For TCI protected by mirror reflection, we already know the topological invariant is the mirror Chern number [25], and for TCI protected by C_4T, the topological invariant is also the known axion-Z_2-index [26]. The TCI protected by $C_4 + T$ indeed has a new Boolean topological invariant that has not been discussed previously. From these examples, we see that 2nd TIs are not necessarily "new states" in terms of topological invariants. Some of these states were known in the literature, only that the $(d-2)$-dimensional edge states had been overlooked by many. Since then, many other symmetries are found to protect 2nd-order TI, including a 2-, 4-, 6-fold (screw) axis, a glide plane, a roto-refection, the inversion, and many others. In fact, nearly all topological states protected by crystalline symmetries are 2nd-order, and the name TCI can almost identify with 2nd-order TI.

The concept of 2nd-order TI suggests a hierarchial way to classify the topological states (Figure 2). Consider a d-dimensional topological state with open boundary, and the boundary consists of $(d-1)$-faces, $(d-2)$-edges, $(d-3)$-vertices etc.. Then this state is of nth-order if the $(d-1)$-, $(d-2)$- … $(d-n+1)$-boundary can be gapped without breaking any symmetry, but at least one piece of the $(d-n)$-dimensional boundary remains gapless. For insulators, this hierarchy only goes to the 2nd-order for in 3D, but for superconductors, it goes to the 3rd-order, where the faces and edges of a topological superconductor can be fully gapped without symmetry breaking, but there remain gapless Majorana zero modes at the vertices.

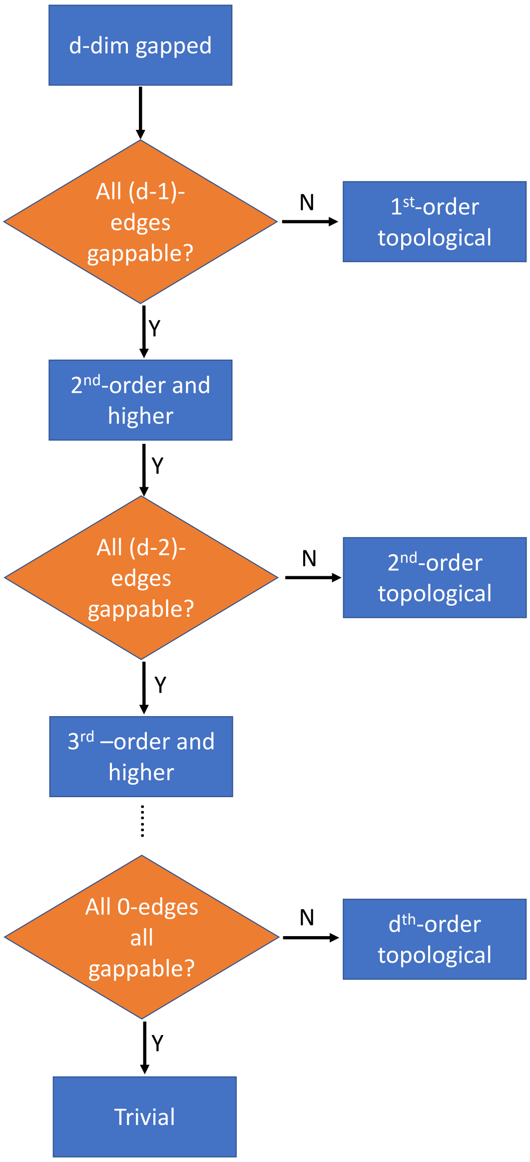

Figure 3: Hierarchy of topological insulators in d dimensions.

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Meeting/conference reports

AC2MP2021: The Asia-Pacific Conference on Condensed Matter Physics was held in online from 1st Dec. to 3rd. Dec. 2021. This is the first major event of the DCMP:Division of Condensed Matter Physics and creates the opportunities for interactions and collaborations among researchers in the field of condensed matter physics in the Asia-Pacific region. Given that international exchange has been difficult due to pandemics over the past two years, it is menaingful to hold this event at this time.

