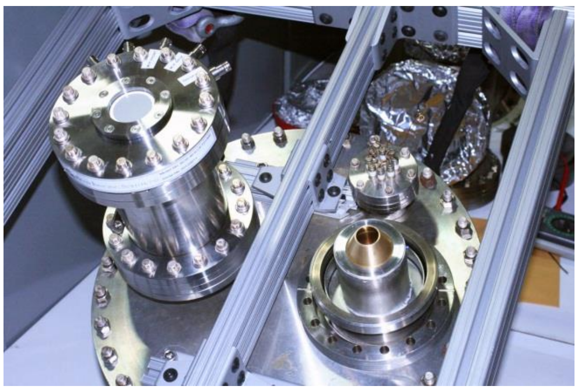
CHA and electron optical assemblies

The energy analysis and image detection electron optics is necessarily unique in that it is used to analyze and focus the angular VPPEM image. The electron optics has been developed in-house apart from the core of the CHA which is a legacy commercial instrument. We are still working on the theory of the electron optics to improve performance and extend the range of magnifications.

CHA

The energy analyzer is a VSW 50mm radius concentric hemispherical analyzer (CHA). This CHA is a legacy VSW instrument and is very basic with fixed apertures and a single mu-metal shield.



The VSW CHA with input lens and output lens/detector assembly is shown in Figure . The resolving power ϱ of the CHA can be written:

$$\frac{1}{\rho} = \frac{s}{2R} + \alpha^2$$

Where s is the slit width in the dispersive direction, and R is the radius of the center orbit.

Figure 1 VSW CHA as an imaging analyzer

Practical upper values of the half angle α are tenths of radians. The energy resolution of the CHA is 50 from the current 2mm slit/radius geometry. With a pass energy of 50eV we would expect a 1eV energy window. However, as it will become apparent from looking at the input lens focus this is not a Gaussian focus. There is energy dispersion across the image so that there is a 1eV shift from top to bottom of the image. The resolving power of the CHA at an image point is higher than expected. As seen from the energy resolution from the Cu Fermi edge on a spot at the center of an image the energy resolution is 0.5eV, Figure .

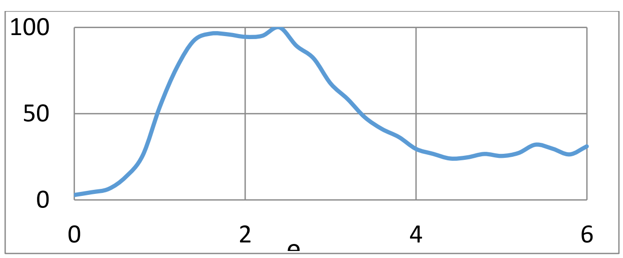


Figure 2 Cu Fermi edge

Input Lens

The input lens design is an electrostatic four element cylinder lens, shown in Figure 1. The lens is fully non-magnetic. The body is aluminum, with aluminum fasteners, and sapphire ball spacers. The mu-metal shield mates with the CHA mu-metal shield and overlaps the mu-metal shield that mates with the Fe ring assembly.

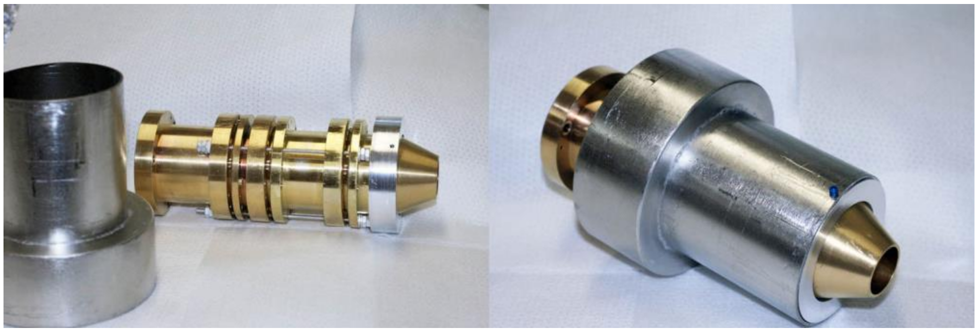


Figure 1 CHA input lens

Previously we used a three element fixed magnification design. For the new design, we have a variable magnification lens that also allows us to change the electron energy imaged from the sample. The current design is for the existing VSW 50mm CHA and a 2-3 Tesla field from a conventional superconducting magnet, with extension to a variable field HTS magnet up to 10 Tesla.

Figure show ray tracing solutions for a four element input lens.

