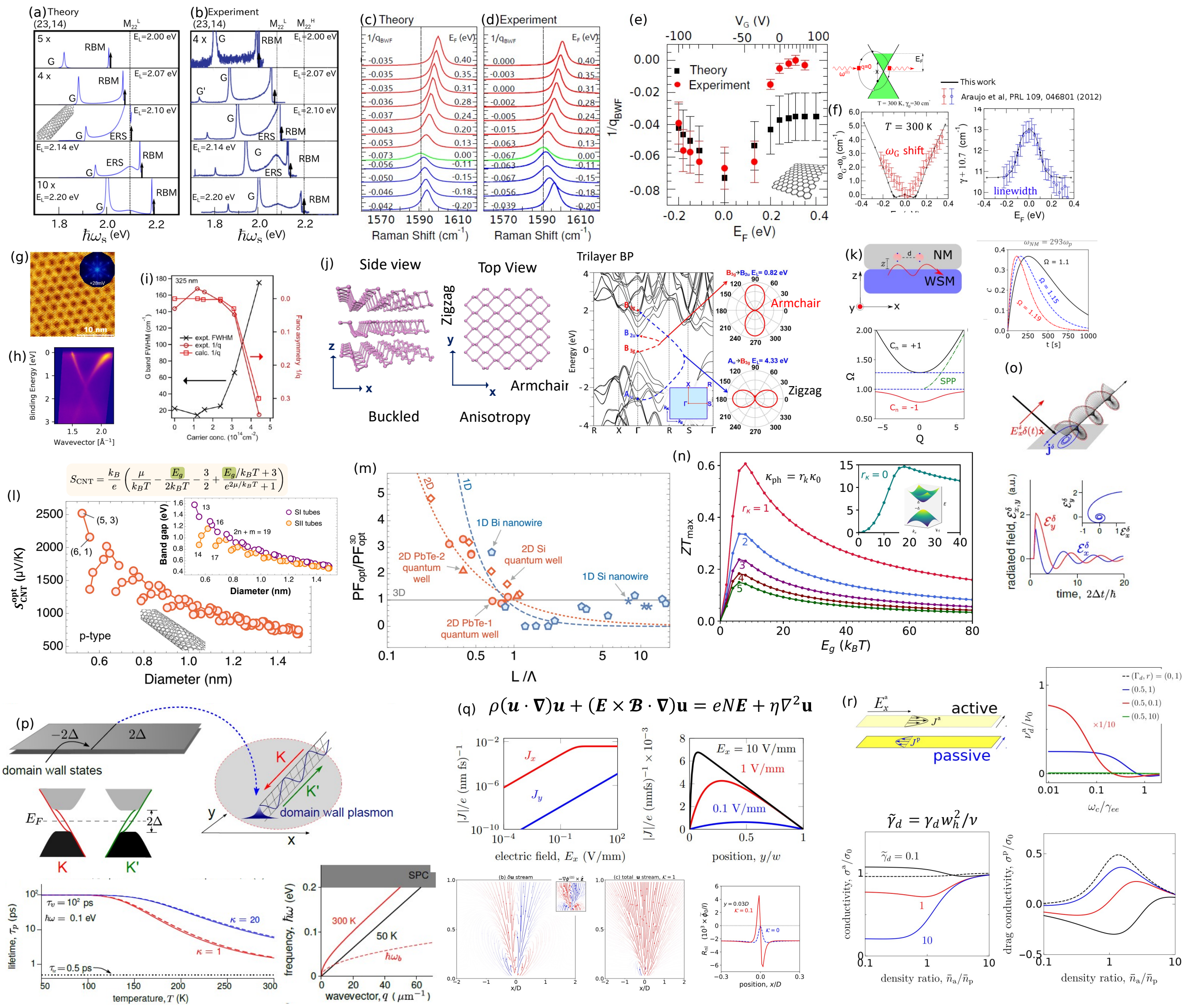

Figure 1: **Overview of past research**. (a)Electronic Raman spectra [PRB 88, 115107 (2013)]. Theoretical calculation of electronic Raman spectra (ERS) in metallic single wall nanotube (SWNT) for different laser energy E_L. Notice the ERS peak remains at electronic resonant energy M_{22}^L and the G band spectra shows asymmetry. The calculation reproduces experiment (b). Raman shift = $E_L - \hbar\omega_s$ (c) Theoretical calculation of Raman spectra in graphene as a function of Fermi energy E_F [PRB 90, 245140 (2014)]. The Raman spectra exhibit Fano or Breit-Wigner-Fano asymmetry $1/q$ [see (e)] and change in peak position as well as linewidth [see (f)]. (d) Reproduce the experimental results. (e) Fano factor as a function of Fermi energy. (f) Kohn anomaly effect in graphene [PRB 94, 075104 (2016)]. Phonon self-energy calculation, the real part corresponds to frequency shift and the imaginary part is the inverse of lifetime. (g-i) Raman spectra of highly doped graphene [Nano Lett. 18, 6045(2018)]. (g) Scanning electron microscopy image of graphene on Ir (111). (h) Angle resolved photoemission spectroscopy of graphene under Cs doping. (i) G band linewidth and Fano asymmetry. The asymmetric factor is opposite from (e) because of Ir screening and first-order perturbation. (j) Anisotropic Raman spectra in black phosporous (BP) [Nano Lett. 16, 2260 (2016)]. Buckled structure of BP allows detection of crystal orientation using photoabsorption and Raman spectra. (k) Topological photonics in Weyl semimetals (WSM) and uniaxial surface wave for qubit entanglement [PRB 106, 155409 (2022)]. Light inside WSM is topological with Chern number ±1. This gives rise to uniaxial surface wave [surface plasmon polariton (SPP) that can be used for qubit entanglement. The concurrence $\mathcal{C}$ measures the degree of entanglement that long last. (l) Diameter dependence of Seebeck coefficient (thermopower) in semiconducting SWNTs [PRB 92, 165426 (2015)] to be compared with the bandgap. (m) Quantum enhancement of power factor of nanostructures [PRL 117, 036602 (2016)] when $L/\Lambda < 1$ where L is the confinement length and Λ is the thermal de Broglie wavelength. (n) Optimal band gap for thermoelectrics [JAP 126, 035109 (2019)]. r_k is proportional to phonon thermal conductivity. (o) Detecting cyclotron motion without magnetic field [NJP 21, 083026 (2019)]. Anomalous Hall materials exhibit cyclotron current that converts linear polarized pulse into circular polarized emission. (p) Plasmons of topological domain wall states in bilayer graphene [Nano Lett. 17, 7252 (2017)]. Plasmon of topological states transcend the bulk lifetime ($\tau_{\rm tr} \sim 0.5$ ps) and limited by intervalley lifetime (τ_v). The plasmon roperties are tunable by temperature and dielectric constant of substrate κ. (q) Quantum geometric correction to electronic Navier Stokes equation [PRB 103, 125106 (2021)]. Here $\boldsymbol{\mathcal{B}}$ is proportional to the Berry flux in the Fermi surface. Including this term, we obtain asymmetric one-dimensional (1D) flow, back flow without boundary in 2D and asymmetric non-local resistance. (q) Negative drag in viscous fluid [PRB 107, L121107(2023)]. Drag conductivity can become negative in small channel width W_h. The negative drag is due to drag viscosity ν_d which is tunable by magnetic field, drag coefficient and density ratio. .

