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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)

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

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EXCO MEMBERS (Term 1): 1 Jan 2021 - 31 Dec 2022

Name	Position	Institute	Email
Je-Geun Park	Chair	Seoul National University, Seoul	jgpark10@snu.ac.kr
Hiroyuki Nojiri	Vice-Chair	Tohoku University, Sendai	nojiri@imr.tohoku.ac.jp
S. M. Yusuf	Vice-Chair	Bhabha Atomic Research Centre, Mumbai	smyusuf@barc.gov.in
Kwang-Yong Choi	Secretary-General	Sungkyunkwan University, Seoul	kchoi@cau.ac.kr
Ya-Ping Chiu	Member of Exco	National Taiwan University, Taipei	ypchiu@phys.ntu.edu.tw
Li Lu	Member of Exco	The Institute of Physics, Chinese Academy of Sciences, Beijing	lilu@iphy.ac.cn
Vandana Nanal	Member of Exco	Tata Institute of Fundamental Research, Mumbai	vnanal@gmail.com
Toru Sakai	Member of Exco	University of Hyogo, Kamigori	sakai@spring8.or.jp
Hai-Hu Wen	Auditor	Nanjing University, Nanjing	hhwen@nju.edu.cn
Feng-Chuan Chuang	Associate Auditor	National Sun Yat-Sen University, Kaohsiung	fchuang@mail.nsysu.edu.tw

Contents:

Chair Message

Dear friends,

I welcome you all to the Vol. 2, 1st issue of the DCMP Newsletter. It is already well into the 2nd year of my term as chair of the DCMP, and there are a few things I would like to accomplish before the end of my term.

First and foremost, we will organize the APPC15 (the 15th Asia Pacific Physics Conference) as an official division of the AAPPS. It will be held on 21 – 26 August as an online conference. It will be the most important event for the DCMP and the AAPPS, and we are trying our best to showcase the best science done in our area.

Second, we will organize the 2nd AC2MP (the 2nd Asia-Pacific Conference on Condensed Matter Physics 2022) on 21 -23 November. We plan to have it as a hybrid meeting with the offline meeting held in Sendai, Japan.

With these two academic events, I will focus on how to grow the DCMP as an organization during my 2nd-year tenure. One of the major initiatives we are making is to increase the number of registered members of the DCMP. For this, I would like to ask you to be the goodwill ambassador of the DCMP and spread the word for us.

I believe that our strength lies in the vast pool of people and good science we are doing in the Asia-Pacific region. With more members, we will be able to become more ambitious about what we can do.

Finally, I hope that you and your nearest family are all ok and well.

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

Vice Chair Message

Two Conferences in 2022

DCMP's activities have entered in the second year and are now we are in fully active phase. The main events of DCMP this year are the two conferences, APPC15:Asia Pacific Physics Conference in Korea in August 22-26 and AC2MP2022:Asia Pacific Conference on Condensed Matter Phytsics 2022 in Sendai, Japan in fall. The latter is the annual conference of the division.

The APPC15 is the main conference of the AAPPS and the first conference that the DCMP organizes programs and sessions in systemtatic way. After the AC2MP2021 was held last year, the DCMP established a permanent program committee to handle the scientific program of the annal DCMP confefrence. For the APPC15, the permanent program committee of the DCMP is at the core and several members from Korea and other associations are added. By the collaborations and hard works of the committee members, the DCMP has successfully nominated 3 plenary speakers and 120 invited speakers as posted in the website of the DCMP, recently. Looking at this list, we will realize again that the field of condensed physics in the Asia-Pacific region is blessed with so many talented researchers and that we know only a part of it personally. I am also very much looking forward to hearing the talks in the coming APPC15 as one of the participants. In the APPC15, the DCMP organizes the prize for best presentations and other supports for young scientists and students. We hope to have participations of many young researchers from the Asia-parific region. The conference wlll be hold in fully online format.

The second conference, AC2MP2022 will be the 2nd annual meeting of the DCMP. After the discussion on the current situation of covid-19, we decided to hold it as hybrid conference with minimum 10-20 oversea participants in Sendai, Japan. This year, in-person conference are hold in many plances after the two years suspention of such activities. In this sence, this will be the first opportinity for the DMCP members to see each others in face to face with relaxed and friendly atomosphere.

As you may know, Sendai is in 300 km north from Tokyo and is easily accessed from many cities of Asia-Paficic areas. I hope you will join us and enjoy the intense scientific exchange and the visiting to different institutes. The date will be Novermber 21-23 and you wil see the beatiful sean of the nature of the late fall. If you have not travel abroad in last two years, it will be the right opportinity for you to resume your international activities.

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

Invitation to APPC15

Three Outstanding Plenary Speakers will talk the best condensed matter physics activites in the Asia-Paficic Areas

Yoshihiro Iwasa, University of Tokyo

Professor Iwasa is the world leading scientist in the field of fullerene, functional FET and Iontronics. The group has recently focused on functionality in the interface and aims to achieve, by the interface and device, the physical properties and functions difficult or impossible, in the thin film single and single crystal. They have developed the electric double layer transistor and have realized the physical properties and functions impossible to achieve in the solid conventional devices such as electronic phase control, including the electric-field-induced superconductivity. To develop more and more such research and create electronic function theory "Iontronics" by ion motion-array control is the core of the research.

Junsung Kim, POSTECH

Professor Kim is a professor at POSTECH. Professor Kim's group-Advanced Materials and Extreme conditions (AMEX) at POSTECH has focused on design, growth and characterization of advanced low-dimensional materials with emergent quantum properties under extreme conditions. The numbers of excellent research have been achieved by balancing the research activities for growing high-quality single crystals, investigation their physical properties under low temperature/high magnetic fields/high pressures, and fabrication of low-dimensional crystal-based devices.

Michelle Simmons, University of New South Wales

Professor Simmons is Director of the Centre of Excellence for Quantum Computation and Communication Technology and one of the leading scientists in the field of quantum computing. Professor Simmons's group leads the field internationally in making precision atomic electronic devices in silicon for both conventional and quantum computing. Using a combination of scanning tunneling microscopy and molecular beam epitaxy phosphorus dopant atoms are controllably placed in Si devices with atomic precision. This has led to the development of the narrowest conducting wires in silicon, the development of the smallest precision transistors, the first two qubit gate between atom qubits in silicon and more complex architectures towards error correction. This ambitious program is currently developing all the functional elements for an error corrected scalable spin-based quantum computer.

