11.2: A Box-Shaped Scan Expansion Lens for an Oscilloscope CRT

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Introduction

Various scan expansion schemes have been devised to produce electrostatic deflection CRT's with high deflection sensitivities and good spot characteristics. One popular method has been the dome shaped mesh [1]. The mesh, while capable of producing a display with low geometry distortion and good linearity, interacts with the electron beam causing reduced beam current, spot defocus, and secondary emission.

The limitations of the domed mesh can be overcome by the use of a three-element axially symmetric lens [2] or by the use of electrostatic quadrupoles [3]. The three-element lens, however, is not capable of producing the excellent geometry and linearity characteristics of the domed mesh because of the limitation of axial symmetry. A quadrupole requires additional quadrupoles to produce a round spot, and thus lacks simplicity. Also, these methods are not compatible with storage tube operation, since they all are optimized for or require post deflection acceleration.

Construction and Operation

Otto Klemperer [4] describes a box lens with lipped electrodes which produces a line focus with low aberration. This type of lens, with proper modification, is useful as a magnifier in a high sensitivity oscilloscope CRT (see figure 1). A wide range of focal lengths is easily obtained without introducing distortion by changing the radii and positions of the circular gaps on the top and sides of the lens and changing the operating voltages. The electrodes are made physically large to ensure a high quality display. Lens size is limited by the need to keep the lens smaller than the screen and the operating voltages within reason.

Figure 2 shows the relative position of the lens in a high sensitivity CRT. The lens generates a focal length of −1.3", which magnifies the scan 4X horizontally. A 0.6" focal length inverts the display and magnifies the scan 4.5X vertically. Figures 3 and 4 show the electron trajectories as they pass through the lens. Properly adjusted, linearity distortion along the vertical axis is less than 2% of that at screen center. Horizontal linearity distortion can be adjusted to expand, compress, or be zero, depending on design choice. Geometry distortion at the edge of scan is less than 0.5%. Spot size growth is less than 1.2X.

Similar to Quadrupole

The box lens operation is similar to a quadrupole, producing focal lengths of opposite sign in each axis. However, quadrupole lenses have electrodes with curved surfaces perpendicular to the axial direction, while the box lens electrodes are flat with curved surfaces elongated parallel to the axial direction. In figure 1, the 4200-volt electrode is likened to positive poles positioned along the sides of the lens, while the 300-volt element is likened to negative poles positioned along the top and bottom. Another difference is that the positive and negative electrodes are not equidistant from the tube axis, which permits individual adjustment of focal length along each axis with minimum distortion. This eliminates the need for additional quadrupoles to obtain optimum focus, and focusing can be done with conventional focus and astigmatism controls.

Modified Lens

The modified lens shown in figure 5 is a version of the lens shown in figure 1 with the 300-volt electrode cut into six separate sections. In this manner, the lens can be made to operate with or without high voltage to improve trace brightness. The voltages depicted are those required to operate the screen at 15 kV. The display characteristics are substantially the same as when operated without high voltage. As shown, additional dc biasing voltages may be placed across opposing lens elements to correct vertical line bowing and keystone distortion caused by parts misalignment.

Computer Program

To facilitate design, a 3-D computer program was written, taking advantage of the rectangular shape, two-fold vertical and horizontal symmetry, and flat electrode configuration. Using a Liebmann procedure, only 27,742 mesh points were needed to make the field calculations to plot trajectories within 1%. Adjacent points were spaced every 0.050" in a cubic array. The potential at each point was calculated from the average of the adjacent six points. By including a relaxation factor, calculation of the potential at all points took only 90 cpu seconds on a Cyber 73 computer. Trajectory calculations took 15 cpu seconds each.

Results

The main reasons for the improved performance of the box lens over the domed mesh shown in figure 6 are the elimination of the beam intercept and spot defocus caused by the mesh. Also, since the box lens operates at a 4.5X magnification ratio and the mesh can operate at only 2.5X, the deflection plates used with the box lens are more widely separated without losing deflection sensitivity. This permits the passing of a larger beam envelope, which is used to improve trace brightness and reduce spot size. Further gains in performance could be realized by including a quadrupole between the vertical and horizontal deflection plates. This would help reduce crossover magnification and further reduce spot size.

References

[1] Grein, Russell and Sverdrup, "A Solid State 50-MHz Oscilloscope," Electronics, July 25, 1966.

[2] Schachert, "Electron Optical Properties of a Postdeflection Acceleration Lens in Cathode-Ray Tubes for Oscilloscopes of High-Bandwidth Capability," IEEE Transactions on Electron Devices, Vol. ED-18, No. 8, August 1971.

[3] Martin and Deschamps, "A Short Length Rectangular Oscilloscope Tube with High Deflection Sensitivity by Using an Original Technique," Proceedings of the S.I.D., Vol. 12/1 First Quarter 1971.

[4] Klemperer, Electron Optics, Cambridge University Press, 1953, pp. 295-296. See also Brit. Pat. 573,901 and 574,056.

