FORUM REPORT 5

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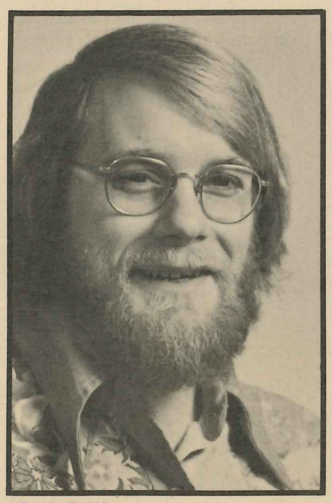
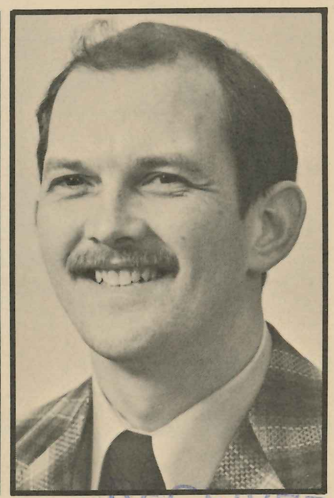
In November 1976, Bill Walker, vice president for the Test and Measurements Group, announced the formation of the Engineering Activities Council. The basic purpose of the council is to provide engineers with a forum in which they can directly present to multiple levels of management what engineers themselves consider to be important in technology.

"New CRT Technologies" was the subject of the fifth forum. Bill Walker introduced the chairmen for the forum: Cal Diller (SID Engineering) and Bob Oswald (TM 500 Series Engineering). Cal and Bob introduced each of the forum panel members: Dave Gutzler (Storage CRT Engineering), Bill Tomison (Real-TimeCRT Engineering), Ron Robinder (Display Research), Bob Arnold (Display Devices) and Bo Janko.

Each panel member gave a brief presentation and answered questions on the work in his area. This forum report summarizes those presentations.