Besides plenary spekaers, we will have 120 invited speakers in vareties of topics of consensed matter physics . The full list of the invited spekaers can be found in the web site of the DCMP.

From Editorial Desk

Dear Readers,

We are pleased to present the June-2022 issue of the DCMP Newsletter after the last two issues brought out in the year 2021. This forms the first issue of the Vol. 2 of the DCMP Newsletter.

In the present issue, we would like to introduce the Condensed Matter & Materials Group of the Australian Institute of Physics (AIP) as our new member in the Division of Condensed Matter Physics of the Association of Asia Pacific Physical Societies. The condensed matter physics activities in AIP have also been brought out in brief. Furthermore, in the present issue, to create collaboration opportunities among countries in the Asia Pacific region, we also include an article from China to introduce the China Spallation Neutron Source (CSNS), the first accelerator-based multidiscipline user facility in China, for our DCMP readers.

We continue to bring out the review of the scientific works from our invited authors, including geometric aspects in nonlinear optical effects, and spin dynamics of the transition metal thiophosphates in the current issue of the Newsletter from DCMP. The issue also includes an article entitled, “Co-based Kitaev physics in two-dimensional honeycomb magnets” under the category of Young Researchers’ Contributions.

We hope that our esteemed readers get some inspired ideas and collaboration opportunities from the current issue. The Editorial desk of the DCMP Newsletter will continue to devote consistent efforts towards increasing the scientific impact of the Newsletter. We also look forward to our readers’ support and engagement to keep the high scientific standard of the Newsletter.

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

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

Condensed Matter & Materials (CMM) Group
of the Australian Institute of Physics

My name is Associate Professor Kirrily Rule from Australia, and I would like to introduce myself and the Australian Institute of Physics (AIP) to the community of the Association of Asia-Pacific Physical Societies. I am the National Honorary Secretary of the Australian Institute of Physics (since 2017) and the current Chair of the Condensed Matter Physics group of the AIP, since 2022. The Australian condensed matter physics community was recently invited to join the newly formed DCMP division of the AAPPS, and I am grateful to the Members of the Executive committee for welcoming Australia to this new group. I have only just taken on the role of Chair of the Condensed Matter Physics group of the AIP and one of my first tasks was to make our application to join the DCMP. I will sit on this committee as an observer for the next 12 months before joining as a regular committee member. I look forward to representing the condensed matter community throughout the Asia-Pacific region.

The Australian Institute of Physics has been a professional member society operating in Australia since 1963, https://www.aip.org.au/. Previously, the Australian physics community was represented by the Institute of Physics (IoP) in the UK. Our goal at the AIP is to promote the role of Physics in research, education, industry, and the community. As part of the AIP we operate through seven regional branches and nine topical groups. The Condensed Matter Physics topical group has long been recognised as an important group of the Australian Institute of Physics with currently over 1100 AIP members and stakeholders choosing to be affiliated with the Condensed Matter Physics topical group. These group members receive regular email updates and information from the AIP as well as representation at the AIP annual council meeting.

The CMP group provides representation of the Condensed Matter Physics community through advocacy (https://www.aip.org.au/Advocacy) and national events. At each of the annual AIP conferences and congresses (held in December each year), the CMM group organises a parallel session with speakers presenting on a wide range of topics relevant to condensed matter physics. From our most recent AIP Summer Meeting held in December 2021, such topics included applications of graphene and graphene-like heterostructures, photovoltaic materials, quantum magnetism, topological materials, exciton-polariton physics, and thermoelectric devices, to name but a few (https://aip-summer-meeting.com/).

However, the main annual event for the Condensed Matter Physics community is always the Condensed Matter and Materials conference. This conference is most often held in February at the Wagga Wagga campus of the Charles Sturt University, and thus the conference has colloquially earned the title "the Wagga Conference". This location, in rural New South Wales, was chosen in 1976 as the ideal location for such a meeting of Condensed Matter Physicists as it was most central to East Coast participants from Melbourne, Sydney, Canberra and Brisbane (however "most central" is a relative term compared to the immense size of Australia – participants from Brisbane still must journey over 1200km!). The location of Wagga Wagga also ensures sustained engagement of delegates throughout the week, as there are no "big city" distractions. February is also the hottest time of the year in Wagga Wagga with daily temperatures often exceeding 30ºC which is a stark contrast to the beautifully cooled and spacious convention centre (Fig. 1).

Figure 1: Charles Sturt University convention centre (top) and engaging discussions during the presentations at the 2019 Wagga conference (bottom)

This meeting is an informal, low-cost meeting at which students and early career researchers are encouraged to present their work and gain experience in chairing sessions. In fact, I first attended the Wagga Conference as an undergraduate, presenting a talk about my Honours project. If I remember correctly, I also won a prize for the best student talk – a bottle of Charles Sturt University wine, produced on-site as part of the Charles Sturt University viticulture course https://winery.csu.edu.au/ .

During this conference, there is a special focus on poster sessions which are often held in conjunction with afternoon tea or pre-dinner drinks. In the early years of the conference, there was a reluctance on the parts of some researchers, to be given a "poster presentation" but nowadays, this format is welcomed by many as it provides an ideal opportunity to discuss ones research with interested delegates. Indeed, it is true to say that many new ideas for condensed matter physics research, have been conceived in front of a "Wagga Poster."

There is also a strong emphasis placed on the diversity of presenters, session chairs and the organising committees – not only do we ensure strong gender diversity (aiming for between 30-50% women presenters) but also national diversity, topic diversity, and age diversity. We believe that this results in an inclusive and engaging conference with many interesting presentations.

The AIP CMP group also joins together with the Materials Division of the Royal Australian Chemical Institute (RACI) as well as the New Zealand Institute of

Physics (NZIP: https://nzip.org.nz/) condensed matter community to hold joint events such as the Wagga Conference – in fact every five years or so, the Wagga conference is hosted by our New Zealand colleagues, the most recent conference having been held in Rotorua in February 2020.

Unfortunately, due to COVID both the 2021 and 2022 Wagga conferences had to be cancelled. With the easing of restrictions, the organising committee is gearing up for a bigger than ever CMM meeting in 2023.

Associate Prof. Kirrily Rule

Principal Instrument Scientist, ANSTO, Australia.

