AN ENDSTATION WITH CRYOGENIC COILS CONTRIBUTING TO A 0.5 TESLA FIELD AND 30-400K SAMPLE THERMAL CONTROL*

G. A. Scharfstein, D. Arbelaez, J. Jung
Advanced Light Source at Lawrence Berkeley National Laboratory, Berkeley, USA

Abstract

The Engineering Division of Lawrence Berkeley National Laboratory presents a design for an Endstation to enable X-ray Photon Correlation Spectroscopy (XPCS), which is a method to study temperature-induced fluctuation in hard and soft condensed matter systems. XPCS, when applied to a magnetic system, can yield information about how domains fluctuate as the system goes through a phase transition; these phase transitions can occur at low temperatures (less than 100K) and at an applied magnetic field. Therefore, requirements for the Endstation include a 0.5 Tesla (T) field at the sample and temperature control of the sample from 30K to 400K.

INTRODUCTION

Our beamline delivers a 10 micron diameter beam of coherent light and the Endstation can hold and manipulate a maximum sample size of about 7 square mm. Coherent x-ray scattering gives rise to speckles; these speckles can be imaged using a CCD detector. Resonantly tuned coherent x-rays that scatter off a magnetic sample generate magnetic speckles which are representative of the exact lateral magnetic heterogeneity (i.e domains). With the addition of low temperature control, the sample can experience a phase transition. During phase transition the sample morphology will change and causes a subsequent change in the speckle pattern. By monitoring the speckle pattern over time at a particular temperature with magnetic and/or electric fields, it is possible to determine the temporal evolution of the surface features.

The magnetic and thermal systems required to produce the above-mentioned environment present a challenge to the engineering team due to the strength of the field, range and stability of the temperature control for the sample and relatively small volume in which to accomplish this. When the motion control of the sample and pinhole are included, the endstation quickly becomes an extremely complex and tightly integrated system.

MAGNETIC SYSTEM

The magnetic system is based on a three-dimensional Opera Vector Field magnet design with vanadium permendur as the pole material and a 5000 ampere-turn coil as the magnetic source. To obtain the proper field strength and meet the thermal requirements, a cryogenic solution was implemented to keep the energized coils from heating the sample. Liquid nitrogen floods a stainless steel can encasing the coil and the resulting thermal balance exhausts gaseous nitrogen via a vacuum chamber feed through. The geometry of the poles is influenced by the proximity of the pole tip to the sample and its translation normal to beam; 5mm is the vertical range (along gravity vector) and 7mm is the horizontal range of motion, along with about 190 degrees of rotation along the horizontal axis. The tapered shape is required to control the flux as the coils are relatively far from the pole tips and magnetic field target. Overall, the magnet system is optimized for field along the beam axis and it can be rotated along the beam-horizontal-to-gravity plane by controlling the power of opposing coils (see Figure 1).

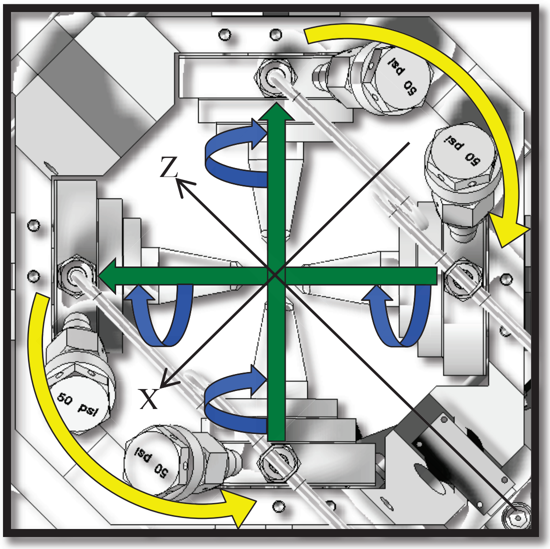

Figure 1: A diagram of the magnet system showing the current direction for each coil (blue arrows), the field vectors (green arrows) and the flux return through the yoke (yellow arrows).

---

*The Advanced Light Source and this work are supported by the Director, Office of Science, Office of Basic Energy Sciences, Division of Materials Sciences and the Division of Chemical Sciences, Geosciences, and Biosciences of the U.S. Department of Energy at Lawrence Berkeley National Laboratory under Contract No. DE-AC03-76SF00098.