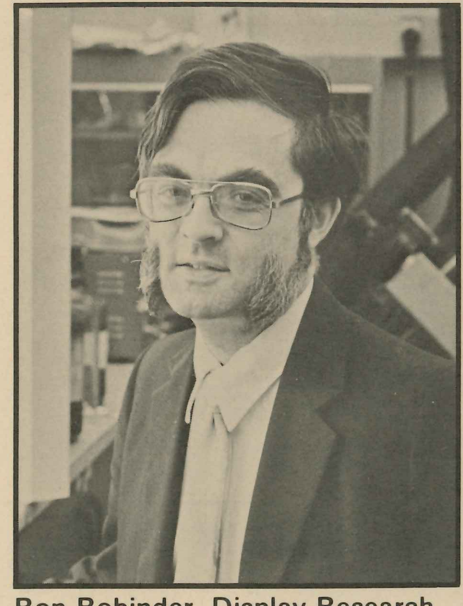


Cal Diller

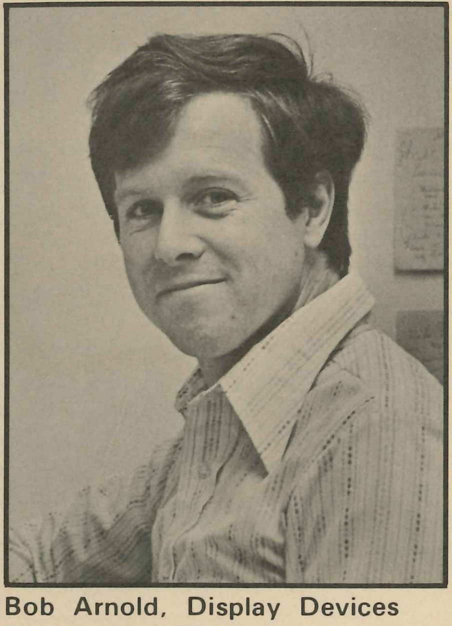


Bob Oswald

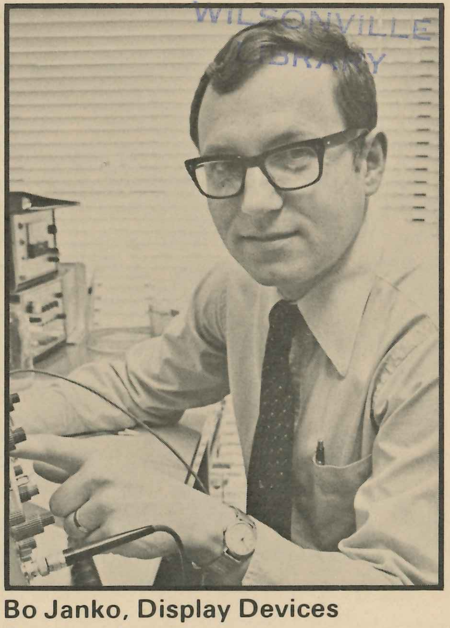
Cochairmen



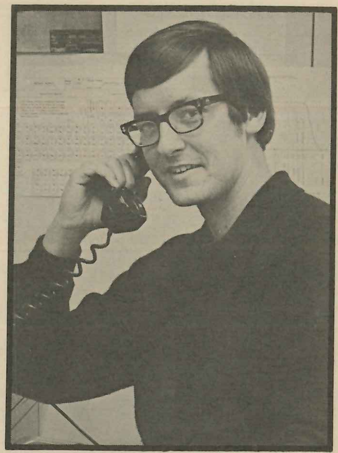
Ron Robinder, Display Research (Tek Labs) discussed color technology at Tektronix.



Bob Arnold, Display Devices Engineering (Tek Labs).



Bo Janko, Display Devices Engineering (Tek Labs).



David Gutzler

RECENT DEVELOPMENTS IN PHOSPHOR STORAGE

Before discussing recent developments in phosphor storage at Tektronix, I would like to begin with a general survey of the field of information display. This will give us a chance to look at what the competition to phosphor storage has to offer.

THE COMPETITION

One competitive display device is the **plasma panel**. Plasma panels were developed in an academic environment and are very popular for programmed instruction. Plasma panels are very viewable and offer selective write and erase: information in a given area of the screen can be erased and new information written without rewriting the entire screen. A disadvantage of the plasma panel is the complicated electronics required for X,Y matrix addressing.

Another device is the **Digisplay** which unlike the other flat panel devices, is a crt. Some of its features are high brightness, fast response, digital address, and simple electronics. The Digisplay has several switching plates between the cathode and the screen. The switching plates are digitally addressed to display the desired information. A disadvantage of the flat panel display is the difficulty of making switching plates for large displays.

Another display device is the **electroluminescent (EL) panel**. It's advantages are long life, brightness, and storage. EL panels share with the plasma panel the disadvantage of requiring complex electronics for X,Y matrix addressing. That brings us to the phosphor storage devices that we have at Tektronix. The display for the storage devices is the direct view storage tube (DVST). We will look at its features in the remainder of the discussion.

PERFORMANCE

In evaluating display devices, there are two performance characteristics to consider: life and viewability. A device has **good life** when performance does not degrade with use. **Viewability** is defined by luminance and contrast ratio. **Luminance** is the brightness of the written trace measured in footlamberts (fL) and **contrast ratio** is the ratio of the luminance of the written trace to the luminance of the background. A good viewable display in a typical user situation has a luminance of 20fl and a contrast ratio of 20:1. Before discussing developments in these areas, let us first look at the operation of a DVST (figure 1).

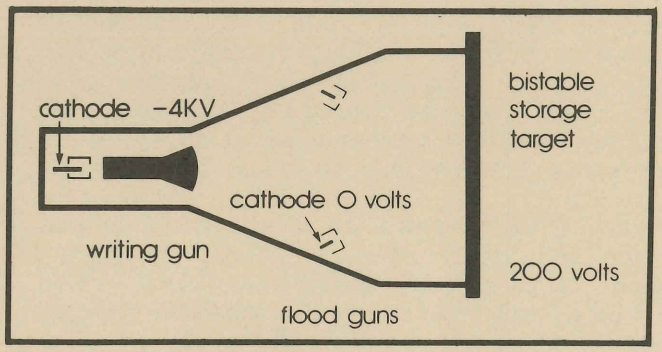


Figure 1. A direct-view storage tube.

In a bistable storage target, there is a glass faceplate, a conducting film electron collector structure, and the phosphor. The crt consists of the storage target, funnel and writing gun. With 4kV on the cathode of the writing gun, electrons are produced which bombard the phosphor screen. In phosphor areas bombarded by electrons, secondary electrons are emitted causing that area to charge positive.

The flood guns, with cathodes at 0 volts, are continuously bombarding the entire phosphor screen of the DVST (at 200 volts relative to the flood gun cathode). The areas written by the writing gun attract the electrons of the flood guns and therefore luminesce.

ROOM FOR IMPROVEMENT

Areas we can examine in phosphor storage displays for increased luminance are current density, phosphor efficiency, and operating level. First, if the amount of current to the screen is increased, the luminance will increase. The current can be increased by increasing the number of flood guns and by positioning them closer to the screen.