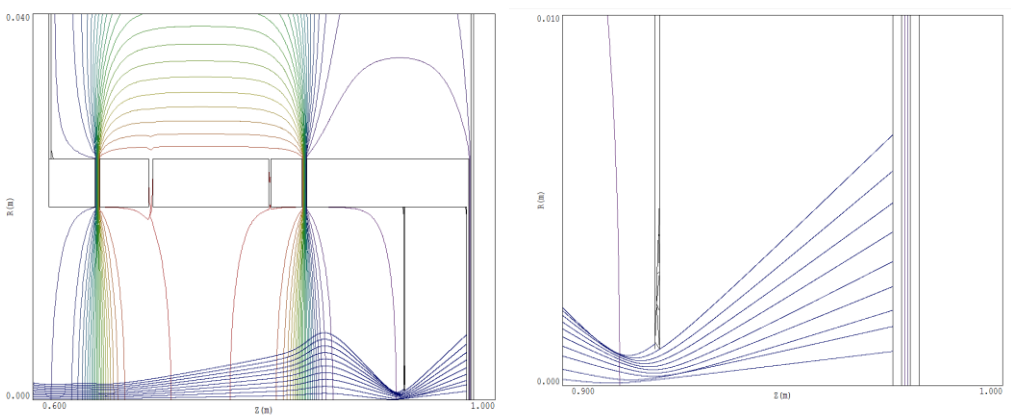


Figure 4 Input lens low magnification solution for 2T conventional superconducting microscope with 120G at Fe ring. Input electrons 100eV, CHA pass energy 50eV, 2 element low magnification operation into 2mm apertures giving 100 micron field of view. Angular magnification: 0.1 rad/50 micron = 2.0E3 rad/m

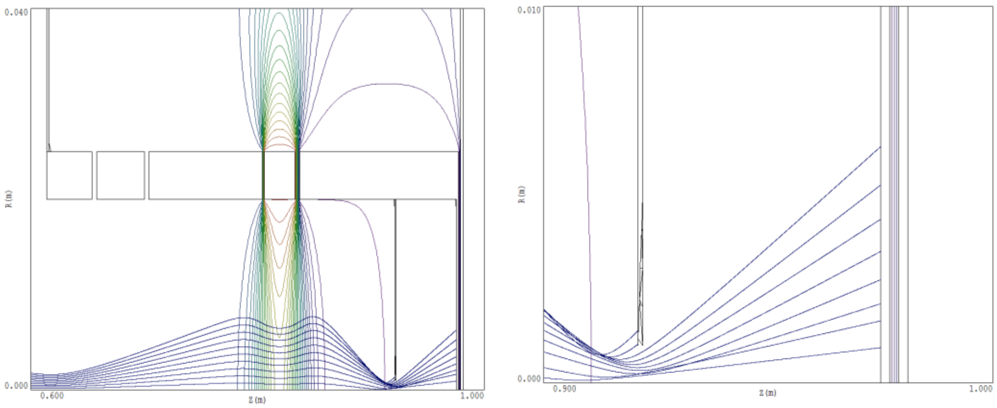


Figure 5 Input lens solution with mag=2.6E3 rad/m

Output lens and detector assembly

The output lens was designed as a three element cylindrical electrostatic lens. The lens acts as a telescopic zoom lens that projects the angular image out of the CHA onto an image plane. At the image plane is an image detector consisting of a dual microchannel plate, and a phosphor deposited on a fiberoptic vacuum window. This is an off the shelf item (BOS-40 Beam Imaging Solutions). All the other parts were developed in-house.

Shown here is the second implementation of the lens and detector assembly that has been used on the prototype instrument. The output lens is physically split in to two parts. One part, element one, is attached to the CHA, and the second part, element two, the image aperture, and the lens support ring, is attached to the same flange the detector is fixed to. This makes the lens assembly much easier to break down for modification and extension later to three element operation.

For completeness we present the design for the three element lens followed by the two element split design.

The previous lens was 130mm long and used a 20cm MCP/phosphor image detector. Figure and Figure show a three element 250mm long lens design that focusses onto a 40mm image detector. In this design the magnification is thus twice that of the previous lens.

