CHESS quick overview (Marian S)
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<u>Where to stop on a tour</u>:

1) Floor plan on the wall near the Ops area, for an overview.
2) A2, a general purpose station.
3) B2 - not always much to see, but a chance to mention high pressure work.
4) F1, the MacCHESS station with the most room, and the crystal automounter.
Substitute F2 or A1 if F1 is disassembled or not available.
If there is time:
5) D1, talk about the surface scattering and art experiments done there.
6) G-line, especially the pulsed laser deposition system in G3.

Along the way, there are several useful posters in the halls.

<u>FAQ</u>:

What is CHESS? A source of very bright X-rays, about a million times brighter than from a laboratory source, also highly collimated, and with tunable energy.

Why come here? Very powerful X-rays mean that experimenters can get results much faster than with home sources. Small beam size is suitable for small samples (protein crystals are typically about 100 microns across), or for high-resolution imaging of larger objects. Energy tunability is important for some experiments. CHESS has good equipment, and very knowledgeable staff, for collecting data and analyzing results.

How many people come here? Over 500 users per year. Resulting publications are about 200 per year. Most users are from the Northeast, but some come from farther away, and even from other countries.

How do people get time at CHESS? Anybody can submit a proposal. There is no fee unless results will be kept secret. Proposals are reviewed and ranked for scientific interest. Most users are academics - professors, research staff, post-docs, and lots of grad students.

How many people work at CHESS? About 50.

What does it cost to run the facility? CHESS and MacCHESS together get about $7 million a year from NSF and NIH. Operating CESR costs about $12 million a year, from NSF; the electric bill alone is about $100,000 per month.

Are there other facilities like CHESS? Yes, about a half dozen in the U.S. and another 30 or so world-wide.

How big is the ring? About half a mile in circumference.

How many stations are there? 6 beamlines, 12 stations. (Details below)

Are the X-rays dangerous? They would be if you were exposed to a direct X-ray beam. However, that doesn't happen because the hutches are well shielded and everything is carefully interlocked to keep people safe. Experiments are run from outside the hutches using computer control. And there are many radiation monitors around, which will shut off the beam if necessary.

Timeline:

- 1979 - Founded with 3 beamlines (6 stations) in the area now called CHESS West.
- 1984 - MacCHESS to support macromolecular diffraction.
- 1989 - CHESS East built, provided 4 new stations.
- 1993 - CHESS West upgraded - removed one station but gave the others more room and improved capabilities.
- 1999-2002 - G-line built, provided 3 new stations.

Scientific highlights:

- First animal virus structure done at CHESS 1985, recording diffraction from dozens of crystals on hundreds of X-ray diffraction films (station A1).

- Rod MacKinnon got Nobel Prize in 2003 for solving structure of the potassium channel, work that started with data collected at CHESS (stations A1,F1,F2). The potassium channel is a ring of protein molecules that sits in the surface of nerve cells and is necessary for nerves to transmit signals.

- Eddy Arnold looks at how drugs bind to the HIV protein reverse transcriptase and is helping to improve treatment for AIDS (station F1).

- A new X-ray detector, the Pixel Array Detector, is being developed in the lab of Sol Gruner, director of CHESS. A prototype PAD was used to find out what is going on inside the spray of fuel that is injected into the cylinder of a gas or diesel engine (station D1). This analysis may lead to more efficient engines.

- Confocal fluorescence microscopy lets one look at the elemental composition of different layers in a painting, to find out something about its history. For example, the painting "The Armorer's Shop" by David Teniers the Younger, which was examined at the D1 station, turned out to be a smaller painting plus some added parts rather than a single composition.

- Also at D1, we have used X-ray analysis of old inscriptions to read letters that have been worn away, by detecting the traces of iron or other elements left by the chisel that was used to make the inscription.

- Another archeological technique is the use of elemental analysis of tree ring samples to identify events such as volcanic eruptions. In this way the tree ring record can be used to date catastrophic events very precisely. This experiment was done at the F3 station.