Figure 2: The Wagga Conference photo from the conference held in 2019. Taken under the iconic old gumtree in front of the Charles Sturt University convention centre.

China Spallation Neutron Source: a Rising Neutron Experimental Facility

China Spallation Neutron Source (CSNS), the first accelerator-based multidiscipline user facility in China, supplies intensive neutron beams mainly for neutron scattering applications to investigate the order and dynamics of atoms, molecules or atomic clusters, also of their magnetic moments, in solids and liquids. CSNS broke ground in October, 2011, produced the first neutron pulse in November, 2017 [Nature 551, 284 (2017)], and accepted for user operations in August, 2018. In February 2020, the CSNS reached the design beam power of 100 kW, with 18 months ahead of schedule. It provides around 4500 hours of beam time to users per year. By updating the DC sextupole to AC sextupole and installing pulsed-type quadrupole correctors in CSNS accelator, CSNS has operated at 125 kW since March 2022, with the beam availability higher than 95%.

Figure 1 Birdview of CSNS campus

The CSNS accelerator, including of a low energy linac and a rapid cycling synchrotron (RCS), provides proton beam pulses of 1.6 GeV kinetic energy at 25 Hz repetition rate. It is designed with a beam power of 100 kW in Phase-I with an upgrade capability to 500 kW. The CSNS linac consists sequently of H^- ion source, low energy beam transport (LEBT), RFQ, medium energy beam transport (MEBT) and DTL to accelerate H- to 80 MeV. The Penning H^- ion source produces a peak current of 15 mA H^- beam, RFQ bunches and accelerates it to 3 MeV, DTL raises the beam energy to 80MeV. DTL consists of four tanks, and each tank is fed by a 324 MHz, 3 MW klystron. The FFDD structure is used in the DTL dynamic design, and EM quadrupoles are adopted. A 4-fold symmetric lattice is chosen for the RCS to separate injection, acceleration, collimation, and extraction to different straights. The whole ring consists of 16 triplet cells with the circumference of 227.92 m. In order to depress strong space charge effect, H^- stripping and painting method are adopted in the RCS injection to match the small emittance beam from linac to large emittance beam in RCS. The acceleration is performed by eight ferrite loaded cavities which provide 165 kV RF voltage with harmonic number of 2. The one-turn extraction from the RCS is achieved by using 8 vertical fast kickers followed by a Lambertson septum.

Figure 2 DTL in linac tunnel

The CSNS target station, including target, moderators, reflector, shielding with 20 beam port, produces pulsed neutrons with a wide energy distribution. In the core, the steady Ta-clapped tungsten target converts 1.6 GeV proton to pulsed

neutrons (average energies of about MeV), which are slowed down and then thermalized to meV region by three wings-type moderators. The coupled hydrogen moderator (CHM) provides high time-averaged flux cold neutron with acceptable pulse width, the decoupled and poisoned hydrogen moderator (DPHM) provides narrow pulse for high-resolution instruments, and the decoupled water moderator (DWM) for middle resolution instruments worked in thermal and epithermal region. Twenty beam ports transport neutrons out of target station to the instrument suite. Due to compact target-moderator-reflector configuration, CSNS neutron source has a highest proton-to-neutron conversion rate of 0.152 n/p/sr (E_n<1eV) from CHM.

Figure 3 The first CSNS target in hot cell

Three Phase-I instruments, General Powder Diffractometer (GPPD), Multi-Purpose Reflectometer (MR) and Small Angle Neutron Scattering (SANS), are full opened to users after the government acceptance. Eight state-of-art neutron instruments funded by the local government, will finish their construction sequently while the total scattering machine MPI has joined the user program. By the end of 2021, more than 3000 users registered in CSNS portal, ~600 user proposals finished, and ~120 related academic papers had been published on the peering review journals. Recent scientific publications are highlighted as follows: sodium-ion batteries [Advanced Materials 1906348 (2020)], ultrastrong steel [Science 368, 1347 (2020)], magnetic skyrmions [Advanced Materials 31, 1900264 (2019) & 1907452 (2020)], thermoelectric materials [Nature Communications 11, 942 (2019) & 11, 3142 (2020)], magnetic thin film for spin electronics [Advanced Materials 33, 2001324 (2020) & 2005920 (2020)], dendrimers as molecular motor [Journal of the American Chemical Society, 142, 8473 (2020)], nanocage [Journal of the American Chemical Society, 142, 16538 (2020)], zeolite mordenite for gas separation [Science 373, 315 (2021)], the antigen-conjugated adjuvant Cy-OVA@CpG for Cancer Immunotherapy [CCS Chemistry 3, 1328 (2021)], clellulose reuse[Carbohydrate Polymers 277, 118848 (2022)]. Industrial use is promoted in CSNS as well, mainly on single event effects of semiconductor device and mobile terminal equipment, performance evaluation of power battery, and non-destructive testing of engineering welding.

CSNS Phase II will be officially lunched in 2022. A suite of 9 state-of-art neutron instruments will be constructed on diffraction, diffusion scattering and inelastic scattering of single crystals, inelastic scattering of chemical small molecules, quasi-elastic neutron scattering of macromolecules and reflectivity of liquid surface. Also a high-energy proton experimental station and a

Muon station will be built for experiments on nuclear/particle physics and condensed matter physics.

CSNS provides a powerful neutron scattering platform for both fundamental scientific research and high-tech development in many fields such as physics, chemistry, material sciences, life sciences, etc. Two rounds of general proposals per year are called in Summer and Winter, and rapid access opens throughout the year for emergent topics. A long-term research plan has been launched recently on strain measurement and stress evaluation in structural materials and components. In the last call for the experimental period of March to July of 2022, we received 457 proposals, and 154 proposals were approved after expert review.

CSNS expects a strong collaboration with reserachers from all around the world. If you plan to apply beam time, please register through http://users.ihep.ac.cn to submit your proposal. Further informations can be found at http://english.ihep.cas.cn/csns.

Fangwei Wang
China Spallation Neutron Source
Institute of High Energy Physics/Institute of Physics , Chinese Academy of Sciences; email: fwwang@iphy.ac.cn

Report 1 Geometric aspects in nonlinear optical effects

The responses of materials to high intensity light, i.e., nonlinear optical responses, constitute a vast field of physics and engineering. They include important effects such as high harmonic generations, photovoltaic effects, and nonlinear Kerr rotations etc. While geometry and topology has been playing a central role in recent studies of condensed matters, geometrical aspects of nonlinear optical effects have been less explored. In this report, we will introduce two examples of nonlinear optical effects that have geometrical origins: shift current and quantized circular photovoltaic effect (CPGE).