1 Overview of Past Research 2pg

Raman spectroscopy of nanocarbons and two-dimensional materials

Raman spectroscopy is inelastic scattering of light. Materials absorb light (photon) energy and normally use it for atomic vibration (phonon excitation). We studied a layer of carbon atoms having the shape of honeycomb (graphene) and its allotrope rolled up into cylinder — single wall carbon nanotube (SWNT). Experiments in metallic SWNTs and graphene showed new Raman signal different from phonon. We investigate this signal by developing programs to calculate electron energy bands, phonon bands, electron-photon interaction, electron-phonon interactions, and electron-electron interactions. We explained the origin of electronic Raman signal and asymmetry in the phonon band. We studied the renormalization of phonon due to conduction electron — Kohn anomaly and quantum interference effects observed in Raman spectra. We extend the work into Raman spectra of black phosphorous where we observed asymmetry in the electron-photon and electron-phonon.

Thermoelectric transport of low dimensional materials

We were inspired by Hicks and Dresselhaus [PRB 47, 12727 (1993) & 47, 16631 (1993)] that low dimensional materials might be good thermoelectric materials. We jump into the calculation of thermoelectric properties of semiconducting SWNT and found diameter dependence of thermopower similar to SWNT band gap energy. We then develop a rule of thumb how to get thermoelectric enhancement in nanostructures, i.e. the confinement length should be smaller than thermal de Broglie wavelength. Furthermore we model many kinds of possible band structures to obtain high performance thermoelectric; for exmple by looking at the optimized band gap, interplay with topology, magnetism in $CaMnO_3$, and spin transport.

Optoelectronics of quantum materials

I realized that quantum materials hold great promise where plethora of new physics emerge. During my postdoc in Singapore, I published two papers on utilizing topological edge mode for long-lived plasmonics and detecting cyclotron motion without magnetic field. The techniques developed during my postdoc have been pivotal for my career up to now. This become inspiration to the quantum hydrodynamic project, as well as the detection of topological phase using rotation of optical polarization (Faraday and Kerr effect).

Hydrodynamic transport of quantum materials

Upon the fabrication of many two-dimensional (2D) materials, hexagonal boron nitride turns out to be the perfect match for graphene that protects it from impurities. Graphene exhibits large mobility and one can imagine what transport may come out if we remove impurities and leave the electrons with themselves. It turns out collective electron moves like water obeying hydrodynamic Navier-Stokes equation. We develop hydrodynamic theory for quantum materials where the wavefunction modifies electron motion which manifest in anomalous velocity due to the Berry curvature. We obtained the quantum correction to the Navier-Stokes equation and show asymmetric 1D flow as well as unconventional back flow in 2D. In other project, we consider a Coulomb drag mechanism in bilayer viscous electron. We discover new drag viscosity due to interlayer interaction and show that drag conductivity can be negative in the limit of small channel. In the last project, We show how the spin-orbit coupling can modify the electron viscosity.

Topological quantum optics and qubits

We have interest in contributing the development of quantum computers using quantum materials. We show that photons inside Weyl semimetal are topological that supports unidirectional surface waves — surface plasmon polaritons (SPP). This unique property is due to the breaking of time reversal symmetry that the Weyl semimetal possess. We utilize this unidirectional SPP as media to connect two quantum bits (qubits) and show that the degree of entanglement can be kept for long times. The other interest is to utilise the currently available quantum computers as quantum simulator for manybody physics. We are in the level of benchmarking and reproducing the previous results and will utilize in the systems with strong correlation.

2 Research plan 2pg

Physical properties of quantum materials

In the world of technologies build with quantum materials, computers will be 100 times much faster, electronics will be efficient and of low energy consumption, energy generators will be cleaner and more powerful, and energy storage will be lighter yet larger capacity. Quantum materials are a new class of materials where quantum mechanical wave functions govern the motion of electrons in a non-classical way or manifest in long-range order and entanglement.

