Second Generation VPPEM proposed design: Notes on the Beam-Magnet-CHA arrangement.

Raymond Browning 2/5/2015

The first generation VPPEM was a proof-of-principle instrument that was upgraded over three years to a prototype. During that time we have learnt many lessons that can be incorporated into a new instrument. Amongst these are:

1. Magnetic containment is complex. The routing of the magnetic flux around the containment yoke needs a full simulation, otherwise stray fields route themselves.
2. Vibration control is relatively straightforward, as the machine has a large mass, but this requires a balanced load
3. Sample drift control will be difficult and critical for 10nm results as we find the shape of the PSF has implications for image stack registration.
4. The imaging field of view is dependent on the size of the CHA.
5. The CHA energy resolution does not depend directly on the size of the input aperture, but is largely set by the output aperture size.

The original VPPEM design was based on ideas extrapolated from the microXPS at Stanford's SSRL. The Stanford instrument was based on the Turner magnetic projection lens. Although the action of the VPPEM is very different to the Turner lens, we carried some of the design elements across, and of course we had most of the parts of the original microXPS instrument including the superconducting magnet. Having the microXPS equipment as a model heavily influenced the design, and we can now see that a very different geometric arrangement of the parts can be made. The new geometry will both simplify the physical design, and the operation of the instrument.

The new geometry is very significant. Figure 1 shows the vacuum system geometry of the original VPPEM instrument.

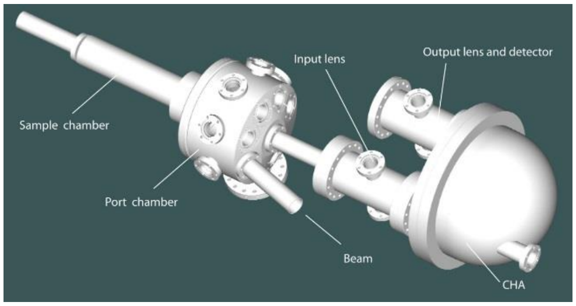

Figure 1. The VPPEM prototype vacuum system.

The sample chamber (on the left) fits into the bore of the superconducting magnet, and the beam coming into the system at 15 degrees intersects the axis in the center of the magnet in the same way as the microXPS. The VPPEM geometry is somewhat different to the microXPS in that the sample is put into the system from the other side of the magnet. In the microXPS the entire magnet was racked backwards on rails to change the sample. This would not be possible for VPPEM with the magnet surrounded by a steel field containment shield. The disadvantage of having the sample put in from the rear is that the sample is mounted on a long rod that was not as stable as would be expected for a microscope stage.

The VPPEM CHA is placed in the position of the microXPS retarding field analyzer, and electron position image detection arrangement, but because of the magnetic shield the VPPEM magnetic field terminates faster, and the vacuum system is much shorter than the micoXPS.

It can be seen that the CHA is placed off center (not placed straight up or down), so that the beam can just come in past the edge of the CHA vacuum jacket. The maximum angle allowable being set by the bore size of the magnet. This off-center mass tends to unbalance the antivibration stage.

Note: the 15 degree beam angle is also very awkward for connections using UHV conflat flanges. These flanges require spacing around the joints implying minimum lengths of vacuum fittings. Placing the magnetic shield, and other parts within these close fitting vacuum parts was also difficult.

One of the lessons from the operation of the VPPEM prototype was that the field of view was dependent on the size of the CHA. But, if we would like to increase the size of the CHA to a 200m radius instrument this would severely unbalance the instrument, and the standoff distance for the CHA would need to be much larger.

The obvious solution to these difficulties, is to change the geometry to a coaxial beam illumination. This simplifies many things. It is actually straightforward to implement because the beam can come in through the CHA alignment port which is axial to the input lens. As the energy resolution is not dependent on the size of the CHA input aperture this aperture can be made as large as necessary to let the (dual) beams through. This arrangement is shown in Figure 2.

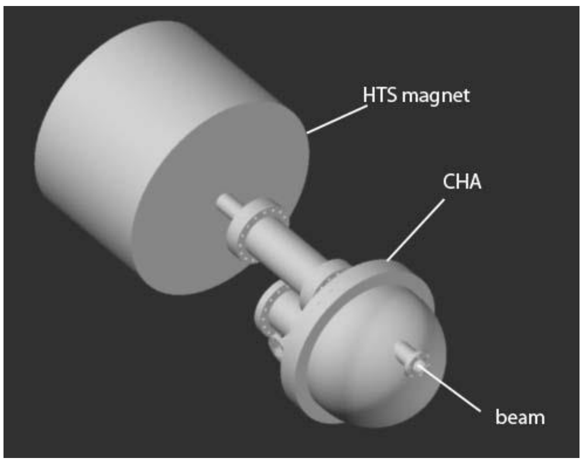

Figure 2 Proposed VPPEM geometry with HTS magnet

Depending on funding, the ideal arrangement would be to use an HTS magnet which can be built as a fully shielded unit, and a 200mm CHA.

With the arrangement of Figure 2 it would be possible to revert back to the microXPS method of loading the sample by withdrawing the magnet. However, that would limit the design of a sample handling and preparation chamber. It is difficult to see how to withdraw a large sample preparation chamber when moving the magnet into place. The current method of loading the sample in a sample preparation chamber behind the magnet, and moving the sample up into the center of the magnet looks preferable. This gives a much wider range of options for sample preparation and exchange. However, this leaves the problem of the sample stability to be addressed.

We need only consider drift in the x,y plane. The drift along the axis will not be noticeable as the depth of focus is so high. Therefore a long rod is still possible if the position can be keep steady and vibration of the rod is low. Although this is an unsolved problem at present, I believe that an active control could be implemented to the required accuracy.