Report on the G-line Division of CHESS

Facility Highlight

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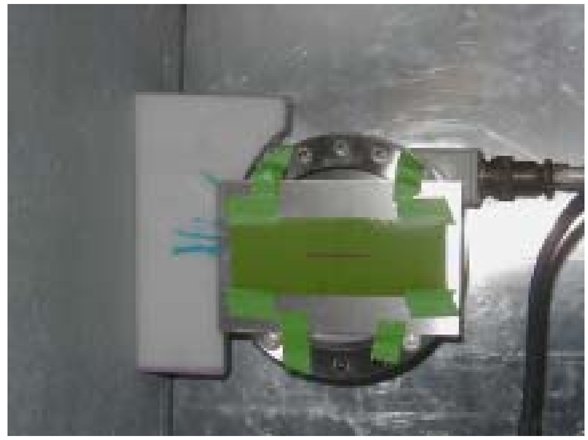

Fig. 1 First burn in G-cave: October 24, 2001.

Introduction: It's a pleasure to report on the recent progress and accomplishments of the G-line division of CHESS. The mission and goals of the G-line division are somewhat different from those of the national user facility. The G-line division is a collaboration of Cornell University research groups. The G-line PIs are collectively responsible for both the scientific research program and the financial support of the facility. In recognition of the close coupling with the national user facility and the crucial contributions of the CHESS scientific and technical staffs, 20% of the available beam time at the G-line experimental stations will be available to the general user pool through the existing CHESS proposal system after the facility is fully commissioned. The primary motivation for Cornell's investment in G-line was integrating the research programs of Cornell research groups into CHESS. As hoped, in addition to housing the research programs of major users such as Abruña, Brock, Ober, Thorne and Gruner, G-line has enticed several research groups that previously had not been major synchrotron x-ray users to base major experimental research programs at CHESS: Baker, Engstrom, Malliaras, Pollack, Suzuki, and Weisner are a few examples. These groups are building specialized equipment and committing graduate students and post-docs. Initial results from a few of these programs are described below. The involvement of graduate students in all aspects of the construction and operation of G-line has also been quite successful. Indeed, the NSF panel that reviewed the 5-year proposal wrote in their report,

> *CHESS has consistently played and continues to play a leading role in educating and training the next generation of synchrotron scientists, who have a sufficiently in-depth understanding of how a synchrotron beamline is put together, maintained, and operated in order to create the best possible science… Of all of the US synchrotrons, CHESS is uniquely able to address this vital national need. This is, in part, because of the Cornell faculty's major commitment to CHESS, evidenced especially at G-line, and the physical location of CHESS right in the heart of the Cornell campus. As a result, there is a strong sense that CHESS is an integral part of the academic infrastructure at Cornell, students have peers working at CHESS, and are comfortable there. Second, CHESS recognizes and promotes its role by encouraging hands-on graduate student involvement in the design, construction and implementation of all aspects of a synchrotron experiment from beamline components, to sample-environment chambers, to detectors, as well as, of course, in the execution of experiments, and analysis and dissemination of their results.*

I couldn't agree with them more!

Construction Status Report: The past several months have been incredibly exciting at G-line. "First light" in the G-line cave occurred on October 24, 2001. While the final x-ray optics are not yet finished or installed, detailed commissioning studies have characterized the properties of the wiggler beam and science experiments are under way using temporary optics. The final optics are being assembled and tested in parallel with operations. Only when everything is completely ready will these x-ray optics be installed. The current target for the installation date is the fall of 2003. This latest change in plans was necessary due to changes in the CESR schedule to allow the installation of the superconducting damping wigglers required for low-energy charm running for CLEO.

To take advantage of the CESR operations, G-line was "commissioned" in a temporary mode. The first commissioning task was to characterize the white wiggler beam, an initiative led by Detlef Smilgies and Peter Revesz. The specific goal was to characterize the properties and stability of the x-ray beam.

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A variety of novel imaging technologies was developed and evaluated including thin diamond films and direct imaging of fluorescence of the helium gas. An image of the complete cross section of the white beam obtained using a black diamond film is shown in Figure 2 and clearly shows the structure of the x-ray beam due to inhomogeneities in the graphite heat filter. Studies using a conventional CHESS beam position monitor demonstrated that CESR could independently steer A- and G-lines, holding vertical beam motions at G-line to less than 100 microns, which is acceptable for the multi-layer optics to be used.

