Peir-Ru, Wang (Louis)

Quantum Physics | Superconductivity | Materials Science | Mechanical Engineering

EXPERIENCE

Pure-Perspective Research Group

2024.10-

Researcher

Focused on research and education in superconducting qubit control and simulation. National Tsing Hua University (NTHU) 2024.03–2024.09

Postdoc in Materials Science and Engineering

Investigate quantum properties of spiral TaS2 using Scanning Tunneling Microscopy.

INVENTION PATENTS

United States Invention Patent

US 10030745 B2 - Continuously Variable Transmission

- This self-adaptable, positive motion CVT is able to transmit power by way of engagement.
- Able to transmit a torque density **8 times** larger than the traditional design.

Taiwan Invention Patent

1580876 - Continuously Variable Transmission

PUBLICATIONS

The Effect of Critical Coupling Constants on Superconductivity Enhancement

Nature Scientific Report 13, 6475 (2023) (Impact Factor: 4.997)

- The theory of critical coupling constants **unifies** the effects of the phonon frequency Ω , the carrier number *Z*, and the pressure *P* on superconductivity.
- Demonstrate general zigzag methods for T_c enhancement.

Low Speed Wind Tunnel Study of Variable Tandem Wing Aircraft Design

A.A.S.R.C Conference (2014)

• The variable tandem wing design can **increase 33%** lifting force.

LABORATORY AUTOMATION

Resistivity-Temperature ρ -T Measurement Automation

- Temperature 70K~400K, resistivity $1\mu\Omega \cdot cm \sim 1G\Omega \cdot cm$
- Program LabVIEW codes to control and collect information from the instruments, including Keithley, HP, Stanford Research Systems, and Cryo-Con.

Chemical Powder Mixture Preparation Automation

• Prepare 96 different mixtures within 14 hours and 40 types of powder for selections.

E D U C A T I O N

2016.09-2024.01

2012.09-2016.06

National Tsing Hua University (NTHU)

Ph.D. in Materials Science and Engineering National Tsing Hua University (NTHU)

B.S. in Power Mechanical Engineering

Minor in Physics

TEACHING ASSISTANT

NTHU Outstanding Teaching Assistant Award (2019)

TA Courses:

- General Relativity I & II
- Classical Mechanics
- Theoretical Mechanics II

- Statistical and Thermal Physics I & II
- Fluid Dynamics
- General Physics I & II

COURSES WITH GOOD PERFORMANCE

Studied across various subjects, including materials science, mechanical engineering, physics, and mathematics. Capable of integrating and applying knowledge from multiple fields.

Materials Science:

- Phase Equilibria of Materials (A+)
- Thermodynamics of Solid State (A)

Power Mechanical Engineering

- Thermal and Fluid Science I (A+)
- Introduction to Nuclear Engineering (A+)
- Electric Circuits (A+)
- Kinematics of Machinery (A)
- Vehicle Power System (A)

Physics:

- String Theory (A+)
- Elementary Particle Physics I (A+)
- Theoretical Mechanics II (A+)
- Statistical Mechanics II (A)

Mathematics:

• Advanced Calculus I (A+)

SKILLS

- LabVIEW
- AutoCAD
- 3D Printing
- Arduino

CERTIFICATE

• TOEIC 880 (Gold)

LINKEDIN

- https://www.linkedin.com/in/peir-ru-wang
- WEBSITE
 - <u>https://pure-perspective.github.io/career/CV.html</u>

- Ceramic Materials (A)
- Transmission Electron Microscopy (A)
- Programming Language (A+)
- Engineering Mathematics II (A+)
- Heat and Mass Transfer (A)
- Manufacturing Processes (A)
- Energy Engineering (A)
- Fluid Dynamics (A+)
- Nonlinear Dynamics and Chaos (A+)
- Quantum Field Theory (A)

- MATLAB
- Python
- VBA
- C

A U T O B I O G R A P H Y

The Self-Adaptable Positive Motion CVT Invention Patents

US Invention Patent 10030745 B2: ppubs.uspto.gov/dirsearch-public/print/downloadPdf/10030745 Taiwan Invention Patent I580876: twpat1.tipo.gov.tw/twpatc/twpatkm?!!FRURLI580876@@gpss

I studied and invented *the self-adaptable, positive motion continuously variable transmission* (*CVT*). Traditional CVTs using friction transmission cannot achieve high torque output. This self-adaptable, positive motion CVT is able to transmit power by way of engagement, such that the coupling between the power transmission mechanism and the conical disk is more stable than the conventional friction CVT. Thus, this invention can transmit a torque density *8 times* larger than the traditional design, making it *competitive in high-torque applications*.



