

## High Pressure Facilities at CHESS

Chang-Sheng Zha - CHESS, Cornell University



Scientists are puzzled by many questions: Does hydrogen really become a metal at millions of atmospheres pressure? How does graphite turn to diamond under high pressure-high temperature? Can we make a new material harder than diamond? What role does pressure play in the struggle against human disease? Is the Earth's core formed by a huge single crystal of iron as predicted by theory? How stable are minerals over enormous ranges of temperature, pressure, time, and how does this relate to earthquakes and volcanic eruptions? Although humans succeeded in landing on the moon 30 years ago, so far they are still unable to enter the world just underneath their feet.

All of these questions are related to high pressure-high temperature conditions. Temperature, and especially pressure, can effectively change the interatomic distance, and hence play an important role at changing the physical-chemical properties of materials. The application of high pressure can produce structural and electronic, as well as other phase transitions, polymerization of organic substances, and many other phenomena.

Professor P. W. Bridgman of Harvard University pioneered the high pressure field using the so-called Bridgman anvil and piston-cylinder device he invented. It was made of hardened steel or carbide. It is surprising that although diamond has been known as the hardest substance in the world, its value for generating high pressure was not realized until the 1950's. The diamond anvil cell (DAC) that ap-

peared in 1959 revolutionized high pressure research. In a DAC (Fig. 1), two natural gem quality diamonds with flattened tips are used for pressure rams. A metal gasket with a tiny hole for a pressure chamber is placed between the rams. Samples can be subjected to pressure as extreme as that in the Earth's center when a force pushes the two opposed anvils together. The big advan-

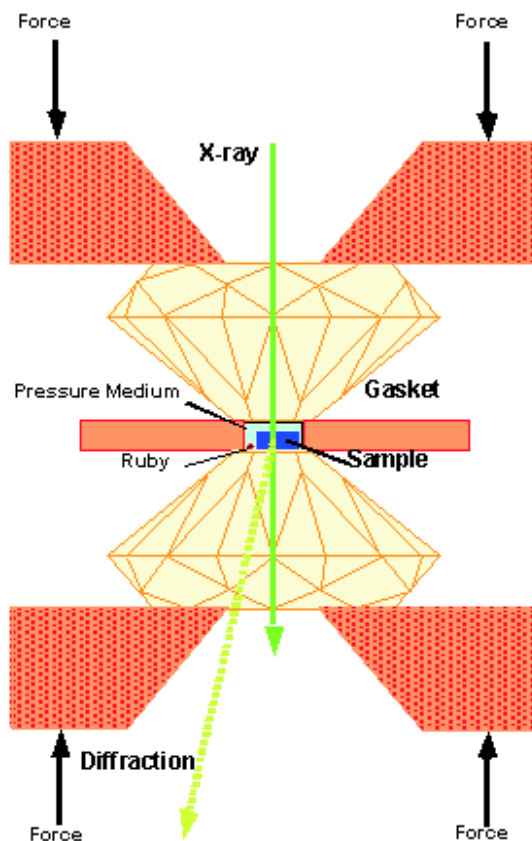


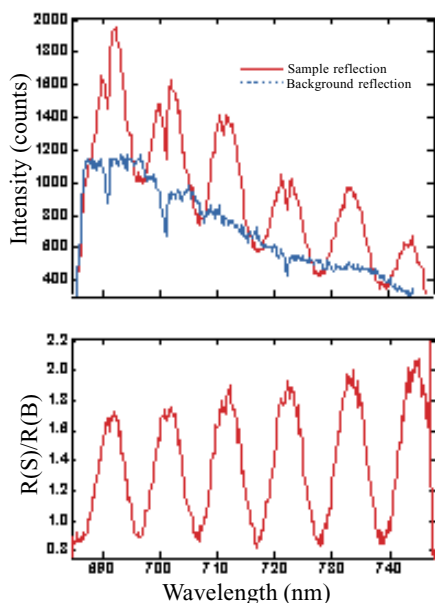
Figure 1: The basic principle of diamond cell X-ray diffraction.

tage of DAC is the combination of the high strength of diamond with transparency over the ultraviolet, visible, infrared, X-ray, and spectral ranges. Together with convenient ruby fluorescence pressure gauges, application of hydrostatic pressure media and various heating techniques, this little gadget (it can be

held in the palm of the hand) has become an ideal instrument for physicists, chemists, and biologists to study various kinds of matter in a wide pressure-temperature range using many modern scientific detecting techniques. Optical spectroscopy and X-ray diffraction are the most frequently used measuring techniques.

