Upgrades to the G-line Experimental Stations

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The original construction grant for G-line foresaw alternating operation of the G2 and G3 hutches. Later it was realized that G2 station could be run in parallel with G3 station with the use of a transparent beam splitter, raising the availability of the G-line stations by 50% (Figure 1). Furthermore, the need for secondary optics inside G1 hutch for experiments requiring smaller bandwidth than supplied by the main G-line multilayer monochromator became apparent. Finally the horizontal G2 diffractometer needed upgrading to a psi-circle configuration with a kappa sample stage to satisfy the needs of the G2 community in a single instrument. In 2002, the NSF awarded two instrumentation grants to help achieve these upgrades. Here, we describe several projects resulting from those awards.

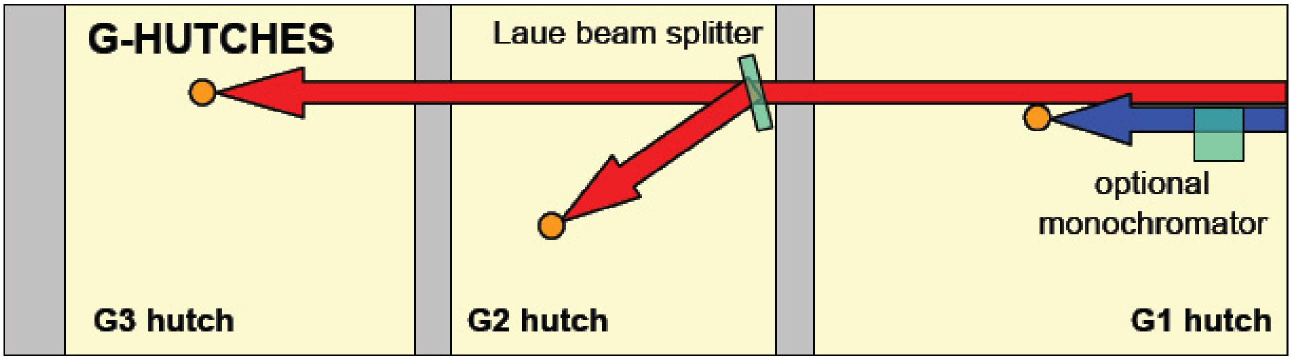

Fig1: Optics upgrades to the G-line hutches: G2 side-bounce beam splitter and G1 optional small bandwidth monochromator.

G1 hutch

A multi-purpose goniometer was assembled by G-line student Sterling Cornaby comprising horizontal and vertical translations, incident angle rotation, and a rotation about the surface normal (Figure 2). The goniometer will serve as a local, high resolution monochromator stage for anomalous SAXS or MAD measurements, as a precision optical mount for lining up x-ray waveguides and capillaries, and as a sample stage for GISAXS applications. First commissioning experiments by Detlef Smilgies have shown that the stage meets the expectations of resolution and reproducibility.

Fig 2: Sterling Cornaby aligning the new G1 monochromator/GISAXS goniometer.

G2 hutch

G2 station has emerged as a beamline for reflectivity, grazing-incidence diffraction, and total-reflection x-ray fluorescence for the study of organic thin films. A second effort is focused on strain measurements in thin metal films using large-angle diffraction.

G2 hutch received major work in the past year. In order to achieve fully independent operation of the G2 and G3 branches, CHESS engineer Brian Clasby designed and installed an optics cave inside G2 hutch comprising a lead-shielded cabin and shutters for the G2 side-bounce beam and the G3 transmitted beam. The shutters have a novel, compact design and a new type of pneumatic control system (Figure 3). The new monochromator enclosure, as well as a two-slit incoming flightpath and a detector flightpath, both built by G-line student Daniel Blasini, have greatly reduced the background in the hutch, as witnessed in recent experiments (Figure 4).