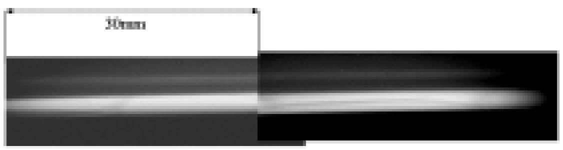


Fig. 2 Complete image of the G-line white beam using a 2" black diamond film, showing inhomogeneities in the beam due to the graphite heat filter and upstream Be windows.

The second challenge was to refurbish an existing monochromator coffin to handle a set of double-crystal multilayer optics using primarily spare parts from CHESS. Because the first multilayer is the first optical element, it must be cooled by a water-cooled copper block and is shielded by a beam-limiting aperture that passes only 2 mm (out of 50 mm) of the 10 KW wiggler beam. Jeff White led the efforts to obtain safety approval from LEPP for the operation of the temporary optics, and approval was granted by the end of the installations. Spare beam shutters were found and installed in each of the G-line hutches.

The third challenge was assembling and commissioning G-line's new motion control and data acquisition systems based on cost-effective personal computers (PC's) and PCI boards, an effort that still involves most of the G-line students. A characteristic of G-line's control concept is to employ local computers in the hutches and in the optics cave, in order to keep motor and detector cables as short as possible. Ethernet connections are used to transfer information between PCs. Control PC's outside each hutch are equipped with dual LCD screens to establish communication with the local PC's (see figure 3). In close collaboration with Gerry Swislow at Certified Scientific Software, SPEC client-server mode was implemented, so that the control PC's can communicate with multiple PC's to control motors, detectors, sample environment, and optics. Finally, Detlef Smilgies set up a beam-splitting side-bounce (Laue geometry) monochromator based on a single crystal of beryllium in the G2 experimental station. This device enables simultaneous running of the G2 and G3 stations.

The result was that experimenters were able to begin performing measurements at G-line this summer and fall. Some of the first science experiments being performed at G-line are described below.

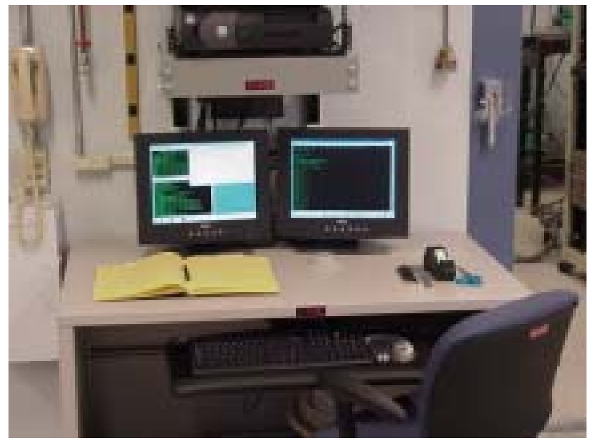
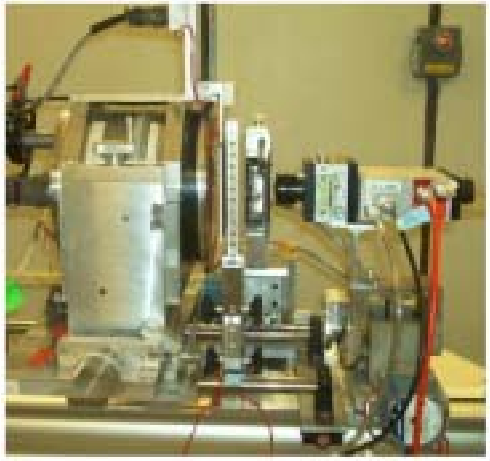


Fig. 3 G2 control station with dual flat-panel displays.

G1 Science: The very 1st experiments at G-line were performed in the G1 experimental hutch by Xuefa Li, Dan Schutte, Hilmar Koerner, and Mark Tate of the Gruner and Ober research groups. Initial calibration experiments were followed by time-resolved studies of the response of liquid crystal systems to applied electric fields and UV irradiation (figure 4). Rong Huang, Ernie Fontes, and Don Bilderback then performed a series of fluorescence imaging experiments on soil samples and fish ear stones. Quan Hao and Richard Gillian of MacCHESS have performed the first protein crystallography studies at G-line and Detlef Smilgies and Arthur Woll have performed the first series of Grazing-Incidence Small-Angle X-ray Scattering (GISAXS) measurements.