(12) United States Patent Wang et al.

- (54) CONTINUOUSLY VARIABLE TRANSMISSION
- (71) Applicant: NATIONAL TSING HUA UNIVERSITY, Hsinchu (TW)
- (72) Inventors: Pair-Ru Wang, Hsinchu (TW); Tzu-Yang Cheng, Lukang Township, Changhua County (TW); Hsiao-Wei Chiang, Hsinchu (TW)
- (73) Assignee: NATIONAL TSING HUA UNIVERSITY, Hsinchu (TW)
- (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 274 days.
- (21) Appl. No.: 15/175,887
- (22) Filed: Jun. 7, 2016

(65) Prior Publication Data

US 2017/0248207 A1 Aug. 31, 2017

(30) Foreign Application Priority Data

Feb. 26, 2016 (TW) 105105774 A

- (51) Int. Cl. F16H 9/24
- *F16H 9/24* (2006.01) (52) U.S. Cl.
- CPC F16H 9/24; F16H 9/10; F16H 9/18; F16H 55/56; F16H 55/38; F16H 37/0846 See application file for complete search history.

(10) Patent No.: US 10,030,745 B2 (45) Date of Patent: Jul. 24, 2018

References Cited

U.S. PATENT DOCUMENTS

5,049,113	A *	9/1991	Graham, Jr I	F16H 55/38
				474/13
9,855,993	B2 *	1/2018	Rockwood	F16H 9/24
2011/0053717	A1*	3/2011	Miura	F16H 9/18
				474/46
2011/0059821	AI *	3/2011	Lee	F16H 9/10
				474/8

* cited by examiner

(56)

Primary Examiner - William E Dondero

Assistant Examiner — Robert T Reese (74) Attorney, Agent, or Firm — Muncy, Geissler, Olds & Lowe, P.C.

(57) ABSTRACT

A continuously variable transmission (CVT) includes a power transmission mechanism and at least one conical disk. The power transmission mechanism has a contact surface, and the power transmission mechanism includes a plurality of engaging elements. The plurality of engaging elements are retractably disposed on the contact surface. The disk surface of the conical disk has a plurality of engaging walls capable of engaging with the engaging elements. The continuously variable transmission is able to transmit power by way of engagement, such that the coupling between the power transmission mechanism and the conical disk is more stable. Thus, the continuously variable transmission is adaptable to high torsion application.

10 Claims, 15 Drawing Sheets



▲ United States patent certificate.

STM Studies of TaS₂: Insights into Quantum Properties (Postdoc)

In my recent postdoctoral research, I have focused on 2D quantum materials, particularly Transition Metal Dichalcogenides (TMDs) such as TaS_2 , NbS₂, and VS₂. These van der Waals layered materials exhibit remarkable properties, including superconductivity, charge density waves, and Moiré phenomena, making them a promising platform for advancing quantum materials research. Scanning Tunneling Microscopy (STM) plays a crucial role in quantum physics by enabling direct, atomic-scale probing of the local electronic density of states, allowing researchers to observe and understand quantum phenomena at the surface level. By using STM, I gain invaluable insights into the physical properties and electronic behaviors of these materials, facilitating a deeper understanding of their quantum nature.