1. Shift current

One of recent remarkable progresses in the photovoltaic effect is the high efficiency solar cell action in perovskite oxides without inversion symmetry [1]. As a candidate mechanism for such efficient photovoltaic effect, shift current is actively studied both theoretically and experimentally.

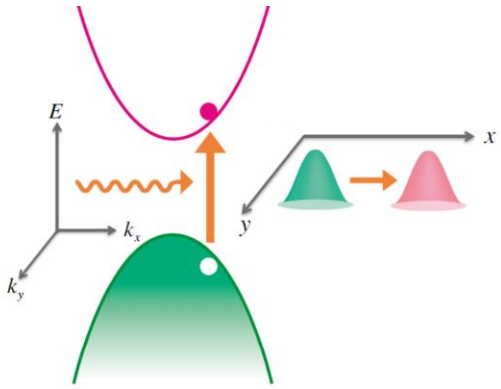

Fig. 1: A schematic picture of shift current. Shift of an electron wave packet upon optical excitation generates dc current.

Shift current is a bulk photovoltaic effect that is nonvanishing in noncentrosymmetric crystals, and it contrasts with the conventional photovoltaic effect of pn junction. For pn junctions, the photocarriers are dissociated by the electric field due to the band bending at the interface, which generates dc current flow. In bulk crystals, there does not exist a net electric field that dissociate photocarriers. In shift current mechanism, on the other hand, a positional shift of a photoexcited electron triggers dc current generation [2]. In noncentrosymmetric crystals, the electron wave packet is generally located away from the center of the unit cell, and the position differs for each band. Therefore, when an electron is optically excited into a different band, the position of the electron wave packet shifts as shown in Fig. 1. Therefore, light illumination constantly creates electron hole pairs with positional shift and electric polarization accumulates. The increase of electric polarization in time induces dc current flow in the sample, which is the shift current.

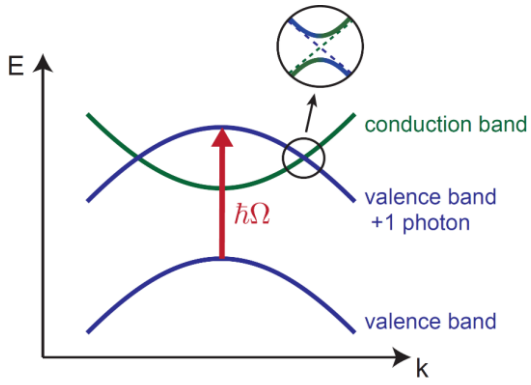

Fig. 2: Description of nonlinear optical effects based on Floquet theory [3]. Anticrossing of Floquet bands gives a description of a nonequilibrium steady state under optical excitation.

According to the modern theory of polarization, the electric polarization in crystals is given by the Berry phase which is an integral

of Berry connection over the Brillouin zone. Intuitively, the Berry connection describes a position (intracell coordinate) of a Bloch electron. Similarly, the shift current is controlled by the so called shift vector that quantifies the positional shift of Bloch electrons. The shift vector contains Berry connection difference between the two bands involved in the optical transition. In this sense, shift current has a geometric origin and is closely related to the modern theory of polarization [3].

Usually, the nonlinear responses are described using perturbation theory and their expressions involves intermediate states, which makes harder to obtain an intuitive picture for the nonlinear responses. We developed an alternative approach to the nonlinear responses based on the Flouqet theory [3]. The Floquet theory is often used to describe nonequilibrium states of periodically-driven systems formalism and gives a concise description of nonequilibrium steady states under intense light irradiation via an effectively static band structure (Floquet bands). Specifically, the nonequilibrium steady state under optical excitation is described by anticrossings of Floquet bands (e.g. a one-photon dressed valence band and a bare conduction band) as shown in Fig. 2. This Floquet approach to nonlinear optical effects has an advantage that the optical responses can be derived from information about only the two bands involved in the optical transition, which contrasts with the conventional treatment based on perturbation theory that requires information of many intermediate states at higher energies. Also a nonperturbative effect with respect to the electric field E is included in this treatment, and the saturation effect of shift current at the higher intensity of light is well described by the Floquet formalism [4].

The role of electron correlation is an interesting issue in the study of nonlinear optical effects. Indeed, shift current in the presence of electron-electron interaction has a potential for novel nonlinear functionalities that do not rely on the flow of free photocarriers in the sample. For example, exciton excitation in noncentrosymmetry crystals is shown to induce shift current response by the Floquet approach [5], and has been observed in CdS [6] and a heterostructure of transition metal chalcogenides [7]. If we consider magnetic systems, multiferroic materials host magnons that accompany electric polarization (called electromagnons). Electromagnons can be excited by light irradiation, and interestingly, they also support photocurrent from the shift current mechanism [8]. Similarly phonons in inversion broken materials accompany electric polarization and are expected to support shift current. Actually phonon shift current is recently observed for soft phonons in a typical ferroelectric BaTiO3 [9].

2. Quantized circular photogalvanic effect (CPGE) in Weyl semimetals

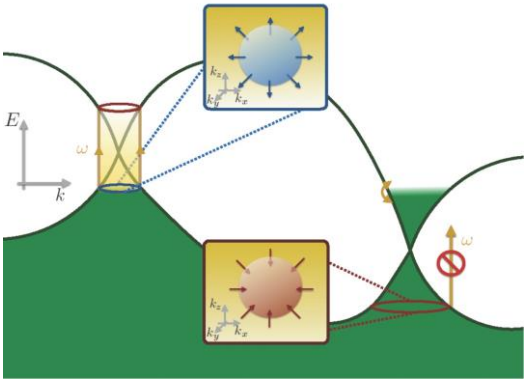

Fig. 3: A schematic picture of quantized CPGE in Weyl semimetals [10]. When only a Weyl node is excited by circularly polarized light, photocurrent shows quantization.

While shift current is driven by the Berry connection difference between the bands, is there any nonlinear optical effect related to Berry curvature? One such example is circular photogalvanic effect (CPGE), a photocurrent induced by illumination of circularly polarized

light. Furthermore, CPGE shows a quantization in some Weyl semimetals [10].