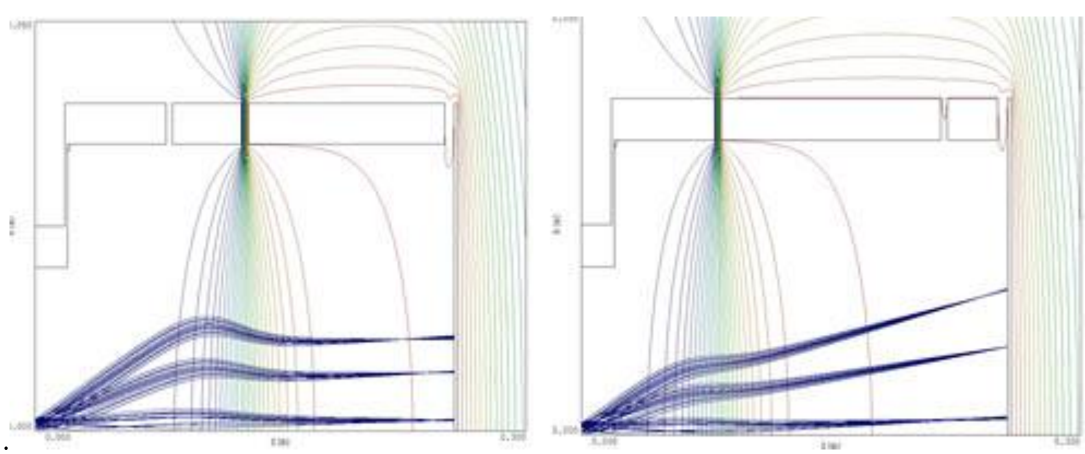


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Figure 6 Three element output lens. Two focus modes are shown.

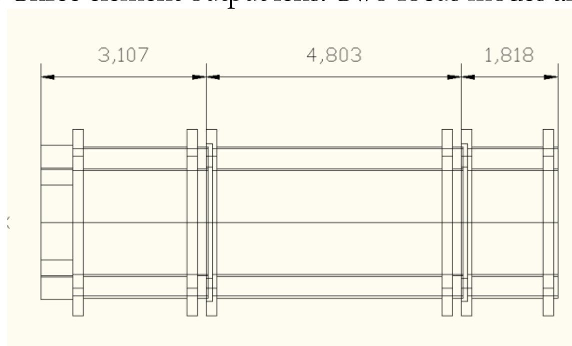

Figure 7 CAD drawings for the three element design.

Ray tracing for the new two element design is shown in Figure . The focal length of the two element output lens is 250mm, and the focus is a compromise between the different modes of the three element design. The image has better than 700 lines in the image. With an expected 40 micron resolution from a double MCP image detector we have 1000 possible lines, and thus this 700 line solution is near optimum.

Note that the number of lines in the image is limited by field curvature. It might be possible to add a gridded element to correct this.

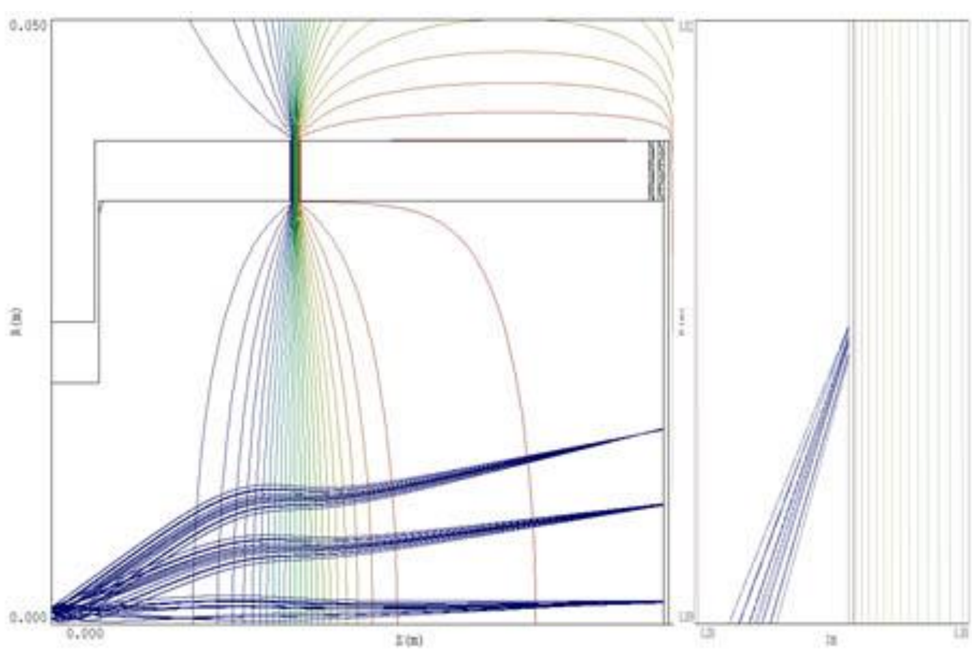

Figure 8 Ray tracing for a two element 250mm focus output lens. This predicts an image with approximately 700 lines on a 40mm image plane.

The lens construction is shown in Figure 2. All elements and fasteners are fabricated from nonmagnetic materials, Al and sapphire ball spacers. Missing from the figures is the extended mu-metal shield. The input and image apertures are Au coated to reduce any charging or stray work function patch effects.