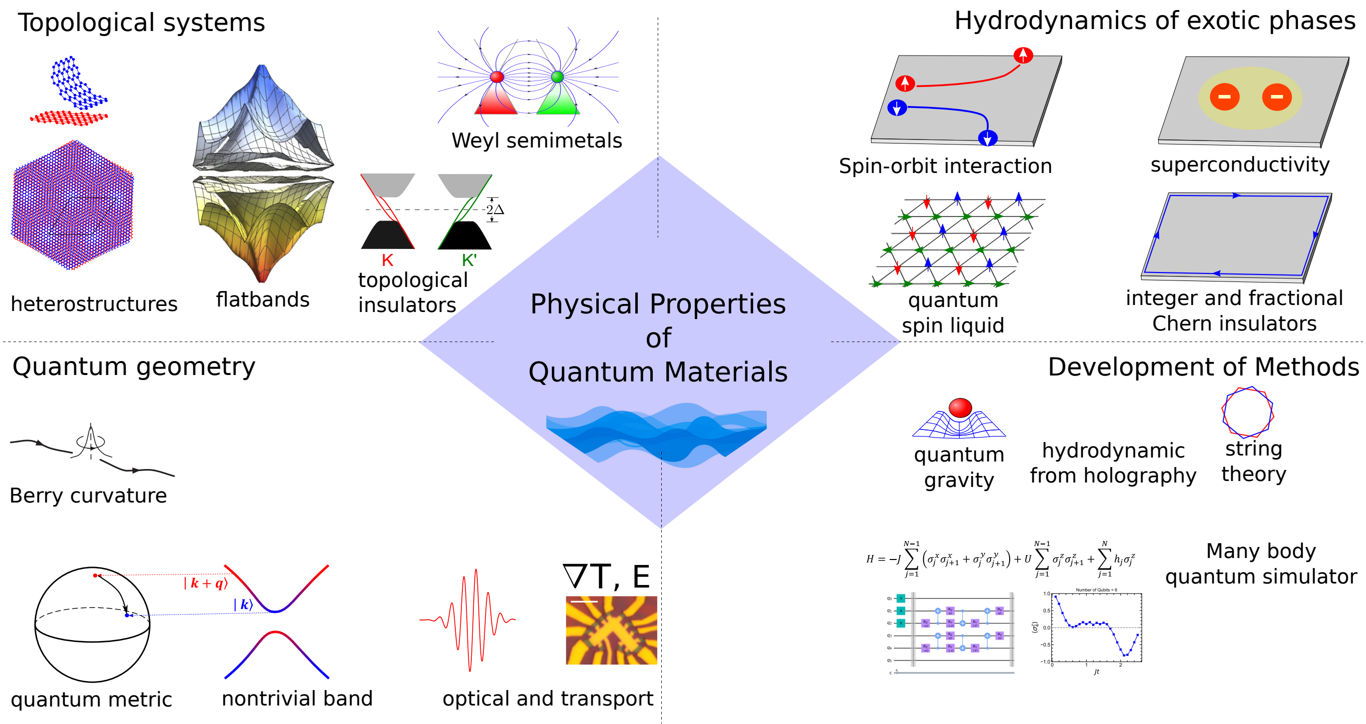

Figure 2: **Research plan:** Physical properties of quantum materials. [Topological systems] Van der Waals heterostructures such as graphene – hexagonal boron nitride (hBN) or twisted bilayer graphene exhibit moiré pattern. This moiré potential modifies graphene's band. We show band structure of 5 layer rhombohedral graphene on hBN that has flat bands and recently reported to show fractional anomalous Hall effect [cite]. The other example are Weyl semimetals whose Berry curvature behaves like magnetic dipoles at two Weyl points. This can give rise to chiral anomaly effect, chiral magnetic effect and axial-gravity anomaly. Topological insulators are bulk insulating states with dissipationless edge states. Here we take example of valley Hall states in inverted-gapped bilayer graphene. [Quantum geometry] Two aspects of quantum geometry manifest in the Berry curvature and quantum metric. Berry curvature can be thought of as self-rotating wave function that can give rise to transverse motion (anomalous Hall effect). Quantum metric appears when there exist a distance between Bloch states $|\mathbf{k}\rangle$ with $|\mathbf{k}+\mathbf{q}\rangle$. The wavefunctions consist of coherence superposition of multi-orbitals with different weight (mixed colors). Using optics and transport, we will investigate new response caused by quantum geometry. [Hydrodynamic of exotic phases] We will use hydrodynamic theory to describe spin-charge dynamics in strong spin-orbit systems or magnetic systems, conventional and exotic superconductors (e.g. anyon and topological superconductors) and anomalous Hall systems (Chern insulators) with integer or fractional quantized conductance, as well as quantum spin liquid where anti-ferromagnetic ordering in triangular lattice cause frustration. [Development of methods] Hydrodynamic transport can be developed from kinetic Boltzmann equation this has been done in the current research. In the future we will incorporate the holography theory (AdS/CFT correspondence) where string theory and quantum gravity coincide. This theory corresponds to ultra-strong correlation limit relevant to condensed matter systems without quasiparticles (e.g. high Tc superconducting cuprates). While all theories mention above is developed using effective analytic model we also emplow numerical method that runs on quantum computer. For the moment this simulation is possible on one dimension only and we will extend to higher dimension.

The list of such materials relevant with the current study includes topological insulators — insulating bulk with dissipationless metallic surfaces, topological semimetals — electrons that obey the relativistic Dirac and Weyl equations, superconductors, quantum spin liquid, integer and fractional quantum Hall states.
Quantum materials can be classified into two categories. First, we will study the non-interacting systems with interesting structure of wave functions (topology and quantum geometry). Second, the dynamics of strongly correlated materials will be approached by hydrodynamic theory as well as computation utilizing quantum computers.

a. Effect of quantum geometry in transport and optoelectronics

Motion of electrons in solid is governed by the energy dispersion relations. The dispersion gives information of the kinetic energy as well as how the particles respond the external field. As quantum particles, the structure of wavefunction which emerges from interaction with periodic potential in solids provides additional non-classical "driving force". The so-called quantum geometry which consist of the Berry curvature and quantum metric is responsible to the plethora of exotic transport observed in experiments. For example, the quantum anomalous Hall effect, where electrons moves with a quantized conductance perpendicular to applied electric field (**E**) at zero magnetic field (**B**) comes about due to the Berry curvature [Science, 340, 167 (2013)]. The dramatic contribution of quantum metric is the observation of superconductivity in flat bands in twisted bilayer graphene [PRL 131,240001 (2023)]. Electrons in that system should have zero group velocity and thus the wavefunction should be localized in space. However, the

quantum metrics dictate the size of electron wavefunction and provide additional ways for electrons to propagate.
Research puspose. Many new physics have been discovered in our previous works including properties of collective electron waves (plasmons) of topological edge states, unconventional electron flow in topological materials, and unconventional linear and non-linear response in topological materials. All of those utilize, Berry curvature as main sorce of non-classical "driving force". Now, we will continue the project focusing on the quantum metric and its interplay with the Berry curvature. We ask the following questions. What is the optical and thermoelectric response in the systems whose dynamics is governed by quantum metric? How to tune the size of quantum geometry? We expect that quantum geometry emerge not only in electronic bands but also in different platform such as spin waves, plasmons, phonons, and even classical waves. We will explore all the possibilities.
Methods. We start with the effective Hamiltonian whose bands obey the symmetry that quantum metric or Berry curvature will show up. From that Hamiltonian, we derive the current operator non-perturbatively in the presence of electric field. We then collect the linear and non-linear responses order by order. We expect that quantum metric will manifest in the non-linear responses. We also derive thermoelectric response in the presence of electric field and temperature gradient. Normally, we linearized the Boltzmann equation. We predict that we need to expand the Boltzmann equation up to higher order terms so that quantum metric may come about in the electrical, thermoelectric and thermal conductivities. We extend this theory using realistic Hamiltonians from tight binding or the first-principles calculation to assist experimental efforts.