Second, if the efficiency of the phosphor is increased, the brightness of the display will also increase for a given level of incident electron power to the screen.

Third, if the operating level is increased to 250 volts, then the luminance of the display will increase. However, the designer must be careful not to degrade one performance parameter while upgrading others. Typically, the screen ages in direct proportion to the flood gun current density. Hence, increased current has not been an attractive alternative.

NEW PHOSPHORS

The phosphor now used in phosphor storage devices is P-1 (Zn_2SiO_4 :Mn). The TV industry, several years ago, began investigating a new family of very efficient phosphors called rare earth oxysulfides. At Tektronix, we have begun to examine the rare earth phosphors in DVST's.

Even though these phosphors were shown to be efficient at the high voltages required for TV, they need to be evaluated at the low voltages used in our crt's. Y_2O_2:Tb, a green emitting phosphor under cathode ray excitation, is more efficient than P-1, and close examination of Y_2O_2S:Tb showed very good life bistable storage characteristics. We have started to replace P-1 phosphor with Y_2O_2S:Tb in the 11" crt (a flat 11" diagonal screen known as the 611 CRT). It is the crt for our small display terminals and it is the display for the 4051 calculator.

Comparing the performance of P-1 and Y_2O_2S:Tb phosphors in a 611 CRT, the present tube with P-1 has a luminance of 8fl and a contrast ratio of 10:1. With Y_2O_2S:Tb phosphor, luminance has increased to 20fl and contrast ratio is 8:1. Life is increased by a factor of four with Y_2O_2S:Tb phosphor.

	Zn_2SiO_4 : Mn	Y_2O_2S : Tb
Luminance	8 FL	20 FL
Contrast Ratio	10:1	8:1
Life Stability	1	4x

NEW AREAS

Areas for future work are background luminance, write-thru, and special applications. With an increase in luminance to 20fl with Y_2O_2S:Tb, the brightness is good but the contrast ratio needs improvement. Improvements in electron collector structure can lead to decreased background luminance.

Write-thru is a relatively new feature being designed for the DVST. This feature allows more user interaction with the display. In write-thru, the writing gun operates in a non-store, refresh mode which allows a series of curves to be displayed and allows the user to select which curve he wishes to store.

Another area of investigation is special applications. It is assumed that the typical location for a terminal is next to one's desk or in some other user area under fluorescent lights. We found, though, that the terminals are used in many different ambients and each affects the viewability of the display. For example, our displays are more viewable under incandescent lighting than fluorescent lighting. New filters and phosphors are being evaluated for viewability. When all of the available combinations which affect viewability are carefully evaluated, we expect to find more customers for our displays.

RESOLUTION AND STORAGE

Two features that keep the DVST the leader in the display device field are high resolution and high information storage capacity. The 19" DVST can display up to 34,000 characters and still maintain good viewability. The resolution of a DVST is better than that of a plasma panel.

I would like to leave you with two thoughts. The first is that the work described here has been very much a team effort: the ideas and talents of many people have been combined to produce the developments described here. Secondly, the improvements seen on the 11" are being pursued on the 19" crt along with some new ideas. The new ideas have been demonstrated in the lab with substantial increases in performance on the 19" crt. With increased performance, we would expect the DVST and Tektronix to remain a leader in the field of information display for several more years.

Bill
Tomison

MESHLESS CRT SCAN-EXPANSION SCHEMES

LOWER POWER AMPLIFIERS

Regardless of what the title says, this report is about **power amplifiers**, because that is 95% of what crt scan expansion is all about. What we mean by **crt scan expansion** is increasing the angle between the electron beam and the longitudinal (or z) axis of the crt after it has passed the deflection plates.

BASIC SCAN EXPANSION

In a simple crt with a scan expansion system, the field between the cathode and grid focuses the emitted electrons into a small region called the **crossover** which is then imaged on the screen by the focus lens and scan magnifier lens. The divergent action of the scan magnifier lens increases the deflection angle generated by the deflection plates. Obviously, the greater the scan expansion by the divergent lens, the smaller must be the applied voltage for a given desired deflection. And the lower the voltage swing in the amplifier, the lower can be the power dissipated in it.

Of course, once the ability to make a low deflection power crt is in hand, it can be traded away for other desirable features such as higher resolution, and greater brightness.

DOMED MESH

The most familiar scan expansion technique at Tektronix, the domed mesh, even goes hand in hand with higher brightness through post deflection acceleration (in which the electrons are sent slowly between the deflection plates for good sensitivity and then accelerated to a high energy to make a bright display). In figure 1 you can see that the domed-mesh shapes the equipotential surfaces so that the electric field rapidly pulls the deflected electrons farther from the z axis.