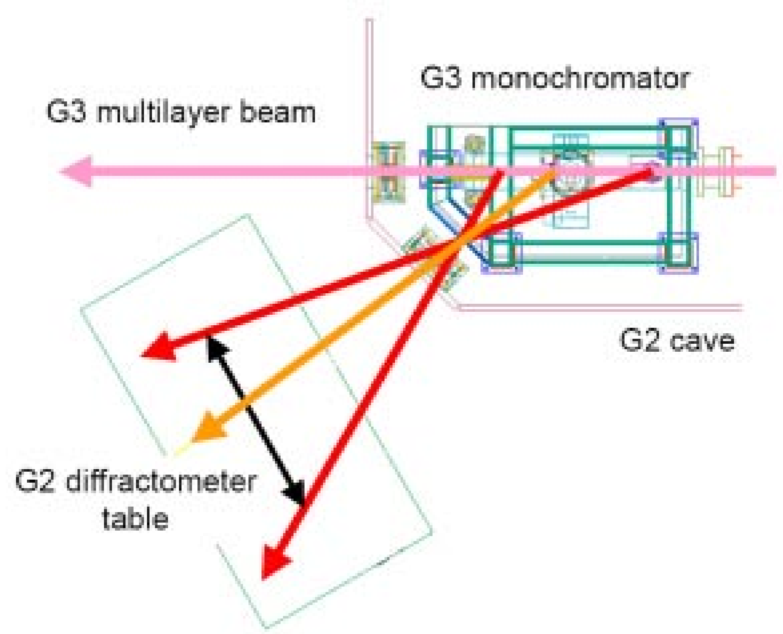

Fig 3: Design for the new beam splitting side-bounce monochromator in G2 hutch. Energy range (red arrows) and working energy (orange arrow) are shown. By virtue of a 0.5 m translation stage, the crossover-point of all three beams lies at the Be window, allowing the use of a small window. X-ray transparent Be single crystals or very thin silicon crystals are used to divert about 1% of the broad bandwidth multilayer beam for G3 station (pink) into G2 hutch. The range of positions for the new G2 diffractometer is indicated by the black double arrow.

In the past running period, G2 Cave was still operated with the old beamsplitter test stand. Meanwhile, Brian designed a new monochromator coffin which recently arrived at CHESS from the manufacturer and will be installed for the summer run. The new monochromator design can cover the full G-line energy range of 8-16 keV for Be(002) and Si(220) reflections. In addition, specifically selected reflections, of interest for the Bragg switch project, can be operated over a somewhat reduced energy range. In order to avoid a large Be window for the outgoing side-bounce beam, the monochromator will be placed on a translation stage inside the coffin. This way the fixed point for all beams throughout the energy range lies at the Be window and a standard 1" by 1" Be window will suffice (Figure 3).

The new monochromator coffin is planned to run under helium atmosphere and will be directly included in the G2/3 transfer pipe system. It is also compatible with possible vacuum operation in the future.

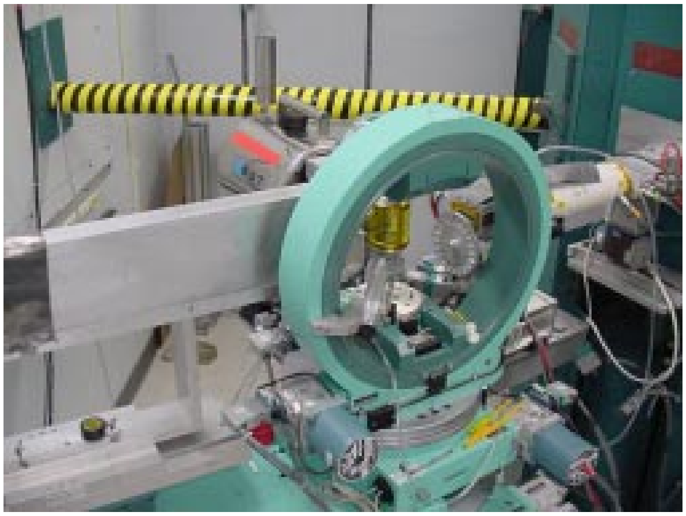

Fig 4: The new grazing-incidence scattering set-up in G2. The G2 shielded optics cave (top, right) supplies beam to the G2 horizontal diffractometer (center) and to G3 through the yellow/black helium transfer pipe. To the left of the sample cell in the center of the diffractometer is the long flightpath for a position-sensitive detector and behind the sample cell is a Ge detector.

