NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2026 Project Summary

1. Student name & home university: Bence Göblyös, Budapest University of Technology and Economics

2. ND faculty name & department: Prof. László Forró and Dr. Bence G. Márkus, Stavropoulos Center for Complex Quantum Matter

3. Summer project title: Melting magnetism with photoinduced electrons in layered magnets

4. Briefly describe new skills you acquired during your summer research:

As a part of my summer research I had the opportunity to work in a condensed matter and materials physics lab. During the design of a new measurement setup I improved my optics engineering abilities and deepened my understanding of solid state physics. I've also gained several new lab skills, including the use of fume hoods and gloveboxes, scientific glass working and crystal growing.

5. Briefly share a practical application/end use of your research:

My project was to enable the study of photoexcited charge carriers and their interaction with magnetic phases relevant for applications in semiconductor, photovoltaic, and magnetic storage. With my upgrades to the lab's instruments, these materials can be studied and their useful properties refined.

6. 50- to 75-word abstract of your project:

My primary task was to upgrade the Physical Property Measurement System (PPMS) with optical excitation and light collection to facilitate absorption and photoluminescence spectroscopy. All this had to be achieved through the construction of a fiber optics-based setup and working around the limitations of the multi-functional probe in which the sample is mounted.

7. References for papers, posters, or presentations of your research:

Rabindra Basnet, Jin Hu; Understanding and tuning magnetism in van der Waals-type metal thiophosphates. *Nanoscale* 2024; 16 (34): 15851–15883. https://doi.org/10.1039/d4nr01577k

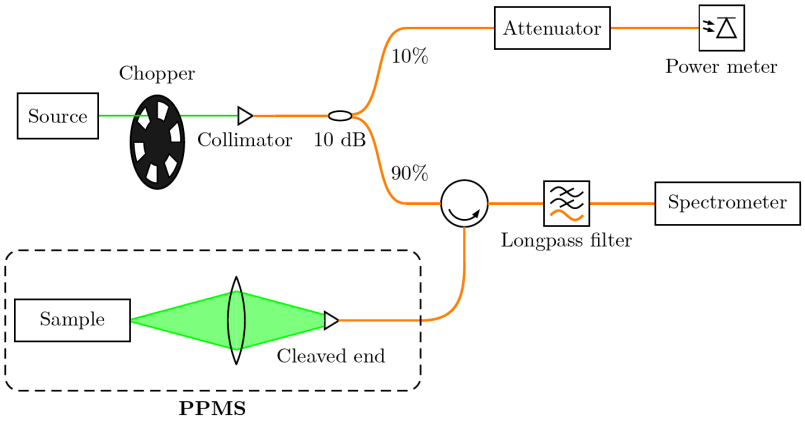
Yuriy Dedkov, Yefei Guo, Elena Voloshina; Progress in the studies of electronic and magnetic properties of layered MPX3 materials (M: transition metal, X: chalcogen). *Electron. Struct.* 2023; 5 043001. https://doi.org/10.1088/2516-1075/acfa4e

M. Grönke, B. Buschbeck, P. Schmidt, M. Valldor, S. Oswald, Q. Hao, A. Lubk, D. Wolf, U. Steiner, B. Büchner, S. Hampel; Chromium Trihalides Cr*X*3 (*X* = Cl, Br, I): Direct Deposition of Micro- and Nanosheets on Substrates by Chemical Vapor Transport. *Adv. Mater. Interfaces* 2019; 6, 1901410. https://doi.org/10.1002/admi.201901410

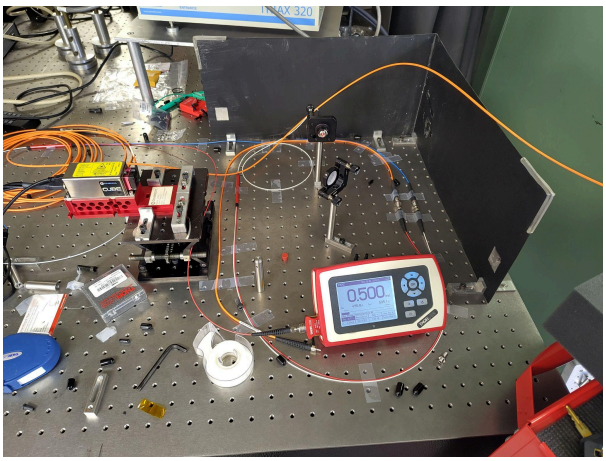
M. Grönke; Synthesis and characterization of layered transition metal trihalides MCl3 (M = Ru, Mo, Ti, Cr) and CrX3 (X = Cl, Br, I). *Brandenburg University of Technology* 2020; https://doi.org/10.26127/BTUOpen-5282.

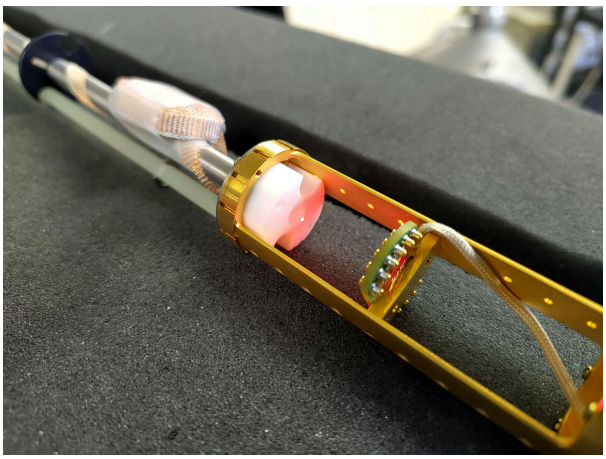
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One-page project summary that describes problem, project goal, and your research activities / results:



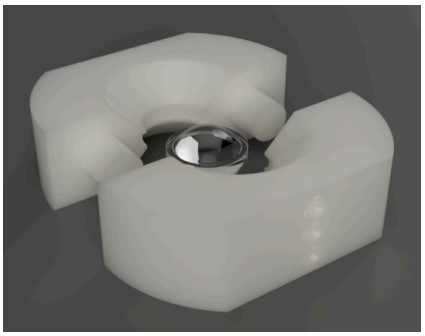
Modern condensed matter physics heavily focuses on layered quantum materials whose electronic and magnetic states can be dramatically altered by light. To study these optical phenomena, we need to shine various wavelengths of light onto tiny material flakes resting inside a Physical Property Measurement System (PPMS) cryostat to measure the changes in the electronic response and collect the resulting photoluminescence or reflection signals. However, operating under a vacuum in a cryogenic environment presents severe physical limitations. The primary goal of this project was to design, construct, and automate a high-efficiency fiber-optic setup integrated into the PPMS probe, enabling precise optical excitation, photoconductivity sweeps, and photoluminescence spectroscopy without compromising the cryostat's vacuum or thermal performance. To achieve efficient light delivery, an optical station was constructed adjacent to the PPMS unit. The core experimental pipeline involved coupling multiple laser excitation sources as well as monochromated white-light lamps into optical patch cables. To separate weak photoluminescence signals from reflected laser pump light, a customized collection pipeline was built using an optical circulator to separate the light that comes back through the fiber into a separate system, where a filter coupling station enables us to attenuate the pump wavelengths before the signal reaches the highly sensitive compact spectrometer. Additionally, a Python measurement suite was developed to automate device communication and run overnight temperature-dependent photoconductivity sweeps. Low-temperature photoconductivity measurements were successfully conducted on molybdenum disulfide flakes from 300 K down to 10 K and the wavelength-dependence was also investigated at certain temperatures. Photoluminescence was also demonstrated using a perovskite sample.



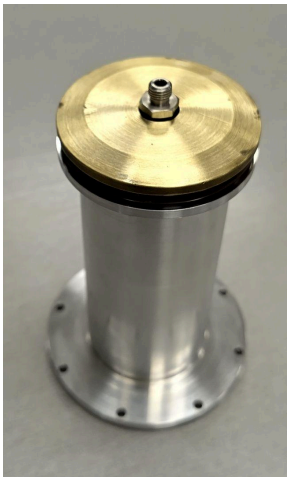


Building a reliable optical cryostat probe required solving several mechanical, optical, and vacuum hardware challenges, spawning three distinct engineering sub-projects. First, custom laser adapter plates and mounting brackets were designed and CNC-machined to securely lock non-standard laser chassis onto positioning stages. To combat thermal runaway during high-power operation, these adapters incorporated custom heatsinks and cooling fan mounts that brought operating temperatures down to ambient levels.



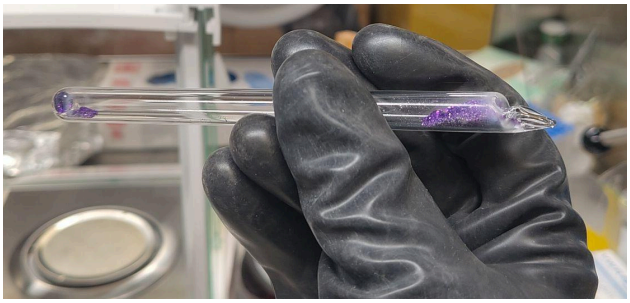


Second, specialized two-part clamshell lens holders were designed in CAD and resin 3D-printed to hold aspheric collimating lenses next to the cleaved fiber ends at the bottom of the narrow probe. These printed components underwent thermal testing in a vacuum oven (up to 450 K) and a cryostat (down to 4K) to ensure the plastic would not crack or misalign the optics under cryogenic temperatures.



Third, the probe's top feedthrough was overhauled to accommodate a thinner 600 µm core, 0.39 NA multimode fiber that matches the characteristics of the fiber system better than the original one. A custom KF40 vacuum flange adapter and end cap were machined to house a standardized SMA-905 optical mating sleeve, which was sealed with O-rings, vacuum grease, and epoxy to maintain a strong vacuum seal during repeated cryostat cooling cycles.

Beyond the optical probe construction, the summer research extended into synthetic materials chemistry through a side project focused on growing chromium trichloride ($CrCl_3$) crystals, which in the ground state is a layered antiferromagnet with a spin-flip field around 0.3-0.5 T, via Chemical Vapor Transport. Coming from a purely physics and engineering background, working in a chemistry lab was a brand new experience, and operating an argon-filled glovebox for the first time was both exciting and challenging. After mastering glovebox handling and switching to flat transfer plates, anhydrous $CrCl_3$ powder was successfully transferred into quartz tubes. These tubes were evacuated under high vacuum, flame-sealed with an oxy-acetylene torch, and loaded into a tube furnace heated up to 650 °C on the hot side to promote single-crystal growth along the previously measured, naturally occurring thermal gradient of the furnace. One of the growth cycles resulted in relatively large crystals, which are currently under study.



Finally, to expand our range of available visible lasers towards longer wavelengths, a custom laser diode driver board was developed, featuring photodiode feedback control for long-term power stability and a microcontroller-based signal generator for precise modulation capabilities. Centered around the specialized iC-NZN integrated circuit, the printed circuit board was designed in KiCad using controlled-impedance traces. The board was assembled in-house using tweezers, solder paste, a box furnace and enormous amounts of patience. Firmware was written for the on-board microcontroller, providing an easy serial interface for controlling output power and current limits.