G2 Science: As mentioned above, the G2 experimental station has been outfitted with a side-bounce (Laue mode) beam splitting monochromator (designed and assembled by Detlef Smilgies). This new device enables simultaneous operation of the G2 and G3 experimental stations. Using an existing four-circle Huber diffractometer, researchers have already performed a series of thin-film reflectivity measurements on a variety of systems including thin-films of Fe on Si(111), p-sexiphenyl on KCl(001), and films of dendrimers on silicon wafers (figure 5).



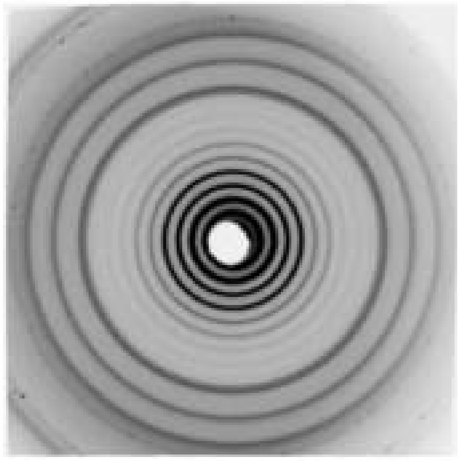
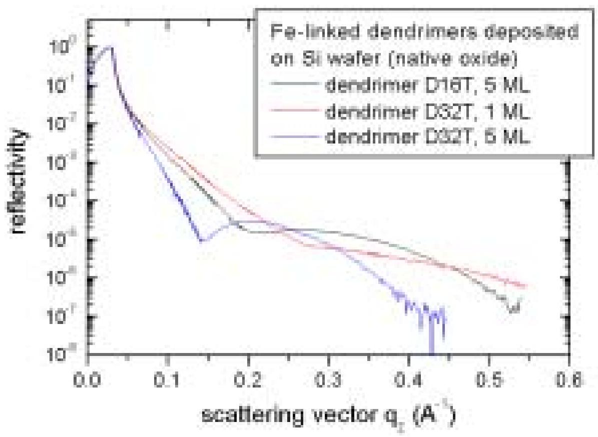


Fig. 4 WAXS at G1. A silver sterate callibration sample demonstrates that with a wavelength of 1.3Å and a sample to CCD distance of ~4cm, d-spacings down to 2.5Å can be imaged.

Fig. 5 (Left) Chemistry graduate student Daniel Blasini working on his experiments in G2 experimental station. (Right) specular reflectivity scans of dendrimers. Reflectivity from monolayers of dendrimers D16T and D32T on a silicon wafer. Thicknesses between 11 and 23 Å were determined from the data. The system seems not to follow a simple layer by layer growth mode.



G3 Research: The G3 experimental station is home to a very ambitious experimental program combining an x-ray surface diffractometer with a pulsed-laser deposition (PLD) system. The goal is to perform time-resolved studies of the evolution of thin-film structure during the PLD growth process. Graduate students Aaron Fleet (Brock group) and Darren Dale (Suzuki group) and post-doc Huan-hua Wang designed, built and commissioned the entire system. In addition, with the able assistance of Todd Schroder (Engstrom group), Jeff White and the rest of the CHESS safety committee, they shepherded the G3 station through the detailed safety review process required to certify that it was safe to use hazardous gases (such as the fluorine required for the excimer laser) in the G3 station. The entire system is now operational and initial measurements demonstrated persistent intensity oscillations indicative of high quality growth. This PLD system is one of several systems being constructed by Interdisciplinary Research Group – D (IRG-D) of the Cornell Center for Materials Research (figure 6). The focus of IRG-D's research is developing an atomistic understanding of thin-film growth and processing. A second chamber designed to grow films using pulsed supersonic particle beams (Engstrom group) is currently being assembled and should be on-line by the summer of 2003.

Photo by Aaron Fleet

Fig. 6 Plume of material ablated from target in lower right of image impinging on substrate in upper center portion of image. Silver paste used to fix the substrate to the heater reflects the light through the clear $SrTiO_3$ crystal.