Vector Potential Photoelectron Microscopy: Magnetic action in two steps.

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The VPPEM imaging action depends on the electrons leaving a magnet field. A good way to think of this action is in two steps. One step the electrons leaving the sample and travelling in the magnetic field, and the second leaving the field.

Using the vector potential field for microscopy can be thought of as having two steps which are illustrated in Figure 1. The first step reduces the angles involved in the imaging. The second step terminates the magnetic field.

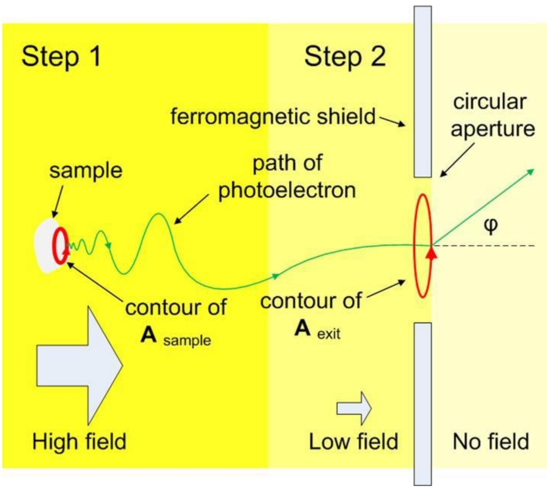

Figure 1. The two steps for an electron trajectory in VPPEM

In the first step, the electrons leave the sample, and exit the strong central field region relatively smoothly following the field lines adiabatically[1]. The electrons travel along the field lines in expanding helical cyclotron orbits[2]. To conserve angular momentum, the helical obits 'unspin' when travelling to a weaker field. Therefore, the photoelectrons which are emitted at all angles into a hemisphere of solid angle 2π steradians are collimated with most of their momentum in the forward direction. At the same time, the vector potential field is becoming weaker so that the imaging angles become smaller.

In the second step, the collimated photoelectrons leave the vector potential field. As in Figure 1, this second step is accomplished by passing the electrons through an aperture in a ferromagnetic shield which terminates the field. The deflection produces an angular image in theta and phi. Theta is in the direction of the magnetic vector potential, and phi is proportional to its value at the point of photoemission. The theta-phi image is mapped point-to-point to the vector potential spatial reference field in theta and radius.

Note that in the first step, both the vector potential field at the termination of the cyclotron orbits, and the off axis momentum of the cyclotron orbits, decrease as the square root of the change in the magnetic field. As the magnetic field decreases going away from the sample, the momentum from the vector potential field, and the momentum from the cyclotron orbits remain in the same ratio. The ratio of the off axis momentum from the cyclotron orbits compared with the momentum from the vector potential field is a limit to the spatial resolution, and this ratio is independent of the change in magnetic field.

The VPPEM angular image is unusual in electron optics. If the VPPEM image was monochromatic, it could be projected onto a real image plane with a simple electrostatic lens (a telescope objective). Fortunately, the theta-phi image is a convenient form for spectroscopic imaging, and it is straightforward to create a monochromatic image from the photoelectron energy distribution.

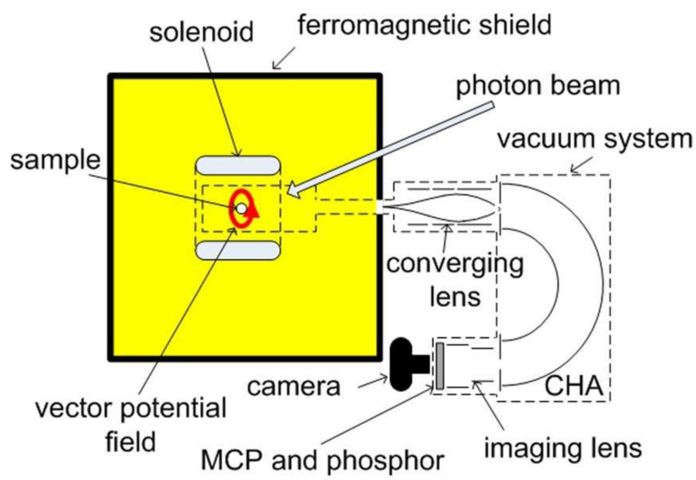

Figure 2 VPPEM schematic

The VPPEM instrument is illustrated in Figure 2. The diverging VPPEM image is converged into the entrance aperture of a concentric hemispherical analyzer (CHA) using an electrostatic lens. The CHA is a double focusing analyzer so that the rotationally symmetric VPPEM image is re-converged in both theta and phi onto the exit aperture of the CHA. At the exit of the CHA, the now monochromatic VPPEM angular image can be imaged as a real image by a simple (objective) lens onto a detector.