b. Hydrodynamic electrons in exotic phase

Recently, people fabricates graphene on top of substrates which have strong spin-orbit coupling or magnetization. In the limit of very clean samples, electrons should moves according to hydrodynamic equation of motion. In the previous work, we show that spin-orbit coupling changes the electrons viscosity. In the next project, we will investigate the spin-relaxation of electron governs by electron-electron interaction. In hydrodynamics, the density, energy, and momentum of fluids are conserved. In the spin-hydrodynamics we expect the conservation of spin–angular momentum which dictates the kinematics of vortices in electron fluids.
Hydrodynamics has been used as an effective description of strongly correlated systems. For example in the chiral fluid of quark gluon plasma, He^4 superfluids, and electrons at fractional quantum Hall states. Recently, multilayer rhombohedral graphene (mRG) on hexagonal boron nitride (hBN) exhibits fractional quantum Hall effect without magnetic field. The fractional excitation is the indication of strong correlation due to the flat band emerging from moire potential induced by mRG-hBN lattice mismatch. The absence of $\mathbf{B}$ field in this phase describes the role played by quantum geometry. We will develop the hydrodynamic theory of electron in fractional quantum Hall states by incorporating quantum geometry. Certain fractional states such as $5/2$ is predicted to have non-trivial statistics different from fermions (e.g. electrons) or bosons (e.g. photons) dubbed as non-abelian anyons that is very important to the development of fault tolerant quantum computers.
Research Purpose. The hydrodynamic theory is relevant to describe strongly correlated regimes where string theory and quantum gravity coincides. There are several area where this theory can be interesting such as hydrodynamic description of collective modes of non-abelian particles, measurement of gravity and chiral anomaly — violation of continuity relation due to relativistic handedness — outside the Weyl semimetals, and transport of strongly correlated systems without Fermi surface.
Methods. We develop hydrodynamic equation from kinetic Boltzmann theory or from field theory with imposing symmetry of the systems. The first method requires the detailed knowledge of quasiparticle dispersion, quantum geometry, external field and interactions. The second method allows the universal description where the details does not matter.
While hydrodynamic theory is a theory for large length and time scales, we shall compare it with numerical manybody problem. In addition to the established numerical methods using classical computers, currently we can utilize quantum circuit to simulate manybody dynamics.

Ingenuity, importance and impact of this research

We unravel the unchartered area to probe the effects of quantum geometry and strong correlation in opto-electronics. We are in the intersection of quantum materials, photonics, and transport communities. Our results are relevant to the development of quantum computers, electronics, spintronics, valleytronics, photovoltaics, thermoelectrics and possibly new transport phenomena. We are developing the theory using the state-of-the-art tools such as quantum field theory, quantum geometry and even quantum computers.

3 Research Achievements

3.1 Papers and other articles which have been published in academic journals

First-authored and corresponding authored papers

1. E.G. Idrisov[†], **E. H. Hasdeo**[†], B.N. Radhakrishnan, T.L. Schmidt, "Hydrodynamic Navier-Stokes equations in two-dimensional systems with Rashba spin-orbit coupling", Low Temperature Physics 49, 1385-1397(2023).
2. J.M. Adhidewata, R.W.M. Komalig, M.S. Ukhtary, A.R.T. Nugraha, B.E. Gunara, **E. H. Hasdeo**, "Trigonal warping effects on optical properties of anomalous Hall materials"Physical Review B 107, 155415 (2023).
3. **E. H. Hasdeo**, E.G. Idrisov, T.L. Schmidt, "Coulomb drag of viscous electron fluids: Drag viscosity and negative drag conductivity", Physical Review B 107 (12), L121107 (2023).
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5. A Habibi, AZ Musthofa, E Adibi, J Ekström, TL Schmidt, **E. H. Hasdeo**, "Kerr and Faraday rotations in topological flat and dispersive band structures",New Journal of Physics 24 (6), 063003 (2022).
6. M Gaffar, SA Wella, **E. H. Hasdeo**, " Effects of topological band structure on thermoelectric transport of bismuthene", Physical Review B 104 (20), 205105 (2021)
7. E Suprayoga, WBK Putri, K Singsoog, S Paengson, MY Hanna, **E. H. Hasdeo**, et al. "Investigation of electron and phonon transport in Bi-doped CaMnO3 for thermoelectric applications", Materials Research Bulletin 141, 111359 (2021).
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9. K. Oktavian, **E. H. Hasdeo**, "Non-universal scaling of thermoelectric efficiency in 3D and 2D thermoelectric semiconductors", Advances in Natural Sciences: Nanoscience and Nanotechnology 12 (1), 015017 (2021).
10. B. Rendy, **E. H. Hasdeo**, "Strain effects on band structures and Dirac nodal-line morphology of ZrSiSe",Journal of Applied Physics 129, 014306 (2021).
11. E. Suprayoga, W. B. K Putri, K. Singsoog, S. Paengson, M. Y. Hanna, A. R. T. Nugraha, D. R. Munazat, B. Kurniawan, M. Nurhuda, T. Seetawan, **E. H. Hasdeo**, "Investigation of electron and phonon transport in Bi-doped CaMnO3 for thermoelectric applications", *submitted*, Mat. Res. Bul 141, 111359 (2021).
12. M. Nurhuda, A. R. T. Nugraha, M. Y. Hanna, E. Suprayoga, **E. H. Hasdeo**, "Thermoelectric properties of Mexican-hat band structures", Adv. Nat. Sci.: Nanosci. Nanotech., 11 015012 (2020)
13. **E. H. Hasdeo**, L. P. A. Krisna, B. E. Gunara, N. T. Hung, A. R. T. Nugraha: "Optimal band gap for improved thermoelectric performance of two-dimensional Dirac materials", Jour. Appl. Phys. 126, 035109 (2019).
14. **E. H. Hasdeo**, A. J. Frenzel , J. C. W. Song: "Cyclotron motion without magnetic field", New J. Phys. 21, 083026 (2019).
15. **E. H. Hasdeo**, and J. C. W. Song: "Long-lived domain wall plasmons in gapped bilayer graphene", Nano Lett. 17, 7252-7257 (2017).
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17. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito, M. S. Dresselhaus: "Breit-Wigner-Fano lineshapes in Raman spectra of graphene", Phys. Rev. B 90, 245140 (2014).
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1. E.P. Sinaga, M. Adams, M. Bersweiler, L.G. Vivas, **E. H. Hasdeo**, et al. "Micromagnetic simulation of neutron scattering from spherical nanoparticles: Effect of pore-type defects",Physical Review B 107 (1), 014416 (2023)
2. JM Adhidewata, ART Nugraha, **E. H. Hasdeo**, BE Gunara, "Thermoelectrics of type-I and type-II nodal line semimetals within the two-band model",Indonesian Journal of Physics 33 (1), 51-57 (2022)
3. MS Ukhtary, **E. H. Hasdeo**, AB Suksmono, ART Nugraha, "Long-lived qubit entanglement by surface plasmon polaritons in a Weyl semimetal",Physical Review B 106 (15), 155409 (2022)