Weyl semimetals support stable gapless excitations that are characterized by quantized Berry flux around the Weyl points. When the photon energy is larger than chemical potential and the interband transition occurs, the CPGE is dominated by so called injection current where the excited photocarriers carries current according to their group velocity. In Weyl semimetals, the time derivative of the injection current (the rate the photocurrent increases) is proportional to the monopole charge of the Weyl point up to some universal constant, reflecting the fact that the Weyl point is a source/sink of a quantized amount of the Berry flux [10].

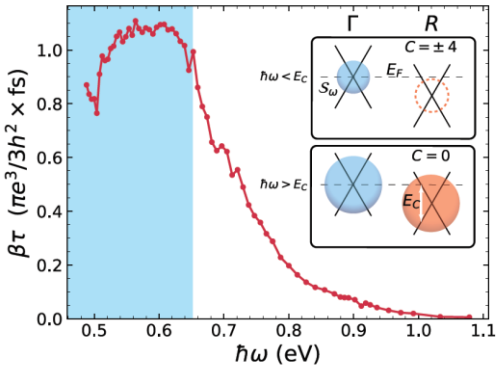

Fig. 4: CPGE spectrum of multifold fermion RhSi [12]. Plateau structure of photocurrent below 0.65 eV is consistent with quantized CPGE.

Observation of quantized CPGE requires that the photocurrent should not be canceled out between Weyl and anti-Weyl points as shown in Fig. 3. Energetically separating Weyl and anti-Weyl points requires the absence of any mirror symmetry, which means particularly low symmetry crystals and makes it difficult to find candidate Weyl materials. Other candidate materials are chiral multifold fermions that support stable gapless point where more than 2 bands are degenerate. It is known that chiral multifold fermions also show quantized CPGE in a similar mechanism as in Weyl semimetals [11]. Recently, RhSi that host multifold fermions are shown to exhibit a plateau structure of photocurrent which is consistent with quantized CPGE (Fig. 4) [12]. Currently, quantization of its photocurrent is actively studied.

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Takahiro Morimoto

Department of Applied physics, The University of Tokyo

Report 2: Spin dynamics of the transition metal thiophosphates (TM-PS3)

I recently attended the MRS Spring Meeting in Honolulu as part of a symposium co-organised by Je-Geun Park. He had asked me to come and talk about my research into the spin dynamics of the transition metal thiophosphates (TM-PS3), a family of magnetic van der Waals compounds. I have studied these compounds since my Ph.D and have enormous respect for Je-Geun, so I was delighted to accept the invitation.

One night while I was there, I went to see a band called “Tower of Power” and was reminded of the subject of my talk. Tower of Power are a soul-funk band that started out in 1968, and are still going strong (they’re great – look them up!). One of their biggest hits was “What is Hip?”, about the nature of fashion. The TM-PS3 compounds have been intensively studied over the same time period, and there have been surges and declines in the interest in the family. At the moment, though, the TM-PS3 compounds are definitely “hip”.

My involvement with the TM-PS3 compounds began in 1990 when I started my Ph.D with Trevor Hicks at Monash University, Australia. At the time, Trevor was a leading expert in the study of magnetic disorder and frustration in condensed matter. He had developed an interest in low-dimensional magnets, inspired by work done by Bob Birgeneau (MIT), Roger Cowley (Brookhaven and Edinburgh) and co-workers on alkali metal-transition metal-halide (AM-TM-Ha) compounds like Rb_2CoF_4, K_2CoF_4 and Rb_2MnF_4. The group had substituted non-magnetic ions for the magnetic transition metals to study percolation networks and random field anisotropies. Trevor tasked me with finding suitable systems for similar experiments.

Time spent in the library revealed that there had been extensive work performed on substituted and doped square lattice antiferromagnets. In addition to the AM-TM-Ha compounds, which had been the subject of comprehensive publications by Birgeneau et al., the hot topic in condensed matter physics circa 1990 was high-Tc superconductors like $(La,Sr)_2CuO_4$ and YBa_2CuO_{6+x}. Studying these systems did not seem like a good idea to me, especially as we would be starting from scratch. There was too much competition, the field was moving too quickly, and sample synthesis looked to be very complicated. By the time we had things running, there was a good chance that our work would have been superceded.

On further reading, I stumbled on the TM-PS3 and TM-PSe3 families of compounds, which looked to be far more promising. The compounds are all essentially isostructural with the transition metals forming a planar honeycomb lattice, which was appealing as it differentiated them from the square lattice systems that were so popular at the time. The metal ions all had 2+ valency, which gave great flexibility and diversity in chemical formulae and stoichiometry, but changing the ion resulted in very different physical

properties. There were substantial efforts to study the magnetism in the 1980s, especially by Raymond Brec (Université de Nantes) and colleagues. The stoichiometric magnetic compounds (TM = Mn, Fe, Co, Ni) had all been shown to be antiferromagnets, but with different magnetic structures and anisotropies. However, there was plenty of scope for development. There had been some efforts to study substituted, non-stoichiometric $TM_{1-y}^{2+}TM'^{2+}_{y}$ compounds where TM'^{2+}_{y} was non-magnetic, but these were fairly preliminary. The interest in the magnetism had largely diminished by the early 90s and the focus for the interest in the family had shifted to possibilities for intercalation, in particular with lithium. Thus there was the luxury of time to begin, develop and understand a research program on the family. The compounds were no longer really "hip", at least as far as the magnetism was concerned, but there was still sufficient interest that any work we did would not be regarded as irrelevant. Finally, and critically, the family was relatively straight-forward to synthesize and we could make decent samples in our laboratory.

The magnetic properties of MnPS3 and (Mn,Mg)PS3 became the subject of my Ph.D thesis. The decision to study sulfur compounds was made as selenium is nasty stuff and more risky to handle when synthesizing samples. We started with MnPS3 as it looked to be the simplest of the magnetic TM-PS3 compounds, having a Néel-type k=0 antiferromagnetic structure and, with a half-filled d-shell, no orbital contribution to the magnetic moment. We studied samples using magnetometry, and neutron powder diffraction with and without polarization analysis at the HIFAR reactor at ANSTO. I think it's fair to say that I made limited scientific progress during my thesis, but Trevor was able to exploit the momentum and the achievements of his subsequent students, particularly people like Darren Goossens and Kirrily Rule, were far more impressive.