I have hands-on experience with maintaining and operating UNISOKU's STM USM-1400 system. Recently, my work with CVD-grown spiral TaS_2 involved capturing high-resolution STM images at both room temperature and 77K. I observed stoichiometric and non-stoichiometric transitions in spiral TaS_2 , demonstrating the capability of CVD growth methods for fine-tuning chemical composition and providing a versatile platform for exploring novel physical phenomena. Additionally, the I-V curve analysis reveals a gap feature in TaS_2 , which may indicate the presence of a Mott gap, offering further insight into its electronic structure.



▲ (Left) This image demonstrates the transition from the stoichiometric phase to the nonstoichiometric phase of TaS₂, showcasing the power of the CVD growth method in precisely tuning chemical composition. (Right) The I-V curve reveals the gap nature of TaS₂, potentially indicating a Mott gap, providing valuable insight into its electronic structure and the underlying quantum behaviors.

Pure-Perspective Research Group

Recently, I established a small education and research group, Pure-Perspective Research Group, dedicated to advancing knowledge in superconducting (SC) qubit physics. My work involves studying the Hamiltonian of SC control circuits and employing Python to simulate and visualize qubit state evolution on the Bloch sphere. Our current research focuses on the mathematical frameworks of Lie groups and gauge theory, with an emphasis on their applications in qubit control and topological physics.

• (Left) Using Python to simulate detuned $\pi/2-\pi/2$ control with varying time delays in the Ramsey experiment and visualize it on the Bloch sphere. This approach helps analyze the impact of detuning on qubit coherence and phase evolution.



Theory of Critical Coupling Constants published in Nature Scientific Reports (Impact Factor 4.997)

DOI:10.1038/s41598-023-33809-5

My Ph.D. thesis is "The effect of critical coupling constants on superconductivity enhancement". In the thesis, it clearly elaborated that the superconducting dome appears when the coupling strength approached to the critical coupling constants. Varying the phonon spectrum Ω , tuning the carrier number Z, and increasing the pressure P were three important approaches to enhance superconductivity T_c . I extended the BCS-McMillan theory:

$$\widehat{H}|\Psi\rangle = \left[\sum_{k\sigma} \xi_k c^{\dagger}_{k\sigma} c_{k\sigma} + \frac{1}{N} \sum_{kk'} \frac{g_{eff}}{M\Omega^2} c^{\dagger}_{k\uparrow} c^{\dagger}_{-k\downarrow} c_{-k'\downarrow} c_{k'\uparrow}\right] |\Psi\rangle$$

to unify effects of the phonon frequency Ω , the carrier number Z, and the pressure P on superconductivity. I derived the explicit form of coupling constant λ and T_c :

$$\lambda = \frac{C\sqrt[3]{Zn_{ion}}}{M\Omega^2} \quad and \quad T_c \sim \Omega \cdot exp\left[-\frac{M\Omega^2}{C\sqrt[3]{Zn_{ion}}}\right]$$

. These equations defined the *three critical coupling constants* λ_c : $\lambda_c^{\Omega} = 2$, $\lambda_c^{Z} = 5/3$, and $\lambda_c^{P} = 4/3$.

These critical coupling constants are consistent with experimental observations and quantitatively classify superconductivity into three categories: weak $(\lambda < \lambda_c^P)$, intermediate $(\lambda_c^P < \lambda < \lambda_c^\Omega)$, and strong coupling $(\lambda > \lambda_c^\Omega)$. Each category corresponds to different enhancement strategies. More precisely, the enhancement strategies for weak and strong coupling regions are opposite, but both inevitably bring superconductivity into the intermediate coupling region. For superconductors in the intermediate coupling region, for example, the superconductivity can be enhanced by increasing P or decreasing Z simultaneously. This general zigzag strategies can further enhance the superconductivity. According to the theory, I focused on the chemical design including high phonon frequency, multiple carriers, and small lattice constants. I synthesized a series of high-entropy oxides based on $Bi_2Sr_2Ca_2Cu_3O_x$ and $YBa_2Cu_3O_x$ superconductors. The micro structure of the HE compounds was





 $\mathcal{X} = \Omega, Z, \text{ or } P$ (Left) The relation between the *critical coupling constant* λ_c and the *superconducting dome*.



▲ (Right) *The general zigzag strategies* further enhance superconductivity by pressurizing and decharging.