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5. J Ekström, **E. H. Hasdeo**, MB Farias, TL Schmidt, " Kerr effect in tilted nodal loop semimetals", Physical Review B 104 (12), 125411 (2021)
6. G. Suwito, M. Fukuda, E. Suprayoga, **E. H. Hasdeo**, A. R. T. Nugraha, M. Sakashita, S. Shibayama, O. Nakatsuka, "Formatio of ultra-thin $Ge_{1-x}Sn_x/Ge_{1-x-y}Si_xSn_y$ quantum heterostructures and experimental observation of resonant tunneling phenomenon", Appl. Phys. Lett. 117, 232104 (2020).
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8. M. G. Hell, N. Ehlen, B. V. Senkovskiy, **E. H. Hasdeo**, A. Fedorov† , D. Dombrowski, C. Busse, T. Michely, G. di Santo, L. Petaccia, R. Saito, and A. Gruneis: "Resonance Raman Spectrum of Doped Epitaxial Graphene at the Lifshitz Transition", Nano Letters, 18 (9), 6045 – 6056 (2018) .
9. Y. Harada, M. S. Ukhtary, M. Wang, S. K Srinivasan, **E. H. Hasdeo**, A. R. T. Nugraha, G. T. Noe, Y. Sakai, R. Vajtai, P. M Ajayan, R. Saito, J. Kono: "Giant Terahertz-Wave Absorption by Monolayer Graphene in a Total Internal Reflection Geometry", ACS Photonics 4 121 (2017).
10. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Selective coherent phonon mode generation in single-wall carbon nanotubes", Jour. Phys. Cond. Matt. 29, 055302 (2017).
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12. N. T. Hung, **E. H. Hasdeo**, A. R. T. Nugraha, M. Dresselhaus, R. Saito: "Quantum effects on thermoelectric power factor of low-dimensional semiconductors", Phys. Rev. Lett. 117, 036602 (2016).
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Book Chapter

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1. E Suprayoga, MY Hanna, **E. H. Hasdeo**, ART Nugraha, "A comparative study of thermoelectric properties of monolayer, bilayer and bulk CrI_3", AIP Conference Proceedings 2382 (2021).
2. NR Ayukaryana, MH Fauzi, **E. H. Hasdeo**, "The quest and hope of Majorana zero modes in topological superconductor for fault-tolerant quantum computing: An introductory overview", AIP Conference Proceedings 2382 (2021).

3. **E. H. Hasdeo**, L. Krisna, A. R. T. Nugraha: "Thermoelectric properties of two-dimensional Dirac materials", AIP Conf. Proc 2256, 030010 (2020).
4. E. Suprayoga, A. Rifai, A. Subhan, G. K. Sunardinanto, M. Y. Hanna, **E. H. Hasdeo**, A. R. T. Nugraha: "Ab-initio calculation of muon spin polarization function to study lithium-ion diffusion in $LiTi_2O_4$ battery material", AIP Conf. Proc. 2256, 030015 (2020).
5. A. R. T. Nugraha, M. Y. Hanna, E. Suprayoga, **E. H. Hasdeo**: "Modulation of coherent phonon amplitudes in low-dimensional materials by ultrafast laser pulse trains", AIP Conf. Proc. 2256, 020005 (2020).
6. M. Y. Hanna, **E. H. Hasdeo**, E. Suprayoga and A. R. T. Nugraha: "Thermoelectric properties of two-dimensional hydrogenated borophene: A first-principles study", AIP Conf. Proc. 2256, 030017 (2020)
7. A. R. T. Nugraha and **E. H. Hasdeo**: "Coherent and squeezed phonons in single wall carbon nanotubes", Jour. Phys. Conf. Ser. 1191, 012002 (2019).