My interest in the family continued after by Ph.D studies. From Monash, I went to work as a post-doc at Oxford University under Roger Cowley. The Oxford group was a powerhouse in neutron scattering, particularly in neutron spectroscopy, and my experience there was an education par excellence. There had been no efforts to study the magnetic dynamics of the TM-PS3 compounds with neutron scattering, which is arguably the most powerful experimental tool to characterise magnetic dynamics, and I decided to give it a try. The challenge with neutron spectroscopy is that the sample mass needs to be as large as possible and the TM-PS3 compounds typically grow as thin platelets, weighing typically only a few milligrams each. However, being at Oxford gave me access to the high-flux neutron instruments at the ILL in France and at ISIS in the UK. Furthermore, there was an excellent crystal growth laboratory at the university. With the help of Keith Godfrey and Roger Ward, we were able to make crystals of MnPS3 that were sufficiently large to measure the spin waves, quantify the magnetic exchange parameters and characterise the magnetic anisotropy.

I learned a lot of physics from studying the MnPS3 sample, working from the principle that the best way to learn is by doing. I have gone on to study the

magnetic properties of other TM-PS3 compounds, using primarily neutron scattering techniques but also other experimental methods. The magnetic properties of the family members differ significantly, so each compound has its own surprises and requires careful thought. The study of the different family members is not an exercise in 'stamp collecting', and I find that I learn many new things with each experiment that we perform. Research into the TM-PS3 compounds forms the majority of my publication record, and it also charts my development and education as a physicist. It has been great fun working with the family and I doubt that we will run out of things to study anytime soon.

In the meantime, though, science has evolved and the TM-PS3 compounds have once again become "hip". The discovery of graphene has led to an explosion of interest in van der Waals compounds especially if, like TM-PS3, they are intrinsically magnetic. Theory developments predict exotic magnetic dynamics in two-dimensional honeycomb magnets, and people are now searching for those phenomenae in TM-PS3. The TM-PS3 and TM-PSe3, compounds show a metal-insulator transition under pressure, with FePSe3 even becoming superconducting at a sufficiently high pressure and low temperature. They thus present potential "clean" avenues to understand the mechanisms behind high-temperature superconductivity, providing something of a circle back to the $(La,Sr)_2CuO_4$ and YBa_2CuO_{6+x} compounds that were so popular in 1990.

There is a great deal of current interest in all of these fields and new publications on TM-PS3 are appearing frequently and regularly. Certainly, there is no longer the luxury of time that I enjoyed when I first started working with the family. When thinking about the future for the compounds, though, I am reminded of the final lines in the song "What is Hip?":

While you're striving to find the right road
There's one thing you should know
"What's hip today, might become passé'."

Will this prove true for TM-PS3? Time will tell!

Dr. Andrew Wildes

Institut Laue-Langevin - GRENOBLE, France

Young researchers

Co-based Kitaev physics in two-dimensional honeycomb magnets

Abstract: Search for Kitaev quantum spin liquid phase in honeycomb lattice compounds, with potential application to fault-tolerant quantum computing, has been actively pursued over the last decade. Recent studies suggested that candidate systems may embrace a new family of Co-based and other 3d-trantision-metal-based compounds, and the report of a field-induced paramagnetic phase in $BaCo_2(AsO_4)_2$ is now kindling vigorous debates in the condensed matter community. In this report we make a brief overview of the study of Kitaev magnetism in layered magnetes, and specifically on recent activities in Co-based magnets.

Quantum spin liquid (QSL) phase has attracted significant interests among condensed matter physicists over last decades for their intriguing quantum entanglements and emergent quasiparticles that it can host [1]. Two ingredients have been considered to be essential for the realization of QSL in magnetic systems; i) low-dimensionality, for the proliferation of quantum fluctuations, and ii) magnetic frustrations, especially geometric one (like 'love triangles' in soup-opera-style melodrama). As such, two-dimensional spin systems with kagome- or triangular-lattice arrangements of magnetic ions have been mostly studied, such as Herbertsmithite $ZnCu_3(OH)_6Cl_2$ or in an organic salt κ-$(BEDT\text{-}TTF)_2Cu_2(CN)_3$ [3].

A different perspective has been suggested since 2006 by Alexei Kitaev at Caltech, who wrote down a fictitious spin Hamiltonian on a two-dimensional honeycomb lattice, where three nearest-neighbor bonding in the honeycomb couples different components (x, y, z) of adjacent spin-1/2 moments [4]. Kitaev's model can be exactly solved and, under magnetic fields, emergent excitations which show non-Abelian anyon statistics occur. If materialized, it can be a breakthrough for the realization of fault-tolerant quantum computing that goes beyond the current noisy intermediate-scale quantum (NISQ) devices [5].

Althouth Kitaev's model was initially suggested as a theoretical tool for the study of quantum information, in 2009 George Jackeli and Giniyat Khaliullin in Max Planck Institute found out that this Kitaev's strange magnetic interactions can be realized in solid state systems under certain conditions, i) the formation of so-called 'spin-orbit-entangled' magnetic moments via atomic spin-orbit coupling, and ii) edge-sharing honeycomb network of metal-anion octahedra [6]. This finding has brought great excitements to the community, and soon after that several reports of several candidate compounds like α-Na_2IrO_3 [7], α-Li_2IrO_3 [8], and α-$RuCl_3$ [9], have followed. Especially in $RuCl_3$, two reports on half-quantization of thermal Hall conductivity in the field-induced paramagnetic phase, which has been predicted to arise from the Chern-insulator phase of spin-fractionalized Majorana fermions in Kitaev's original paper, has been published recently

[10,11]. There are still debates ongoing on the nature of the field-induced phase and the origin of the thermal conductivity, though.