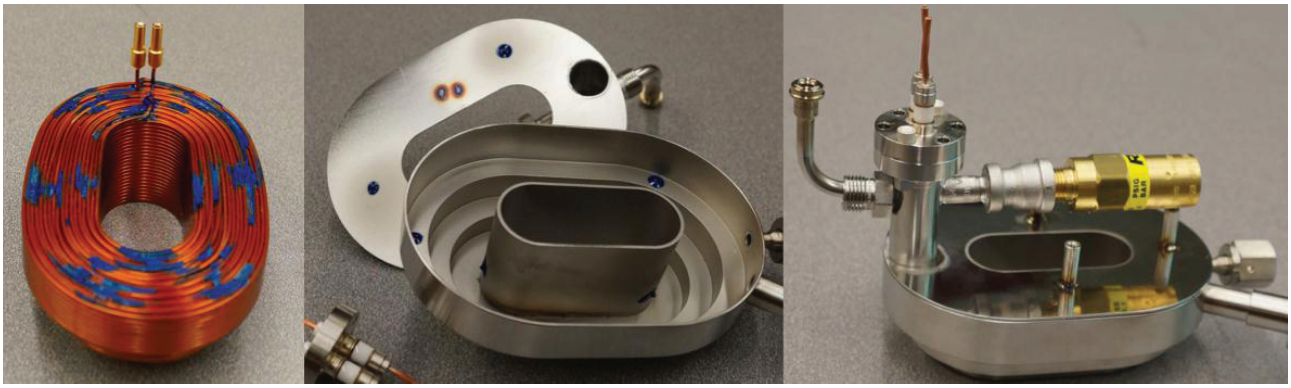

Figure 2: Our prototype wound coil (left), stainless steel coil can prior to final assembly (center), and the final assembled prototype coil-can assembly (right).

We have completed analysis of the magnet using Opera Vector Field and performed a cold test of one prototype coil-can assembly (see Figure 2). The results of the cold test yielded a maximum power of 18A at 2.85V.

The top-level magnetic assembly has a repeatable, three-point mount at the vacuum chamber base with flexlines connecting the LN2 and two independently-controlled power connections. For serviceability, the system is removable after full integration. With its sub-mm proximity to the sample hardware, a precision lifting fixture will be designed to facilitate this task.

SAMPLE THERMAL CONTROL

Sample cooling is enabled by a coaxial flow cryostat that is attached to a trunnion that rotates the sample. The rotary axis is electrically isolated from the experiment, as the Endstation User would like to apply up to 200V to the sample. The yoke of the trunnion sits atop two translation stages at six degrees to produce motion normal to the beam. The system requirements called for a short cryostat design, which is accomplished with a serpentine path for the exhaust (see Figure 3). The unique helium exhaust transition employs automatic thermal control to ensure an ice-free feed through.

Figure 3: A cross section of the cryostat exhibiting the serpentine design.

The scattering requirements put strict demands on the stability of the sample. While the cryostat is cantilevered off the chamber wall, the cold finger reaches the sample via copper braid to the trunnion through the center of the sample axis. The goal is that the trunnion with provide dimensional stability as the system maintains thermal equilibrium. Active and passive shielding will be added as testing continues and the system is better understood from a thermal standpoint.

Preliminary thermal tests of the cryostat-trunnion subassembly reveal a cold-finger temperature of about 5K with the sample holder getting to 13.9K after two hours of cooling. Figure 4 shows the test apparatus used for this test; the cold fingers connect to the trunnion via copper braids and the sample holder is made of glidcop. These results are promising for the final sample temperature, which will be determined after the complete Endstation is assembled and tested.

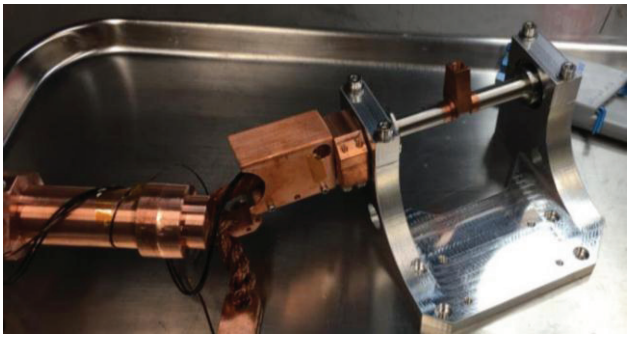

Figure 4: Apparatus used for the preliminary thermal tests. The copper hardware on the left connects to the cryostat (not shown) and an aluminium yoke holds the stainless steel-glidcop sample holder to complete the trunnion assembly.

CONCLUSION

The Endstation is in the final stages of design with preliminary tests and analysis forecasting a 0.5 T field while meeting the required field stability within the sample volume. The thermal system is also showing promise with early tests revealing excellent helium vaporization at the cold tip. We have enhanced the shielding and thermal connections to provide an efficient thermal path to the sample. Near term activities include further testing of both systems to correlate analysis and early tests with the final hardware. The system is scheduled to be commissioned by mid-2017 with final tests wrapping up in early 2017.