Statement of Purpose

Doctoral Program, Graduate School of Science, University of Tokyo

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Academic Background and Motivation

I am a final-year undergraduate Physics major at Beijing Normal University (ranked 2/23, GPA 3.7/4.0) with research in optical physics (diffractive neural networks, SLM beam shaping) and nanophotonics. Currently at UC Berkeley (Aug–Dec 2025), I have been exposed to cutting-edge condensed matter physics and ultrafast spectroscopy. This crystallized my scientific passion: **How can we disentangle electron-phonon coupling, electron-electron correlations, and topological band structure that govern exotic quantum phases?** This fundamental question, rather than mere technical fascination, motivates my commitment to a five-year doctoral program in experimental quantum materials physics.

My technical skills—precision optics, signal optimization, computational methods (Python/PyTorch, MATLAB)—are tools to address deep physics questions through advanced ultrafast spectroscopy, where experiment meets theory to probe non-equilibrium many-body phenomena.

Why School of Science, University of Tokyo, and Tentative Research Plan

Research Alignment with Professor Takeshi Kondo's Laboratory (ISSP)

I am strongly motivated to join Prof. Kondo's laboratory due to exceptional research synergy. The lab's world-leading ARPES work on topological materials and strongly correlated systems—**combined with strategic development of time-resolved and spin-resolved ARPES (as described in Section 7 of the laboratory website)**—represents the intersection of ultrafast optics and quantum materials physics where I aspire to build my career.

My D2NN optical systems experience, SLM feedback control algorithms, and computational physics background directly apply to laser-ARPES, OPA tuning, and high-dimensional data analysis. The lab's discoveries (*Nature* 2019, 2021 topological states; *Science* 2020 cuprate mysteries) and ISSP resources (ultrahigh-resolution laser-ARPES, global synchrotron access, theory/synthesis networks) provide ideal environment.

Alignment with the laboratory's trARPES development: The lab's time-resolved ARPES development complements my dual-modality approach. My pump-probe expertise enables rapid parameter screening (*when/what conditions*), while trARPES collaboration (Years 3–5) reveals momentum-space dynamics (*how*). This synergy contributes to technical development while advancing ultrafast many-body physics.

Tentative Research Plan: Band-Selective Ultrafast Spectroscopy for Many-Body Physics

Core Physics Questions:

1. **Can we disentangle electron-phonon versus electron-electron interactions?** Band-selective spectroscopy in kagome metals (CsV_3Sb_5) and cuprates extracts quantitative timescales ($\tau_{e-e} \sim$ 50–100 fs vs. $\tau_{e-ph} \sim$ 0.5–2 ps) and coupling constants (λ, Z).
2. **How does correlation-topology interplay manifest in non-equilibrium?** Dual-modality measurements (pump-probe + trARPES) map Van Hove singularities and Dirac cone dynamics.
3. **Can we access photo-induced metastable phases?** Light-driven state engineering (Floquet, hidden order) via systematic fluence/wavelength studies.

Technical Approach and Feasibility: My methodology builds directly on Kondo Lab's established platforms:

- **Band-selective pump-probe (Y1–2):** Leverage lab's ultrahigh-resolution laser-ARPES ($\Delta E < 1$ meV) for momentum-resolved equilibrium mapping. Add tunable pump (OPA 1.2–6 eV, <100 fs) + broadband probe (white-light generation 1.5–3.5 eV) to track $\Delta R/R(k, \omega, t)$. Initial work on CsV_3Sb_5 exploits lab's topological material expertise.
- **Dual-modality synergy (Y3–5):** Pump-probe identifies *when/where* dynamics occur (fluence/wavelength parameter space, ~100 conditions/week); collaborate with the lab's trARPES development to resolve *how* (k-space evolution, quasiparticle lifetime). Cuprate focus (BSCCO, LSCO) leverages Kondo Lab's world-leading sample growth (*Science* 2020) and antinodal/nodal ARPES mastery.
- **Risk mitigation:** Strong electron-phonon screening (kagome)? → Switch to Bi_2Se_3/topological insulators (lab expertise). Pump-induced damage? → Cryogenic environments (<20 K), fluence optimization (<1 mJ/cm^2). Data complexity? → ML-based analysis (my PyTorch/computational background).