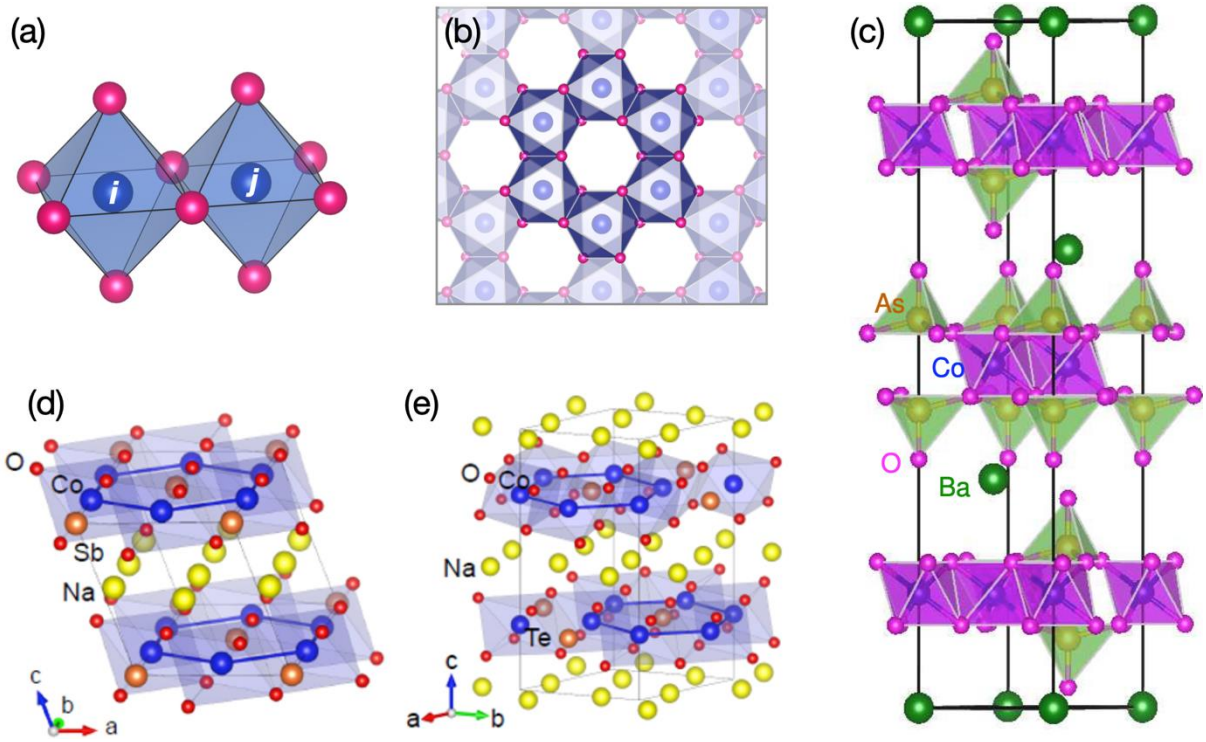

Figure: (a) Edge-sharing metal(blue)-anion(violet) octahedra as the building block of Kitaev magnetism, and (b) its 2D honeycomb network. (c,d,e) Crystal structures of representative Co-based candidate compounds for Kiatev magnetism: (c) $BaCo_2(AsO_4)_2$, (d) $Na_3Co_2SbO_6$, and (e) $Na_2Co_2TeO_6$. Figures slightly adapted from Ref. 17 and S. Samanta et al., arXiv:2204.11465.

All of the suggested Ru- or Ir-transition-metal-based Kitaev candidates show long-range magnetic order at low temperatures, which breaks the spin-liquid physics and needs to be suppressed via external magnetic fields as done in α-$RuCl_3$. In such systems long-range orders originates from Heisenberg interactions, either in nearest-neighbor or third-nearest-neighbor bondings within the honeycomb lattice. Such long-range magnetic exchange interactions are likely to arise from spatially extended nature of d-orbtials in heavier transition metal ions such as Ru or Ir, as well as stronger d-p hybridizations between metals and anions, compared to lighter 3d-transition metal systems [12]. In this regard, employing lighter transition metal ions, such as Co, can be thought as an alternative path to realize more robust Kitaev magnetism and less tendency towards symmetry-broken magnetic order.

Because the first and foremost condition of Jackeli-Khaliullin mechanism was the formation of the spin-orbit-entangled moments, employing lighter transition metals with much weaker spin-orbit coupling (SOC) apparently does not seem to be promising because SOC may easily be

quenched by crystal fields. However, in compounds with edge-sharing transition metal octahedra and t_{2g}-orbital degree of freedom (i.e. systems with partially-filled t_{2g}-shell within the full d-orbital space), strength of trigonal or other symmetry-lowering distortions away from cubic limit can often be smaller than the size of SOC. Compounds with d7 configurations, such as systems with Co^{2+}, like $Na_3Co_2SbO_6$, $Na_2Co_2TeO_6$ [13], and $BaCo_2(AsO_4)_2$ [14], are such examples. Because d^7 high-spin configurations host a hole in the minority-spin t_{2g}-subspace, the resulting L_{eff} = 1 orbital momentum can couple with S=3/2 to result in J_{eff} = 1/2 atomic multiplets. Hence the first requirement of spin-orbit-entangled magnetic moments can be fulfilled. Huimei Liu and Giniyat Khaliullin [15], also Yukitoshi Motome's group in the University of Tokyo [16], pointed this out in 2018 and derived a spin Hamiltonian for the J_{eff} = 1/2 moments based on perturbative approaches. Their Hamiltonian hosts significant ferromagnetic (i.e. negative sign) Kitaev-type exchange interactions, and this finding initiated a new interest in Co-based 3d-transition-metal-based Kitaev magnet compounds.

Since initial suggestions of Kitaev magnetisms in Co-based honeycomb magnets, early studies on candidate systems were focused on $Na_3Co_2SbO_6$ and $Na_2Co_2TeO_6$. Inelastic neutron scatterings (INS) on powdered samples reported the presence of spin-orbit excitations between the low-lying J_{eff} = 1/2 and 3/2 states around 20 meV. This test was also employed to screen out another candidate system $CoPS_3$, which showed no SO excitation around the energy range due to overwhelming trigonal crystal fields [17].

INS results on powdered samples were also employed for linear spin-wave fitting, which commonly reported the presence of significant Kitaev exchange interactions. However, different studies presented conflicting results on the sign of the Kitaev term. While initial theoretical analyses based on perturbation theory suggest ferromagnetic Kitaev interaction, which is supported by a following INS result [13], another independent INS study claims that antiferromagnetic Kitaev interaction yields a better fit of neutron data [18]. It was further suggested that, based on density functional theory calculations, initial theoretical derivations of spin Hamiltonian that predict FM Kitaev interaction may have largely neglected effects of direct overlap in Co-Co exchange paths and need significant improvements [17]. The debate on the significance of Kitaev term and sign of it in these systems is still under debate, and may need high-quality single crystal sample for better INS data and numerical estimation of magnetic exchange interactions as well.