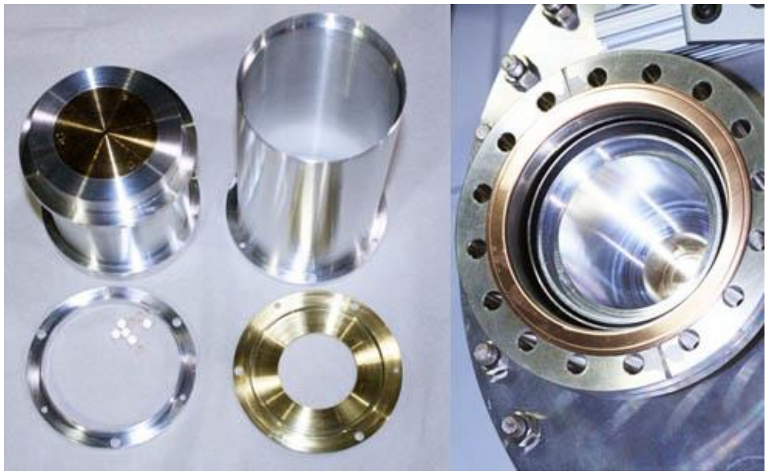

Figure 2 Output lens construction

The partially assembled lens is shown in Figure .

Figure 10 Output lens assembly

The Beam Imaging Solutions BOS-40-6 is a single unit mounted on a 6" CF flange. Four blind tapped holes were specified in the detector for mounting the output lens Also extra SHV feedthroughs were specified for connection to the output lens eleemnts. The detector is shown in Figure 3.

Figure 3 BOS-40 dual MCP beam imaging detector

Figure 12 Output lens elements mounted on the detector assembly

Figure shows how the output lens elements mounted on the detector assembly. On the right, the output lens is mounted in a six inch nipple. A mu-metal sleeve fits inside the nipple.

As can be seen from Figure the second element of the output lens, the imaging aperture, and the detector form a very convenient assembly. This detector assembly mates in proximity with the first element of the output lens which is attached to the CHA. While the relative alignment of the first and second output lens elements is important this is not overly critical. This solution is robust and easily demountable for maintenance and modification.

Image Detection Camera

The design issue for the camera system is that with the increase in output lens length there is a limited distance between the fiber optic window of the detector and the magnetic shield. At the same time as the working distance has been decreased, the area of view of the fiber optic window is larger than the previous implementation. If we are to image the 40mm window directly (rather than through a right angle prism) we need to have a 4x1 demagnification in the cooled CCD camera. The camera, lens system, and working distance must also fit into 140mm (5.5"). A wide angle lens from Navitar was reasonably close in specifications. The lens is an extended field 5 mm EFL, f/2.8 for a C mount. After some experimentation it was found a simple addition of a focus ring extended the back plane focus distance, without introducing visible distortion. The image focal length could be made short, 20mm, while the field of view could be adjusted to 40mm. Figure shows the camera and lens in position imaging the fiber optic window. Note: in operation the camera will have a light shroud.

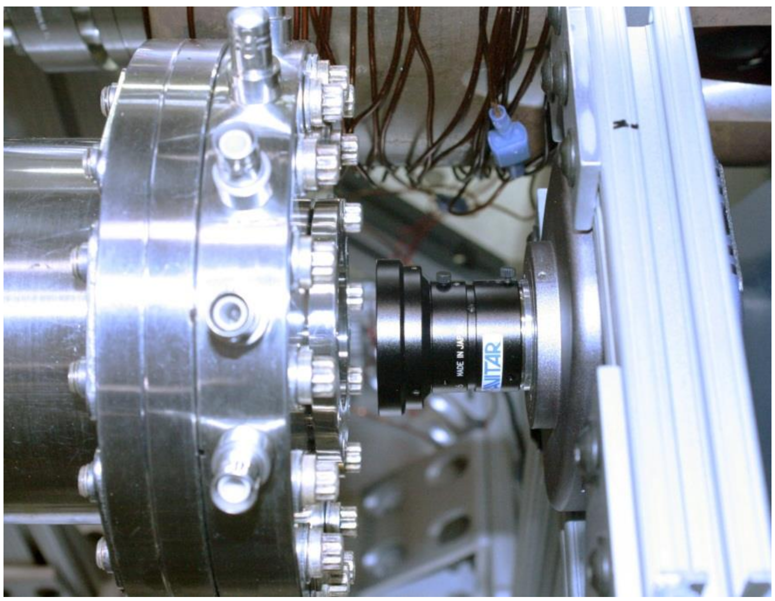

Figure 13 Cooled CCD camera and lens focused on the image detector fiber optic window