Five-year trajectory with milestones:

- **Years 1–2 (Foundation):** CsV_3Sb_5 band-selective methodology development. Extract $\Delta E(t)$ (meV precision), $\tau_{e-e/e-ph}$ (fs/ps regime), λ (0.1–0.5 range), $Z(k)$ at Van Hove singularities. *Milestones:* First pump-probe setup (Month 6), initial kagome data (Month 12), 1–2 *PRB* submissions (Month 18–24).

- **Years 3–4 (Cuprate Focus):** Probe pseudogap dynamics in BSCCO/LSCO (antinodal vs. nodal regions) using lab's cuprate samples (*Science* 2020; 5/5 mastery rating). Map $\Delta_{\mathrm{PG}}(k, t)$ collapse/recovery timescales, test competing order scenarios. *Milestones:* Cuprate measurement campaign (Month 30–36), high-impact paper submission *PRL*/*Nature Communications* (Month 42–48).
- **Year 5 (Frontier & Dissertation):** Explore photo-induced phases (Floquet engineering, hidden order), implement ML-accelerated analysis pipelines, or extend to new platforms (nickelates, twisted bilayers). 200–300 page dissertation integrating all findings. *Milestone:* Defense + postdoc applications (Month 60).

Expected outcomes: 5–6 first-author papers ($\geq$1 high-impact *PRL*/Nature-family), dual-modality technical innovations (potential patent/technique papers), mentorship of 2–3 junior students (Years 3–5), international collaborations (synchrotron beamtimes, theory groups), strong positioning for postdoc at world-leading institutions.

Career Goals

The GSGC program's interdisciplinary training and international collaboration align with my goal to become an experimental physicist at the physics-materials-instrumentation interface. Studying in Japan offers immersion in leading condensed matter physics culture, Japanese language proficiency (target JLPT N1 by Year 4), and international research connections.

Career Aspirations and Commitment

Doctoral goals: Become expert in band-selective ultrafast spectroscopy; publish 5–6 papers ($\geq$1 *PRL*/Nature-family); develop novel dual-modality techniques; build international collaborations; mentor 2–3 students (Years 3–5); achieve JLPT N1 for full integration.

Long-term vision: Postdoc at world-leading institution (Stanford, MIT, Max Planck, Berkeley) developing advanced spectroscopies, then establish research group as tenure-track faculty or national lab PI, bridging experiment-theory through data-driven modeling and ML, mentoring next generation, addressing quantum many-body far-from-equilibrium physics.

My commitment:

- **Full dedication:** Prepared for intensive research, thriving in challenges (double major Physics+Economics, rank 2/23), viewing obstacles as growth opportunities.
- **Cultural integration:** Intensive Japanese study (JLPT N1 by Year 4), active university engagement beyond research.
- **Leadership transition:** Student (Y1–2) $\rightarrow$ junior researcher (Y3–4) $\rightarrow$ research leader (Y5), taking ownership, mentoring, initiating collaborations.
- **Scientific excellence:** Top-tier publications; annual international conferences (APS, MRS); competitive fellowships (JSPS DC2, GSGC); teaching/grant experience.

Conclusion

The University of Tokyo's School of Science, particularly Prof. Kondo's ISSP laboratory, represents my ideal environment for a five-year doctoral program addressing fundamental quantum materials physics through ultrafast spectroscopy. The lab's ARPES expertise (*Nature* 2019, 2021; *Science* 2020), time-resolved technique development, and focus on correlated/topological materials align perfectly with my vision of disentangling competing interactions via band-selective methods.

My optical systems experience (D2NN, SLM), computational skills (ML, optimization), and hands-on experimentation provide technical foundation. More importantly, my intellectual passion for understanding how electron-phonon coupling, electron-electron correlations, and topological structure produce exotic quantum phases drives my five-year commitment. I am prepared to transition from student to research leader, contributing transformative advances to ultrafast quantum materials physics.

Thank you for considering my application. I am excited to join the University of Tokyo and collaborate with Professor Kondo's group to advance quantum many-body phenomena understanding.

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