Macromolecular crystallography:

Crystals of protein, or DNA or RNA, are grown by biologists in their home labs and brought to CHESS in order to determine their molecular structure using X-ray diffraction. These structures are useful in understanding how molecules such as enzymes work, which can lead to medical advances.

The crystals are small, of order 100 microns across. They must be kept cold, or else they only survive a few minutes in the beam. Also, they crack if they dry out. So, crystals are mounted in small loops along with a drop of a liquid in which they are "happy" and rapidly chilled to about 100 K. At a MacCHESS station, you will see that the crystal, mounted on a pin, is surrounded by: a nozzle through which cold dry nitrogen blows to keep it at 100 K, a video camera with a magnifying lens that lets you see the crystal and center it in the beam, a collimator to deliver a beam of X-rays, about 100 microns in diameter, to the crystal, and a CCD detector to record the diffracted X-rays. The detector has a phosphor layer to convert the X-rays to light, fiber optic tapers to reduce the size of the image, and 4 CCD chips to record it. The actual CCD's are similar to those in a digital camera, but bigger and more accurate. The entire detector costs about $400,000.
There is also a beamstop to block the direct beam, and the crystal is mounted on a rotation stage so diffraction images can be taken at many angles.

Stations:

- X-ray source: The B1, B2, C1, D1, and F3 stations get their X-rays from the bending magnets that make the electrons and positrons go around the ring. A1, A2, and the G-line stations receive X-rays from a device called a wiggler, which is in one of the straight sections of CESR and uses magnets to "wiggle" the particle beam back and forth, generating X-rays in the process. F1 and F2 get X-rays from a second wiggler. The wiggler X-rays are more powerful than the bending magnet ones. Other synchrotron sources use similar devices called "undulators", which produce even more concentrated beams.

- A1, F1, F2: Dedicated almost entirely to macromolecular crystallography. A1 and F1 are at fixed wavelengths around 1 Angstrom, F2 is tunable and is suitable for MAD (multiwavelength anomalous diffraction) experiments. F1 has a BL2 biocontainment facility, which means people can bring crystals of viruses such as rhinovirus (causes colds) and parvovirus (causes dogs to get diarrhea). More dangerous viruses, such as HIV, are not allowed. F1 also has a crystal-mounting "robot", for automatically transferring tiny crystals from storage into the beam, and back again. There is special eqipment, including glass capillaries that focus the X-rays, for dealing with microcrystals, which can be as small as a few microns in size.

- A2: A tunable monochromatic general purpose station, used especially for applications which need high-energy, penetrating X-rays, for example looking at strain in metallic alloys.

- B1, B2: For studying samples in diamond anvil cells under high pressures, up to millions of atmospheres. Because the diamonds are transparent to both light and X-rays, experimenters can look at what happens to samples as the pressure is varied. The sample can also be heated, using either an embedded hot wire or a laser. This means that we can find out what happens to minerals at the high pressure and temperature found deep inside the Earth, or even inside Jupiter.

- C1: A flexible general-purpose station, used for experiments such as resonant scattering, topography, and EXAFS (extended X-ray absorption fine structure), which gives information about the chemical environment of atoms such as iron or zinc.

- D1: Used mostly to look at surface scattering from thin films of polymers, but has also been used for experiments in art, archeology, and fuel spray structure.

- F3: Used about half the time for crystallography, with special optics called multilayers, which produce a flux similar to that at F2, even though F2 has a wiggler source and F3 has a bending magnet source. The rest of the time, F3 is used for fluorescence experiments to determine the elemental composition, as a function of position, of samples such as tree rings and fish ear-stones.

- G1: Used mostly for small-angle scattering (SAXS) experiments on protein and other samples. SAXS can tell us something about the shape of molecules in solution - not as detailed as crystallography, but useful when crystals are not obtainable, or to have the molecules in a more natural environment.

- G2: Much of the equipment in this station was built by graduate students as part of their research. It is used for high resolution diffraction and grazing incidence studies, among other things.

- G3: Facility for pulsed laser deposition of films, which can be examined in real time as they grow.