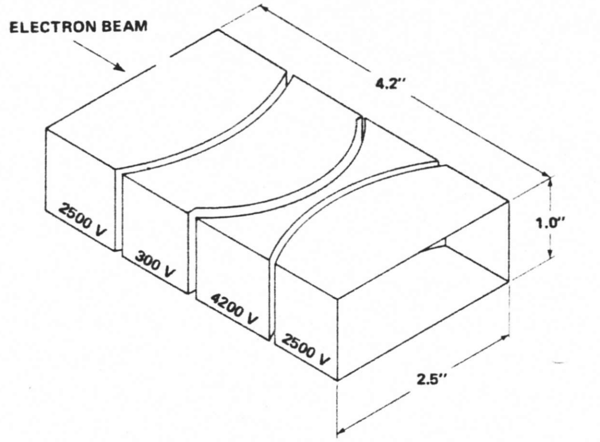

Figure 1. A box lens as used in a non-PDA application (screen at 2500 volts).

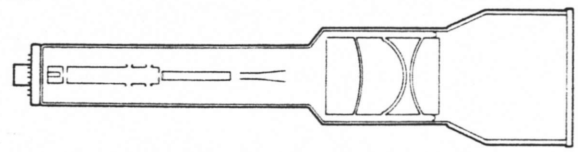

Figure 2. Lens location in CRT.

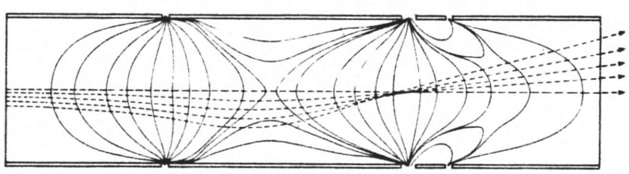

Figure 3. Equipotentials and trajectories along center vertical CRT axis.

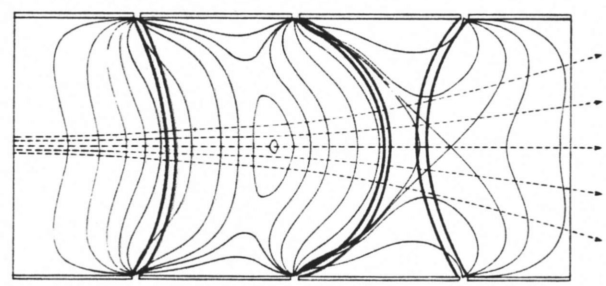

Figure 4. Equipotentials and trajectories along center horizontal axis.

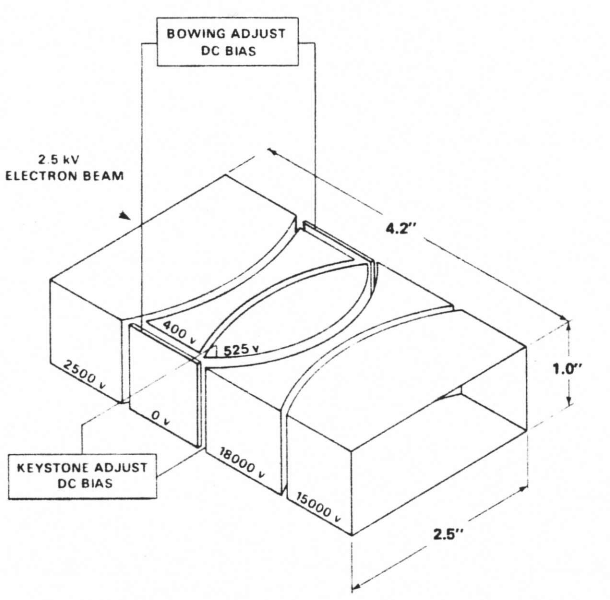

Figure 5. Modified lens as used in PDA application (screen at 15 kV) showing connection of variable dc bias voltages for correction of bowing and keystone distortion.

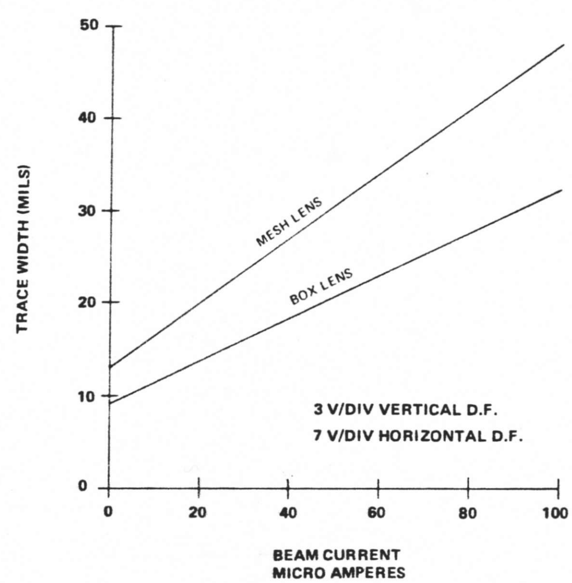

Figure 6. Beam current vs tracewidth for box lens and mesh lens.