There have been 12 scientific sessions, three tutorial talks, one sponser session and one poster session. 10 kenotes, 15 invited and 16 young researcher invited talks as well as 10 contributed talks were presented. The number of the poster was 31. The number of the registered participants was 372. Participants mainly belong to the Asia-Pacific region, but there were also participants from other continents such as Afirca. The details of the program is as follows.

Day1-December 1st. The conference began with the opening ceremony at 11:00 am, and at the beginning, Dr. Je-Geun Park, the Chair of DCMP, gave the opening remarks, and the processes of forming the division and of leading up to this conference were briefly introduced. After that, Dr. Yokoyama, the President of AAPPS: Association of Asia-Pacific Physical Soceties, gave a congratulatory address. The two parallel sessions started after the ceremony. Four invited talks by young researchers were given in sessions of "2D Material and Spintronics" and "Skyrmion and Magnetism of Molecules". In the lunch time, Prof. Ogata gave a toutorila talk on "Dirac Electrons in Solids".

In the afternoon, the 1st session was on "Topological Physics in Solids and 2D Materials", which is one of the most active fields in condensed matter physics. There were two keynote talks by Prof. Zhang: Quantum Anomalous Hall Effect in an Intrinsic Topological Insulator and by Prof. Cheong: Optical Spectroscopy of Antiferromagnetic 2-Dimensional van der Waals Materials, which were followed by three invited and one contributed talks.

After the session, there are breakout and mixing times. In the main hall, Dr. Ania Wronski, IOP Publishing, talked "How to get published" for young researchers and students. In the evening, the 2nd session on "Strongly Correlated Electron System and Novel Magnetism", which is also one of the most active areas, was hold. Dr. Lee and Dr. Kusunose gave keynote talks on "Orbital Hall Effect and its Detection" and "Cross-correlated Phenomena Viewed from Electronic Multipoles", respectively. The session included other two invited and two contributed talks and finished at 20:00 PM.

Day2-December 2nd. In the morning, six inviated talks of young researchers were given in two parallel sessions on "Graphene and Dirac Systems" and "Superconductivity". In the lunch time, Prof. Moon gave a toutorila talk on "Recent Progress in Kitaev Quantum Spin Liquids".

The 1st session in the afternoon was on "Physics of Functional Materials and Novel Devices". It included semicondutors spintronics and functional materials. Dr. Guo and Dr. Wan gave keynote presentations on "Bulk Photovoltaic Effect in 2D Semiconductors and 3D Topological Semimetals" and "Determining the Range of Magnetic Interactions from the Relations between Magnon Eigenvalues at High-symmetry ***k*** Points". The talks were followed by three invited and two contributed talks. The second afternoon session was titled as “Control of Matters with Symmetry Change and Disorder”. Dr. Ghosh gave a keynote talk on “Thermoelectricity of Correlation States in Twisted Bilayer Graphene” and there were one invited and three contributed talks.

In the evening, 90 minutes poster session was hold by using breakout rooms of Zoom. The short presentation moive was also presented in the break times for advatizement. Despite some difficulties in communination in online poster sessions, there had been active discussions and communications.

Day3-December 3rd. In the morning, six inviated talks of young researchers were given in two parallel sessions on “Extreme Conditions and Novel Tools” and “Complex Matters and Nano Materials”. As such, diverse areas of condensed matter physics were covered in the conferenes in addition to the some focus on the topics of current intersts. In the lunch time, Prof. Jain gave a toutorial talk on “The GW Approximation”.

The 1st afternoon session was on “Spectroscopies on Superconductivity and Quantum Matters”. Dr. Shimano gave a keynote talk on “Ultrafast Control of Symmetry Broken States in Solids by Terahertz Pulse”. There were also four invitaed talks and one contributed talks presented.

The last scientific session was on “Nanoscience and Quantum Technology”. Dr. Chen and Dr. Waghmare gave keynote talks on “Atomic-design and Surface-probing of Selective Two-dimensional Nanomaterials as Photo-catalysts for CO_2 Reduction to Solar Fuels” and “Ferroelectricity at Ultimately Small Length Scales”. There were two invited talks and one contributed talks.