3.2 Presentations at international conferences and symposiums

Oral Presentation

1. **E. H. Hasdeo**: "Effects of electron wave function in optoelectronics and transport", International Symposium on Physics and Applications, ITS Surabaya, Indonesia ☆, (2023.11.21 –22).
2. T Schmidt, **E. H. Hasdeo**◯, E Idrisov: "Coulomb drag of viscous electron fluids: drag viscosity and negative drag conductivity", APS March Meeting, Las Vegas, USA, (2023.03. 5–10).
3. **E. H. Hasdeo**◯, MS Ukhtary, ART Nugraha, AB Suksmono: "Topological photonics and unidirectional surface plasmon polaritons in a Weyl semimetals", APS March Meeting, Las Vegas, USA, (2023.03. 05–10).
4. P Poduval, T Schmidt, **E. H. Hasdeo**: "Plasmon-induced magnetization in the edges of higher Chern insulators", APS March Meeting, Online, (2022).
5. **E. H. Hasdeo**◯, E Idrisov, T Schmidt: "Electron-hole drag viscosity and magnetotransport in semimetals", APS March Meeting, Online, (2022).
6. E Sinaga, L Vivas, **E. H. Hasdeo**, P Bender, A Michels: "Magnetic neutron scattering of nanoparticles: failure of the superspin model", APS March Meeting, Online, (2022).
7. **E. H. Hasdeo**◯, E Idrisov, J Ekström, T Schmidt: "Navier-Stokes flows meet topological electronics", APS March Meeting, Online, (2022).
8. **E. H. Hasdeo**: "Novel Optoelectronics of Nanomaterials", Brawijaya University, Physics Departmental Seminar, (26/12/2018)☆
9. **E. H. Hasdeo**: "Theoretical analysis of quantum materials for optoelectronics", Bandung Institute of Technology, Physics Departmental Seminar, (23/11/2018)
10. **E. H. Hasdeo**: "Optoelectronics of low dimensional materials", University of Indonesia, Physics Departmental Seminar, (12/09/2018)☆
11. **E. H. Hasdeo**, J. C. W. Song: "Novel plasmonics in topological edge states of gapped bilayer graphene", NUS, Physics Departmental Seminar, Singapore, (30/08/2017)☆
12. R. Saito, **E. H. Hasdeo**, K. Sato, S. Siregaar, H. H. Guo, T. Yang: "Raman spectroscopy of graphene and transition metal dichalcogenides atomic layer (invited)", Physics and Chemistry of Atomic Films: Fundamental Science and Applications, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, (2014.11.4-8).
13. Ahmad R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Coherent and squeezed phonons in single wall carbon nanotubes", The 48th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2015.2.21-23).
14. R. Saito, **E. H. Hasdeo**, A. R. T. Nugraha, H. Guo, T. Yang, S. Siregar: "Raman spectroscopy of graphene and transition metal dichalcogenides (invited)", 29th International Winterschool on Electronic Properties of Novel Materials: "Molecular nanostructures", Kirchberg, Austria, (2015.3.7-14).
15. **E. H. Hasdeo**◦, A. R. T. Nugraha, R. Saito: "Interplay of electron-phonon and electron-electron interactions in gate modulated Raman spectroscopy of graphene", CCTN15: The Tenth International Symposium on Computational Challenges and Tools for Nanotubes, Nagoya University, Japan, (2015.06.28).
16. R. Saito, M. S. Ukhtary, **E. H. Hasdeo**, A. R. T. Nugraha, C. Reynolds: "Tunable absorption of electromagnetic wave at graphene interface between two dieletcric materials (invited)", 6th RIEC-RLE meeting on research collaboration in photonics, Sendai, (2015.10.26).
17. R. Saito, Y. Tatsumi, A. R. T. Nugraha, **E. H. Hasdeo**, H. L. Liu, H. Guo, T. Yang: "Raman spectra of tran-

sition metal dichalcogenides and phosphorene (invited)", 6th A3 symposium on Emerging Materials, Kyushu University, Fukuoka, (2015.11.9-11).

18. R. Saito, M. S. Uktahry, A. R. T. Nugraha, **E. H. Hasdeo**, C. Reynolds: "Tunable absorption of electromagnetic wave of graphene (invited)", CEMS Topical meeting on Emergent 2D Materials, Riken, Wako, (2015.12.12).
19. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Coherent phonon spectra of G band in single wall carbon nanotubes", NT14: The Fifteenth International Conference on the Science and Application of Nanotubes, University of Southern California, Los Angeles, USA, (2014.06.02-06).
20. **E. H. Hasdeo**, A. R. T. Nugraha, M. S. Dresselhaus, R. Saito: "Quantum interference effect in Raman spectra of metallic nanotubes", NT14: The Fifteenth International Conference on the Science and Application of Nanotubes, University of Southern California, Los Angeles, USA, (2014.06.02-06).
21. R. Saito, **E. H. Hasdeo**, K. Sato, H. H. Guo: "Raman spectroscopy of graphene and atomic layer materials (invited)", RIEC symposium on Graphene, Tohoku University, (2014.6.11).
22. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito, G. D. Sanders, C. Stanton: "Coherent G band phonons in single wall carbon nanotubes", ATI 2014 Nano-Carbon Meeting, Yamagata-Zao, (2014.7.31-8.1).
23. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: "Asymmetric lineshape in G band Raman spectra of graphene", ATI 2014 Nano-Carbon Meeting, Yamagata-Zao, (2014.7.31-8.1).
24. R. Saito, A. R. T. Nugraha, **E. H. Hasdeo**, S. Siregar, M. S. Ukhtary: "Raman and coherent phonon spectroscopy of carbon nanotubes and graphene (invited)", Materials Research Society of Indonesia Meeting 2014, Aston Denpasar Hotel and Convention Center, Bali, Indonesia, (2014.9.26-28).
25. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Origin of coherent phonons in single wall carbon nanotubes", Materials Research Society of Indonesia Meeting 2014, Aston Denpasar Hotel and Convention Center, Bali, Indonesia, (2014.9.26-28).
26. R. Saito, **E. H. Hasdeo**, S. Siregar, H. Guo, T. Yang: "Raman spectra of Graphene and transition metal dichalcogenides (invited)", The 5th A3 Symposium on Emerging Materials, Nankai University, China, (2014.10.19-21).
27. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Exciton effects on coherent phonon spectroscopy of carbon nanotubes", The 44th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2013.03.11-13).
28. R. Saito, A. R. T. Nugraha, **E. H. Hasdeo**, K. Sato: "Raman spectroscopy of metallic single wall nanotubes and doped graphene (invited)", 4th A3 Symposium on Emerging Materials: Nanomaterials for Energy and Electronics, Daemyung Resort, Jeju, Korea, (2013.11.10-14).
29. R. Saito, K. Sato, **E. H. Hasdeo**, A. R. T. Nugraha: "Coherent phonon and Raman spectroscopy of single wall carbon nanotubes (invited)", Building blocks for carbon-based electronics: from molecules to nanotubes, University of Regensburg, (2013.4.10-12).
30. R. Saito, **E. H. Hasdeo**, A. R. T. Nugraha: "Exciton effects on coherent phonon and electronic Raman spectroscopy of single wall carbon nanotubes (invited)", 5th Workshop on Nanotube Optics and Nanospectroscopy, Eldorado Hotel, Santa Fe, NM, USA, (2013.6.16-20).

