

## High Pressure Workshop



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# Innovations in high pressure neutron scattering at the Spallation Neutron Source

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Recent progress in instrumentation at neutron sources is also enabling innovation in high pressure neutron scattering. Together with pressure cell development, advances are driven by increased neutron flux, improved beam focusing and alignment capabilities. At the Spallation Neutron Source (SNS) of Oak Ridge National Laboratory (ORNL) we use these advances to push the limits in high pressure neutron diffraction and spectroscopy. Here, I will highlight several of these developments and will also give a perspective for applications at neutron sources beyond the SNS.

The development of the neutron diamond anvil cell (DAC) based on gem-quality synthetic single-crystal diamonds has enabled studies in the megabar regime at SNS's SNAP diffractometer [1]. A wide-reaching user program requires, however, optimization of these DACs for specific, often more complex applications. A key example is the use of such DACs with corrosive gases. This is made challenging by the large areas that form the diamond culets, but also by the diamond anvil shape itself. I will detail some of the challenges posed by combining these large diamonds with hydrogen loadings [2] as well as some potential avenues forward.

Furthermore, research often requires combining high pressure with other extremes. Yet even ultra-low temperature (ULT) conditions at pressures above 2-3 GPa are challenging. We are addressing this through coupling a large-volume DAC equipped with polycrystalline diamond anvils with a dilution refrigerator. Successful magnetic structure determination was achieved at 5 GPa and below 200 mK on Yb<sub>2</sub>O<sub>3</sub> [3], although challenges for a broader user program remain.

Beyond these DACs used for neutron diffraction, the high flux of the SNS can also be exploited for advances in high pressure neutron spectroscopy. Leveraging the much larger sample volumes of the Paris-Edinburgh (PE) press, *in situ* high pressure studies of full phonon density of states commenced on the ARCS spectrometer. While data were successfully collected to ~9 GPa using single-toroidal zirconia toughened alumina anvils and to ~14 GPa using double-toroidal polycrystalline diamond anvils, the quantitative data analysis is proving complex. Here, I will conclude with an overview of the current state of analysis and highlight the ongoing challenges.

### References:

- [1] B. Haberl, M. Guthrie, R. Boehler, *Scientific Reports* 13, 4741 (2023).
- [2] B. Haberl, M.E. Donnelly, J.J. Molaison, M. Guthrie, R. Boehler, *Journal of Applied Physics* 130, 215901 (2021).
- [3] Y. Wu, T.E. Sherline, J.J. Molaison, A.M. dos Santos, J.J. Pierce, B. Haberl, *Physical Review R* 7, 043063 (2025).

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