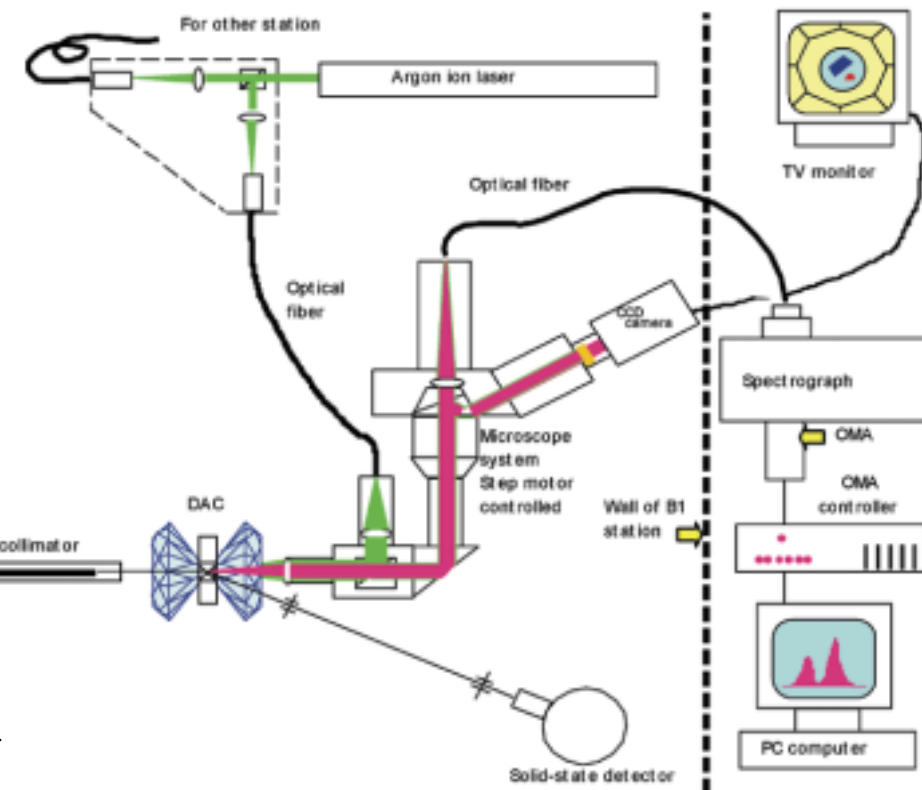
Thanks to synchrotron radiation facilities (which bring us very intense, highly collimated X-ray beams over a wide energy range), exposure times have been reduced by orders of magnitude, and the choice of radiation energy has been made easier and better. Combining well-designed optical systems and on-site experimental support facilities, synchrotron radiation facilities are now becoming powerful research centers for high pressure experimenters. CHESS is one of these centers.

CHESS has been used for high pressure experiments since the early 1980's. A dedicated B-1 station was specially developed for high pressure energy dispersive diffraction experiments. Recently, we have constructed a portable angle dispersive workbench equipped with an imaging plate detector for two dimensional data collection. This small workbench can be easily moved to other stations which provide monochromatic X-ray beams at various energy ranges. A compact, well-designed optical system based on fiber optics was installed for



**Figure 3:** The interference pattern measured from cubic BN sample inside of the DAC by the optical system setup in the B-1 station.

both in-situ pressure-temperature measurements inside the hutch and on-site measurements for technical support outside the hutch (Fig. 2). The system can also be used for Raman spectroscopic measurements which serve as a cross-check when phase transitions occur. Although the optical reflectivity measurements can be done only within the visible range, the capability of producing nice interference patterns in the reflecting measurements offer a good opportunity to study the dielectric properties



**Figure 2:** Schematic of X-ray diffraction.

under pressure (Fig. 3).

DAC preparation and sample loading are critical steps in high pressure experiments. During the experiments, DAC re-preparing and sample re-loading are often necessary owing to diamond or sample failure. A well-equipped, on-site high pressure laboratory at CHESS can offer complete technical support for users (Figure 4).

Pressure effects on soft matter and biomaterial such as proteins, membranes, lipids, complex fluids and polymers, are among the fastest growing areas in high-pressure science. Synchrotron X-ray scattering studies are one of the few ways to probe the structural changes in these materials while in thick-walled pressure bombs. Sol Gruner's group in the Physics Department has devised various pressure vessels and X-ray experimental methods in order to study these soft materials. The observed pressure effects have proven to be diverse and interesting. Users are invited to collaborate on further research in this area.