While the debate is still ongoing, there has been reports on another promising candidate, $BaCo_2(AsO_4)_2$. Quite surprisingly, two recent studies report vanishing magnetic order under magnetic fields of 0.5 T [14, 19], which is reminiscent of similar finding in $RuCl_3$ under B = 6T and the report of half-quantized thermal Hall conductivity [10, 11]. Note that, similar finding has been also reported in $Na_2Co_2TeO_6$ [20]. On the other hand, a couple of theoretical studies, based on density functional theory and cluster exact-diagonalization methods, reports dominating Co-Co direct hopping channels and the resulting marginal Kitaev interactions [21, 22, 23].

Theoretical studies also claim that, the presence of further-neighbor exchange interactions can be non-negligible due to the active eg orbital and the resulting large third-neighbor hopping channels, as reported in other Co-based compounds. Reconciling the discrepancy between experimentally observed field-induced paramagnetic phase and theoretical estimations of magnetic effective models may need further efforts in both experimental and theoretical sides, for example high-quality single-crystal INS results or more elaborate theoretical models. This also calls for further extensive search for candidate systems among layered oxide, chalcogenides, or halides that better host Kitaev magenetism and realize QSL with the need of external perturbations or ultra-low temperatures.

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Heung-Sik Kim

Assistant Professor

Department of Physics

Kangwon National University

Meeting/conference reports

DCMP International Program Committee (DCMP IPC)

The international program committee (IPC) as a supporting branch of the academic activities of DCMP. This IPC has the two year term. This IPC has played an important role in preparing the AC2MP. We expanded this IPC for the APPC15. The enlarged DCMP IPC members are listed below.

Organization	Name	Affiliation
DCMP	H. Nojiri (Chair)	Tohoku Univ.
	S. M. Yusuf (Co-chair)	Bhabha Atomic Research Centre
	D. Feng	Univ. of Science and Technology of Ch
	A. V. Gopal	Tata Institute of Fundamental Researc
	Y. J. Kao	National Taiwan Univ.
	T.-H. Kim	POSTECH
	Y. Matsuda	Univ. Tokyo
	S. Narasimhan	Jawaharlal Nehru Centre for Advanced
	C.-H. Yang	KAIST
	Tse-Ming Chen (Nationa	National Cheng-Kung University
	S. Zhou	Tsinghua University
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	N. J. Park	UNIST
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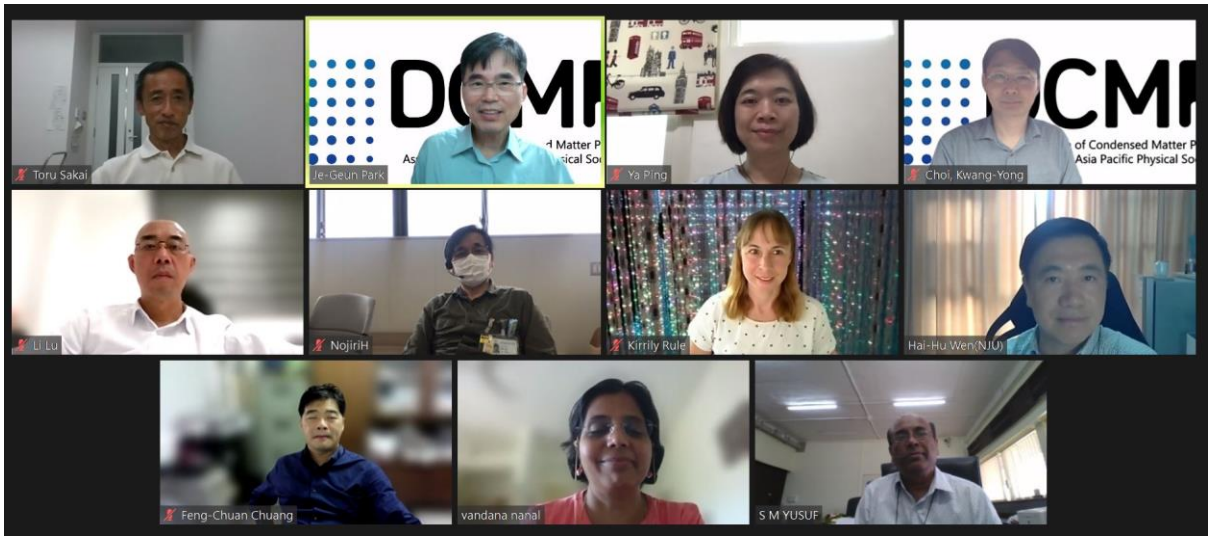
Nonmembers	A Wee	National Univ. Singapore
	K Rule	ANSTO
	G Chen	Univ. Hong Kong
Observers	Je-Geun Park	Chair, DCMP
	Hyoung Joon Choi	Vice-president AAPPS
	Kwang Yong Choi	Secretary-General DCMP

The 9th Executive Meeting (Chair, Vice-chairs meeting) **Date: 30 April 2022**

Participants: Je-Geun Park, Hiroyuki Nojiri, S M Yusuf, Kwang-Yong Choi, Jaehoon Kim (observer for the APPC15)

7th DCMP EXCO Meeting **Date: 7 May 2022**



Participants (attended): Je-Geun Park, Hiroyuki Nojiri, S. M. Yusuf, Kwang-Yong Choi, Hai-Hu Wen, Ya-Ping Chiu, Feng-Chuan Chuang, Li Lu, Vandana Nanal, Toru Sakai, Kirrily Rule

Yearly calendar and events of the DCMP

Date	Event	Location	URL
22-26 August 2022	The 15th Asia Pacific Physics Conference (APPC15)	Korea (On line)	https://www.appc15.org/
21-23 November 2022	Asia-Pacific Conference on Condensed Matter Physics (AC2MP2022)	Institute for Materials Research, Tohoku University, Sendai, Japan (hybrid conference with an in-person meeting in Sendai, Japan) Co-Chairs: H. Nojiri and J-G. Park	
6 August 2022 at 5-7 pm in KST	10th DCMP-Executive Meeting	On line	
24 September 2022 at 2 pm in KST	8th DCMP EXCO Meeting	On line	

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

Membership:

As of 30 April 2022, we have 324 members.