Poster Presentations

1. **E. H. Hasdeo**○, E Idrisov, T Schmidt: "Electron hydrodynamics in quantum materials", ICTP summer school, Bukhara, Uzbekistan, (2023.09.22–30).
2. **E. H. Hasdeo**, Ahmad R. T. Nugraha, R. Saito: "Kohn anomaly and quantum interference of one- and two-phonon Raman spectra in graphene", NT16: The Seventeenth International Conference on the Science and Application of Nanotubes and Low-dimensional Materials, University of Vienna, Austria, (2016.8.7-13).
3. **E. H. Hasdeo**, Ahmad R. T. Nugraha, R. Saito: "Asymmetric Kohn anomaly in G′ band of graphene", The 50th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2016.2.20-22).
4. **E. H. Hasdeo**, A. R. T. Nugraha, K. Sato, R. Saito: "Electronic Raman scattering and origin of the Fano resonance in metallic carbon nanotubes", The 44th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2013.03.11-13).
5. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: "Coherent phonons and single phonon mode generation in carbon nanotubes", 6th A3 symposium on Emerging Materials, Kyushu University, Fukuoka, (2015.11.9-11).
6. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: "Screening of electron-phonon coupling due to electron-electron interaction in graphene", 6th A3 symposium on Emerging Materials, Kyushu University, Fukuoka, (2015.11.9-11).
7. M. S. Ukhtary, **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: "Switching of electromagnetic wave by graphene",

NT15: The Sixteenth International Conference on the Science and Application of Nanotubes, Nagoya University, Japan, (2015.06.29-07.03).

8. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: “Squeezed phonons in single wall carbon nanotubes”, NT15: The Sixteenth International Conference on the Science and Application of Nanotubes, Nagoya University, Japan, (2015.06.29-07.03).
9. Syahril Siregar, **E. H. Hasdeo**, Ahmad R.T. Nugraha, Hsiang Liu, R. Saito: “G^* band Raman spectra of single layer graphene revisited”, The 48th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2015.2.21-23).
10. **E. H. Hasdeo**, Ahmad R. T. Nugraha, R. Saito: “Kohn anomaly meets Fano resonance in G and G' bands Raman spectra ofgraphene”, The 48th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2015.2.21-23).
11. Muhammad Shoufie Ukhtary, **E. H. Hasdeo**, Ahmad R.T. Nugraha, R. Saito: “Surface plasmon excitations in graphene”, The 48th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo , (2015.2.21-23).
12. Pourya Ayria, Ahmad R.T. Nugraha, **E. H. Hasdeo**, S. Tanaka, R. Saito: “Photon energy dependence of angle resolved photoemission spectroscopy in graphene”, The 48th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2015.2.21-23).
13. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: “Coherent and squeezed states of phonons in single wall carbon nanotubes”, 29th International Winterschool on Electronic Properties of Novel Materials: “Molecular nanostructures”, Kirchberg, Austria, (2015.3.7-14).
14. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: “Interplay of electron-phonon and electron-electron interactions in gate modulated Raman spectroscopy of graphene”, NT15: The Sixteenth International Conference on the Science and Application of Nanotubes, Nagoya University, Japan, (2015.06.29-07.03).
15. P. Ayria, A. R. T. Nugraha, **E. H. Hasdeo**, S. Tanaka, R. Saito: “Photon energy dependence of ARPES in graphene”, NT15: The Sixteenth International Conference on the Science and Application of Nanotubes, Nagoya University, Japan, (2015.06.29-07.03).
16. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: “Coherent G-band phonons in single wall carbon nanotubes”, The 46th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2014.3.3-5).
17. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: “Quantum interference effect in Raman spectra of metallic nanotubes and graphene”, The 46th Fullerenes-Nanotubes-Graphene General Symposium, The University of Tokyo, (2014.3.3-5).
18. S. Siregar, **E. H. Hasdeo**, A. R.T. Nugraha, R. Saito: “Absence of Raman G' band By Ultraviolet Excitation in Monolayer Graphene Systems”, The 47th Fullerenes-Nanotubes-Graphene General Symposium, Nagoya University, (2014.9.3-5).
19. P. Ayria, A. R.T. Nugraha, **E. H. Hasdeo**, R. Saito: “Polarization Dependence of ARPES Intensity in Graphene”, The 47th Fullerenes-Nanotubes-Graphene General Symposium, Nagoya University, (2014.9.3-5).
20. M. S. Ukhtary, **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: “Propagation Properties of Graphene Surface Plasmon”, The 47th Fullerenes-Nanotubes-Graphene General Symposium, Nagoya University, (2014.9.3-5).
21. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: “Coherent G-band and RBM Phonons in Single Wall Carbon Nanotubes”, The 47th Fullerenes-Nanotubes-Graphene General Symposium, Nagoya University, (2014.9.3-5).
22. **E. H. Hasdeo**, A. R. T. Nugraha, R. Saito: “Quantum interference effect in Raman spectra of metallic nanotubes”, 4th A3 Symposium on Emerging Materials: Nanomaterials for Energy and Electronics, Daemyung Resort, Jeju, Korea, (2013.11.10-14).
23. A. R. T. Nugraha, **E. H. Hasdeo**, R. Saito: “Exciton effects on coherent phonon dynamics in single wall carbon nanotubes”, 4th A3 Symposium on Emerging Materials: Nanomaterials for Energy and Electronics, Daemyung Resort, Jeju, Korea, (2013.11.10-14).
24. R. Saito, **E. H. Hasdeo**, A. R. T. Nugraha, K. Sato, M. S. Dresselhaus: “Electronic Raman spectra and origin of Fano resonance in metallic single-wall carbon nanotubes”, 14th International Conference on the Science and Applications of Nanotubes (NT13), Dipoli Congress Center, Aalto University, Espoo, Finland, (2013.6.24-28).
25. **E. H. Hasdeo**, A. R. T. Nugraha, K. Sato, R. Saito: “Theory of electronic Raman scattering in metallic single wall carbon nanotubes”, 2012 A3 Symposium of Emerging Materials: Nanomaterials for Energy and Environments - ATI International Forum, Tohoku University, Sendai, Japan, (2012.10.29-31).
26. A. R. T. Nugraha, E. Rosenthal, **E. H. Hasdeo**, R. Saito: “Exciton effects on coherent phonons in single wall carbon nanotubes”, 2012 A3 Symposium of Emerging Materials: Nanomaterials for Energy and Environments

- ATI International Forum, Tohoku University, Sendai, Japan, (2012.10.29-31).