The Powder Mixing Robotic, and ρ-T Measurements Automation

More details: pure-perspective.github.io/career/CV.html

The chemical powder mixture preparation automation can prepare 96 different mixtures within 14 hours, which is 6 times faster than manual preparation. The machine offers 40 types of powder for selections. I designed components using AutoCAD and printed them with Ender-3S 3D printer. I also soldered electronic components onto circuit boards to control the step motors. 12 step motors controlled the XY motions of the powder boxes and the empty bottles. The weight of powder mixture is measured by Shimadzu ATY-124 balance. The control program integrated LabVIEW, Arduino, and VBA. This machine can weigh the powder according to the user's experimental design and record any discrepancies.

The resistivity-temperature $\rho - T$ measurement automation can measure 15 oxide or alloy pallets simultaneously with the temperature range from 70K to 400K. The range of resistivity covers $1\mu\Omega \cdot cm$ to $1G\Omega \cdot cm$. LabVIEW codes control and collect information from the instruments through GPIB. Instruments include Keithley 237 and 617 meters, HP34420A meter, Stanford Research Systems SR830 Lock-in, and Cryo-Con 32B temperature controller. The modular design of the measurement circuit allows for easy expansion and routine maintenance.

• Teaching Assistant in Physics and Recognized Outstanding TA Award

TA Award: mse.site.nthu.edu.tw/p/405-1298-182360,c16769.php?Lang=en

I am the teaching assistant in *statistical and thermal physics I & II*, *general relativity I & II*, *theoretical mechanics II*, *fluid dynamics*, classical mechanics, general physics I & II, etc. I was recognized with the *NTHU Outstanding Teaching Assistant Award* in 2019 due to dedicated teaching efforts.

Minor Degree in Physics(B.S.) and further studied physics during Ph.D.

Beside the major subject in power mechanical engineering, I also have minor degree in physics. I have taken the courses including *theoretical mechanics I & II, electromagnetism I & II, and quantum physics I.* I am interesting in the variational principle of least action and the Noether's theorem, which imply the relation between the symmetry and the conservation law. These elegant results showed the beauty of physics, leading me to further study more physics courses and become TA in physics during my doctoral studies.

During my Ph.D. period, I further studied more advanced courses in physics. The superconductivity is a *macroscopic quantum state*, typically explained through the concept of *symmetry breaking*. I studied *quantum field theory, statistical mechanics, and condensed matter physics* to further investigate superconductivity. Additionally, to understand symmetry breaking, I studied *elementary particle physics, gauge theory*, and even *principal bundle theory* from the Mathematics Department. The *Ginzburg-Landau (GL) theory* is one of the theories that explain superconductivity. I learned to use *MATLAB* to simulate the phase separation in GL theory during the course on *nonlinear dynamics and chaos*.



▲ B.S. in *Department of Power Mechanical Engineering* at NTHU. Minor degree in *Department of Physics*.

Wind Tunnel Study of Variable Tandem Wing Aircraft

Article: pure-perspective.github.io/career/images/tandem/Tandem-Wing-article.pdf

During my bachelor's studies, I studied on the *aerodynamics of variable tandem wing aircraft*. The variable tandem wing design can change the center of lift to match the center of gravity. This design can *increase 33% lift and optimize the aerodynamic efficiency*. The model aircraft was set up in the wind tunnel, and measure the lift force and the drag force to investigate the aerodynamic performance. We summarized these result and published in *Aeronautical and Astronautical Society of the Republic of China (A.A.S.R.C) 2014 conference*.

Cross-disciplinary Learning, Integrating and Applying Knowledge

During my bachelor's and Ph.D. degrees, I studied across various disciplines, including *mechanical engineering*, *physics*, *materials science*, and *mathematics*. I *maintained curiosity* and *strong learning capabilities*, *integrating knowledge from multiple fields* to advance the formulation of superconducting theories, the automation of measurement, and the powder mixing robotic. I have shown *curiosity* and *gained expertise in various fields*, and I'm able to *provide solutions to complex problems*!