Another feature of the new monochromator will be the use of very thin silicon Laue crystals that can be bent in order to focus the beam, rather than the present unfocused beam provided by a Be single crystal. A first test of a simple Laue bender using ultrathin Si wafers has been performed by Sterling Cornaby and Detlef Smilgies (Figure 5). The challenge for the bender design is how to mount the Laue crystal without inducing parasitic strain fields. A simple three-point bender achieved a focal spot of 0.5 mm horizontally at the detector position, about 2 m downstream from the monochromator. In comparison, the incoming multilayer beam had a width of about 10 mm.

Fig 5: The simple three-rod bender mechanism used to curve an ultrathin silicon crystal wafer. The incident broad bandwidth x-ray beam from the main multilayer monochromator comes in from the left. Approximately 1% of the beam is diverted through the ion chamber (top) into G2 hutch.

A first experimental test of the prototype bender by Daniel Blasini revealed that, because of focusing, the silicon bender supplied a similar flux onto the sample as the beryllium mosaic crystal for Grazing-Incidence Diffraction, despite having a total integrated flux of only about 10% that of the beryllium monochromator. The transmission of the 50 mm silicon wafer was 80% at 10 keV. For future applications we envision using even thinner wafers with a transmission well above 90%.

As a second upgrade project for the G2 hutch, a new kappa diffractometer (Figure 6) has been specified by G-line student Dave Nowak which will enhance the current horizontal four-circle diffractometer. The new diffractometer will feature a vertical kappa stage on a horizontal rotation stage as well as a two-component detector arm. This way, large-angle x-ray diffraction for strain measurements, planned by the Baker group (Cornell Materials Science and Engineering) can be combined with x-ray reflectivity, grazing-incidence diffraction, and total-reflection x-ray fluorescence, ongoing research by the Abruña group (Cornell Chemistry and Chemical Biology) and others. The local company Advanced Design and Consulting (Lansing, NY)- has started the mechanical design and manufacture of the new diffractometer. In addition, Dave Nowak is working on designing the detector arm optical bench comprising motorized entrance slits, a long flight path or a Soller slit, and a 100 mm position-sensitive gas detector.

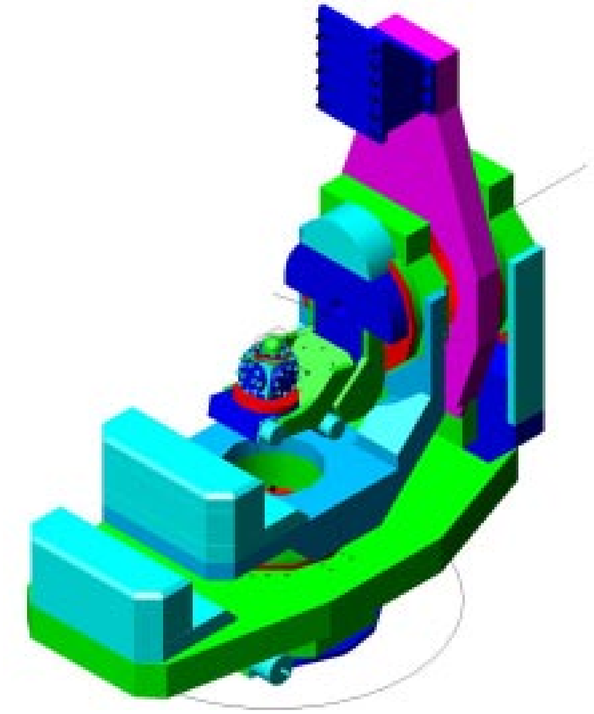

Fig 6: Schematic of the general purpose 6-Circle Kappa diffractometer for the G2 hutch.

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