27. **E. H. Hasdeo**, A. R. T. Nugraha, K. Sato, R. Saito: "Theory of electronic Raman scattering in metallic single-walled carbon nanotube", The 43th Fullerenes-Nanotubes-Graphene General Symposium, Tohoku University, Sendai, (2012.9.5-7).

SCHOLARSHIPS AND AWARDS

MEXT Scholarship for master course in Tohoku University, Japan, October 2011 - September 2013.

MEXT Scholarship for doctor course in Tohoku University, Japan, October 2013 - September 2016.

JSAP Paper Award (2017) for: Fermi energy-dependence of electromagnetic wave absorption in graphene, Journal: Appl. Phys. Express 8 (2015) 055102

GRANTS AWARDED

eASIA JRP, "Data-driven computational design of high-performance thermoelectrics in atomic layers and topological materials", Japan, Thailand, and Indonesia, 516000 USD, 2022 – 2025

FNR CORE Junior, "Navier-Stokes flows in quantum materials", Luxembourg, 370,000 EUR, 2022/01 – 2024/12

FNR CORE + DFG , "Topology in Relativistic Semimetals", Luxembourg & Germany, 950,000 EUR, 2021 – 2024

Travel grant for to Sakhon Nakhon, Thailand, "Designing quantum materials for thermoelectrics", Indonesian Institute of Science, 90 Million IDR, 2019

Toray Science and Technology Research Grant, "Two dimensional materials simulation for advancement of thermoelectrics", Indonesia, 25 Million IDR, 2019

DAAD Research Stay for University Academics and Scientist, "Electron-phonon interactions of two dimensional superconductors", Cologne University, Germany, 7500 EUR, May – July 2019

Brawijaya University Research Fund, "Design of quantum materials for enhancement of thermoelectrics and solar cells efficiency", Indonesia, 100 Million IDR, collaboration with Prof. Nurhuda 2019

WORKSHOPS AND OUTREACH

First-Principles Calculation Workshop with the Quantum ESPRESSO, Tohoku University (26/02/2016), Indonesian Computational Society (1/11/2019), Sakon Nakhon Rajabhat University, Thailand (12/2019)

Frontiers of Solid State Physics and Electronic Structure Workshops, Brawijaya University (19-21/12/2012, 14/11/2016, 26/12/2018), Malang State University (6/2019)

Workshop on Scientific Method and Writing for Natural Sciences, Selected High School Students in Merauke Regency, Papua, Indonesia (27-30/08/2019)

MENTORING ACTIVITIES

1. Jyesta Adhidewata, BSc – MSc Bandung Institute of Technology, Indonesia, Now PhD UC Berkeley, USA, "Thermoelectrics and Optoelectronics of quantum materials" (2020 – 2022)
2. Ravanny Komalig, MSc Bandung Institute of Technology, Indonesia, Now PhD UC Berkeley, USA, "Optoelectronics of quantum materials" (2021 – 2022)
3. Johan Ekström, PhD University of Luxembourg, Now KPMG Luxembourg "Optical properties of nodal line semimetals" (2020 – 2021).
4. Lukas P. A. Krisna, MSc Bandung Institute of Technology, Indonesia, Now PhD Osaka University, "Thermoelectric properties of Dirac materials"(2018 – 2019)
5. Zainul Mustofa, MSc Brawijaya University, Indonesia, Now highschool teacher "Nonlinear optics of Dirac materials" (2018 – 2020)
6. Muhammad Hanna, Junior researcher BRIN, "Topological aspects of InBi Dirac semimetals" (2018 – 2020)
7. Junjung Sugiarto, BSc IPB University, Indonesia, Now PhD SKKU South Korea, "Thermoelectric properties of $PbCsBr_3$ perovskites" (2019 – 2020).
8. Bernandus Rendy, BSc Bandung Institute of Technology, Indonesia, Now PhD UC Berkeley, "Strain effect on nodal line semimetals", (2019 – 2020).
9. Nur Ayukaryana, BSc Bandung Institute of Technology, Indonesia, Now PhD Tokyo University of Agriculture and Technology, Japan, "Majorana fermions and quantum computing" (2019 – 2020).
10. Muhammad Gaffar, BSc University of Indonesia, Now PhD Shanghai Jiao Tong University, China, "Thermoelectric properties of bismuthene", , (2019 – 2020).

11. Rizqiatul Hasanah, BSc State University of Malang, Indonesia, "Thermal conductivity of 2D materials", (2019 – 2020).
12. Galih Suwito, BSc Nagoya University, Now Postdoc University of Cambridge,UK, "Resonant tunneling quantum wells", (2019)
13. Kevin Octavian, BSc Bandung Institute of Technology, Indonesia, Now MEng KAIST, South Korea, "Thermoelectric of 2D and 3D materials", (2019 – 2020)

REFERENCES

Prof. Riichiro Saito
Theoretical Condensed Matter and Statistical Physics Research Group
Department of Physics, Graduate School of Science, Tohoku University
Sendai, 980-8578, Japan
Email: rsaito@flex.phys.tohoku.ac.jp
Homepage: http://flex.phys.tohoku.ac.jp/

Prof. Thomas Schmidt
Department of Physics and Material Science, University of Luxembourg
Luxembourg 1511
Email: thomas.schmidt@uni.lu
Homepage: https://tmqs.uni.lu/schmidt.html