PennState College of Engineering

Shengxi Huang, Ph.D.
Assistant Professor
Department of Electrical Engineering &
Department of Biomedical Engineering
The Pennsylvania State University

Tel: 814-863-6711
Email: sjh5899@psu.edu
https://sites.psu.edu/shengxih/

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Re: Dr. Qingkai Qian's faculty application

Dear search committee,

It is my great pleasure to write this letter **in the strongest possible support** of Dr. Qingkai Qian's application for the faculty position in your institute. Qingkai is a postdoctoral scholar in my research group since January 2019 working on optical and quantum properties of 2D materials. He has shown excellent research capability and potential as a professor. I believe he will be a great addition to your department.

Please allow me to introduce myself first. I am an assistant professor at The Pennsylvania State University, USA. I obtained my bachelor's degree in microelectronics at Tsinghua University, China. My PhD study at MIT was under the supervision of Prof. Midred Dresselhaus, a highly esteemed scientist in the field of nanomaterials. Following that and before joining Penn State, I carried out my postdoctoral research at Stanford University, with Profs. Tony Heinz and Jonathan Fan. Over the years I have collaborated and interacted with the brightest young researchers in the field. Many of them have recently started their own research groups as assistant professors in prestigious universities around the world. I am confident to say that **Qingkai is on par with them**.

During less than 2 years in my group, Qingkai has worked on 3 major projects. All these projects are challenging and are very different from his past projects. Qingkai learns very fast and can quickly take control of a new project. He has been highly productive and has published 2 papers with an additional one under review.

The first project focuses on single photon emission in 2D materials. Single photon emitter (SPE) is a building block for the next generation quantum communication and quantum information science, and 2D materials is a highly promising matrix to host SPEs due to their high efficiency in light extraction, readiness in integrating with photonic chips, and high tunability of SPE properties. However, deterministic generation of highly efficient SPE in 2D materials is a bottleneck. Qingkai's goal is to tackle this bottleneck through a combination of defect and strain engineering for 2D materials. The material processing and device fabrication involve a number of intricate steps but Qingkai can manage them well, including material engineering, fabrication of strain-engineered devices, and quantum optical characterization. So far, Qingkai has systematically studied the defects in 2D tungsten diselenide, a material promising for SPE generation. He has discovered the ultra-long lifetime for the defect-bound excitonic states, and has published the finding in *Nanoscale*.

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The second project is ultrafast electron diffraction (UED) of van der Waals materials. UED is a very unique characterization technique where an ultrafast laser beam pumps the material, followed by an ultrafast electron beam to measure the material diffraction pattern in an ultrafast timescale. The experiment is in collaboration with SLAC National Laboratory in California, USA. Qingkai was working on gallium telluride, a layered material with unconventional crystal symmetry and layer stacking orders. This leads to a peculiar UED pattern: the Friedel pairs always oscillate out-of-phase, which breaks the Friedel's law dynamically. This phenomenon has been rarely reported, and Qingkai has successfully discovered the cause through meticulous theoretical calculations: symmetry and acoustic phonon motions of the GaTe lattice. This finding can lead to a series of material structural and phononic engineering. This first discovery of dynamic violation of Friedel's law has been reported in Qingkai's recent publication in *ACS Nano*. During the experiment, we found another unconventional phenomenon related to the temperature dependence of the UED pattern, and Qingkai, again, discovered the reason through calculations and carried out clever control experiment to solve the puzzle. This provides valuable guidelines for future UED sample preparation. In this project, Qingkai carried out the entire UED data analysis, simulation, theoretical calculations, which is significant amount of work and requires extremely strong background in material symmetry, phonon, lattice dynamics, thermal transport. I am very impressed that Qingkai could individually complete all these tasks with high caliber.

The third project is the nonlinear optical properties of nanoscrolls. Similar to nanotubes, nanoscrolls are 1D materials, and can be fabricated by "rolling" a flat 2D material. We first got the samples from a collaborator at MIT, without specific goals of study. When Qingkai learned about this material, he quickly realized that the nanoscroll structure and symmetry can produce interesting second harmonic generation (SHG), which may in fact enhance SHG intensity compared to their flat 2D counterpart, and can be tuned by parameters including rolling angles (or chirality), layers, and ellipticity. He collaborated with a nonlinear optics group on the measurement and confirmed his hypothesis. Together with his computational analysis of SHG signals as a function of nanoscroll structure, Qingkai summarized the results in a manuscript now under review in *ACS Nano*. This work can lead to nanomaterials with higher SHG intensity and more straightforward fabrication, compared to the flat 2D materials with various stacking maneuvers.

Qingkai is the major force to keep these projects moving by carrying out both experimental and computational aspects. His research portfolio is uncommonly comprehensive, including experimental skills (material processing, nanofabrication, optical characterization) and theoretical/computational skills (including DFT calculations). Recently due to COVID-19 and our campus closure, Qingkai has even embarked on a new theoretical project on understanding charge-density wave materials which requires in-depth understanding of DFT calculation. He has a strong foundation in materials physics, which allows the breadth of his research. He also writes very well, which leads to the efficient publication of high-impact papers in a short period of time. These qualities render Qingkai's extreme independence in conducting research, future vision, and flexibility to adapt to the fast-evolving materials and device field, which are

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among the most essential characters of research leaders.

Overall, Qingkai is an outstanding young researcher in the field of nanomaterials and nanodevices. I have no doubt that his research capability makes him well qualified for this faculty position, and he will become a valued talent in your institute. I therefore provide my strongest recommendation for his nomination for this faculty position. Should you have any questions, please do not hesitate to contact me.

Sincerely,

Shengxi Huang