A Simple and Inexpensive Permanent Magnet Electron Lens

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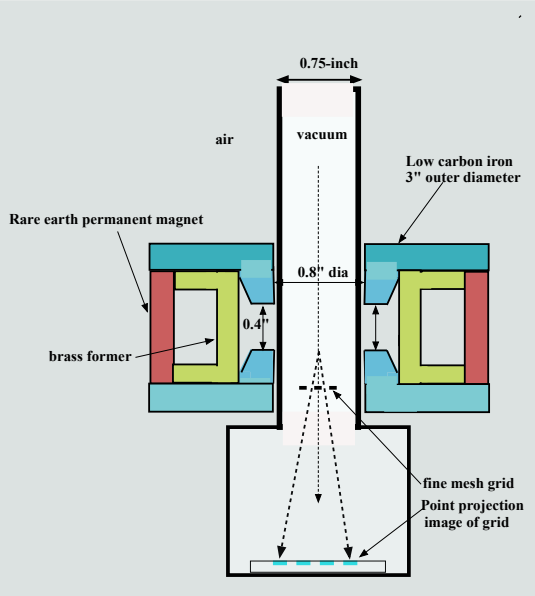
As part of a program to engineer a scanning electron microscope that is affordable for, say, high school students we are developing a lens that does not require a highly stabilized current supply and is inexpensive to build. The prototype, shown in figs. 1,2 comprises 2 circular pieces of low carbon iron, aligned with a brass former and held together with neodymium permanent magnets. The lens sits outside the vacuum tube. Each polepiece has a bore diameter of 0.8" the gap between polepieces is 0.4" Standard machining tolerances of +-0.005" were used throughout. Assuming a saturation flux density of 10,000 gauss we should be able to achieve a focal length of less than 10 mm. for a 40KeV beam. The strength of the lens can be controlled by varying the number of Nd magnets inserted. In fig. 2 there are four such magnets as we were focusing 10KeV electrons. There is space for more than 20 magnets but it appears the iron saturates with 12 magnets. In preliminary experiments using point projection images of a fine (2000mesh/inch) grid with focusing 30KeV electrons we have obtained focal lengths below 10mm and an estimated value of Cs of 15mm. An example of a point projection image is shown in fig. 3. The brass former has space for auxiliary windings for fine focusing but because the lens is so compact it can easily be moved vertically for focusing. Astigmatism can be corrected by moving the lens laterally (there is at present about +-0.025" room for lateral travel). The ongoing experimental program includes providing a smaller source size and a mechanical scanning system for the sample to measure beam diameter both within the vacuum and on the far side of a 20nm membrane outside the high vacuum region.

Fig. 1 Schematic of permanent magnet lens.



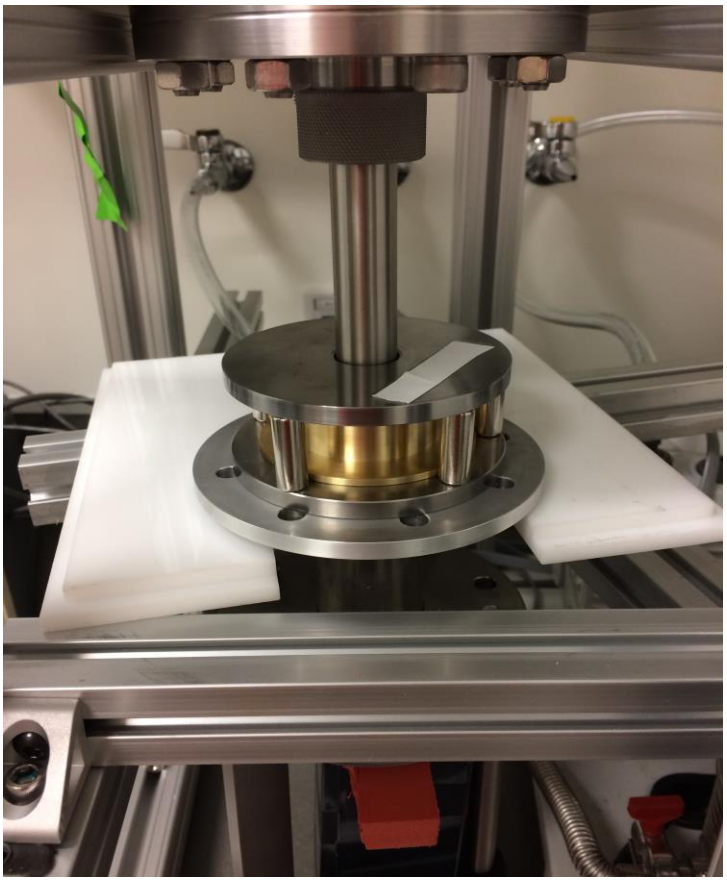


Fig 2. Permanent magnet lens on test bed showing the ¾" diameter vacuum tube and 3 of the 4 Nd magnet used to generate the focusing field (part of the 4th is just visible). The lens measures 3" diameter x 1.4" high and is on a flange 4.5" diameter.

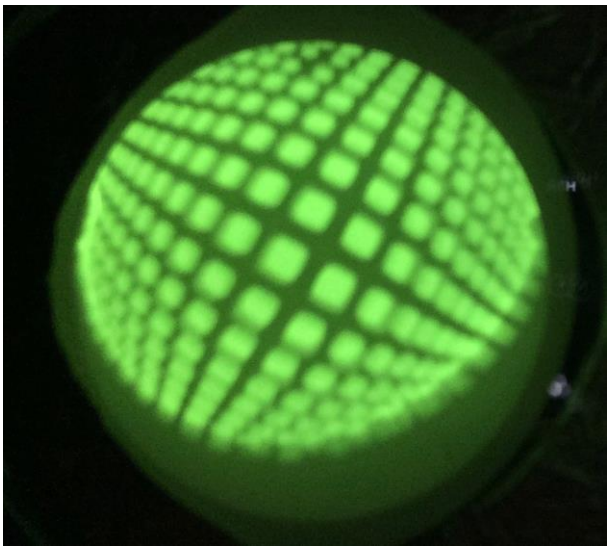


Fig. 3. Point Projection Image of a 2000 mesh/inch grid (25KeV).