In the last part of the conference there was a session of the DCMP. The DCMP chair gave the short history for the DCMP establishment and the brief report on the activity in 2021. As the final part of the conference, there was a closing cetemony. At first, the winners of the presentation award of contributed talks and the poster presentation were announced. The Best Presentation Awardees are, Pratap Chandra Adak (Tata Institute of Fundamental Research Mumbai, India) and Young Woo Choi (Yonsei University, Republic of Korea)

The Best Poster Awardees are, Hyoung Joon Choi(Yonsei University, Republic of Korea), Zhishuo Huang (National University of Singapore, Singapor), Katsuki Nihongi (Osaka University, Japan) and Iduru Shigeta (Kagoshima University, Japan)

Then the outline of the main event of the DCMP and AAPPS in 2022-Asia-pacific Physics Conference 15(APPC15) was introduced. Finally, DCMP vice chair Dr. Nojiri gave a closing remark. He expressed deep gratitudes for speakers, program committee members, the local organizing committee and support by APCTP as well as all participants for their support and contributions.

He concluded that the DCMP commitments on scientific challenges on important problens of human beings, strengthen the global partnerships and share the knowledge with general public will contribute to heal the wounds left by the covid-19 pandemic and prevent or minimize the damage from future disasters. The event shows that the brilliant light of challenge in condensed matter physics in Asia-Pacific area.

Yearly calendar and events of the DCMP

Event Calendar

Date	Event	Location	URL
Jan, 2022	Executive Meeting	TBD	TBD
2022.01.22-24	International Conference on frontiers of physics 2022	Kathmandu	https://icfp.nps.org.np
Feb, 2022	EXCO Meeting	TBD	TBD
2022.02.01-04	The 45th Annual Condensed Matter and Materials Meeting, Wagga 2022	Wagga	https://www.aip.org.au/CMM-Conference
March, 2022	Executive Meeting	TBD	TBD
March, 2022	APPS Council Meeting	TBD	TBD
2022.03.07-10	ARPS 2022 conference is 'Legacy and Innovation in Radiation Protection'.	Canberra	https://publons.com/researcher/1648797/michelle-yvonne-simmons/
2022.03.15-19	JPS Annual Meeting	Okayama	https://publons.com/researcher/1648797/michelle-yvonne-simmons/
2022.03.22-26	JSAP Spring meeting	Tokyo	https://meeting.jsap.or.jp/english/entry
May, 2022	Executive Meeting	TBD	TBD
May, 2022	EXCO Meeting	TBD	TBD
2022.06.26-07.01	International Conference on the Physics of Semiconductors (ICPS 2022)	Sydney	https://www.icps2022.org/
July, 2022	EXCO Meeting	TBD	TBD
July, 2022	Executive Meeting	TBD	TBD
Aug, 2022	APPC15	Korea	TBD
2022.08.14-22	29th International Conference on Low Temperature Physics	Sappro	http://www.lt29.jp
Sep, 2022	Executive Meeting	TBD	TBD
2022.09.20-23	JPS Fall meeting	Tokyo	N.A.
2022.09.20-23	JSAP Autumn meeting	Sendai	https://www.jsap.or.jp/english/meetings-events/annualmeeting/future-meetings
Nov, 2022	AC2MP	TBD	TBD
Nov, 2022	DCMP Annual Meeting	TBD	TBD
Nov, 2022	Executive Meeting	TBD	TBD
Dec, 2022	APPS Council Meeting	TBD	TBD
Dec, 2022	EXCO Meeting	TBD	TBD

The DCMP membership application

To obtain the full benefit of the DCMP, please apply the membership. There is no membership fee and is free. There are two types of memberships in the DCMP

1. Regular member: Scientist who has a Ph.D. degree in physics or related areas or equivalent qualifications and agrees with the DCMP's purpose.

2. Associate member: Person who had a university-level education in physics or related area

The main target of the associate member is the PhD students.

Members can participate in the range of the DCMP activities and can receive the news letters. A membership card showing your status will be supplied after the logo of the DCMP was fixed. Currently, you can apply the membership at a tentative DCMP website. We hope that you and members of your group to join the DCMP.

http://aapps-dcmp.imr.tohoku.ac.jp/eng/index.html