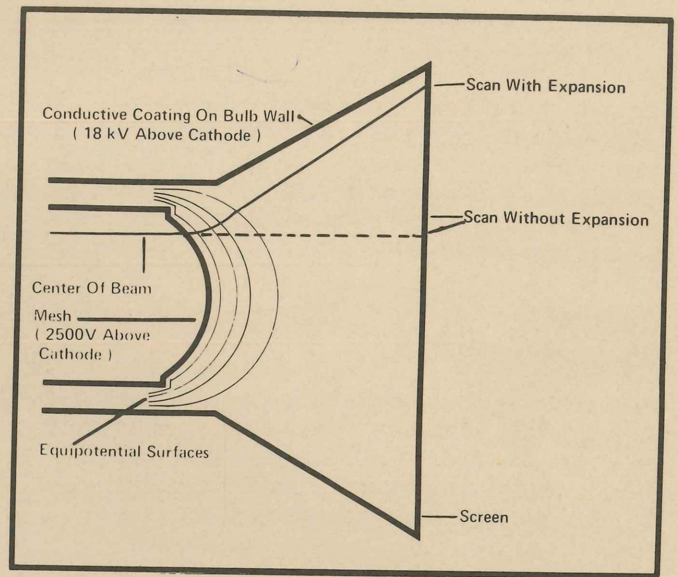


Figure 1. The domed mesh scan-expansion scheme.

Thus the high voltage beyond the mesh creates an axi-symmetric divergent lens which can expand the crt scan typically 2.5 times in the vertical and 2 times in the horizontal.

This system works fairly well and is employed in the crt's of several models of laboratory and portable scopes.

The domed mesh does have some characteristics which keep it from being the ideal scan expansion lens. First, the mesh intercepts 30 to 35% of the beam current thereby reducing brightness.

Second, small lenses formed in the holes of the mesh refocus each portion of the beam, thereby causing an increase in spot size.

Third, the beam knocks secondary electrons from the sides of the holes in the mesh. These secondary electrons reach the screen and form a halo (about 0.5 cm across) near the spot. The halo is quite visible if the spot is moving slowly. This **mesh halo** can be reduced substantially but not eliminated.

Fourth, the mesh lens does nothing to reduce **space charge** (the mutual repulsion of electrons traveling together in the beam) which makes the spot expand for high beam currents.

Fifth, 2.5 times vertical expansion is nice but more would be better.

Sixth, an important class of storage crt's can not use the domed mesh scheme because it requires a very high voltage at the target. (The presence of kilovolts on a storage target precludes economical storage circuitry.)

ELECTROSTATIC QUADRUPOLE

The scan expansion lens which overcomes some of these problems is the electrostatic quadrupole. To see how it is used to achieve scan expansion, let's first look at the simple quadrupole in figure 2. Imagine that we see here the cross section of four line-charges extending out of the page and arranged symmetrically about the z axis and equidistant from it.

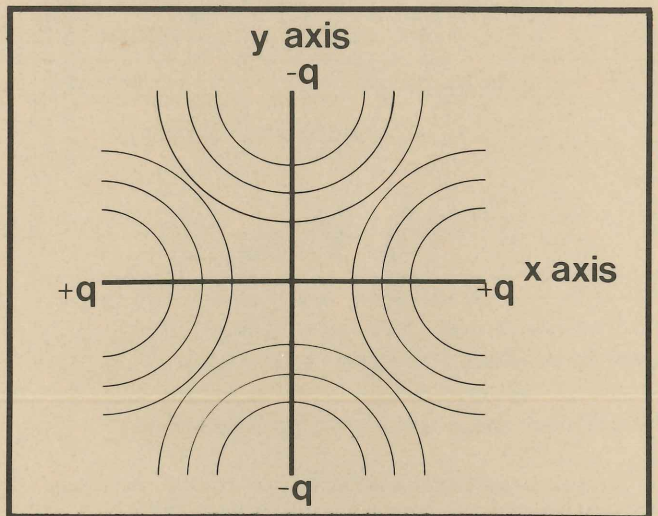


Figure 2. A simple quadrupole.

The four charges are equal in magnitude. The equipotential surfaces between them form two families of hyperboloids with foci coincident with the lines of charge. If an electron between the charges were displaced vertically from the z axis, it would be pushed toward the x-z plane with a force proportional to its displacement in the y direction. Also the electron would be pulled away from the y-z plane with a force proportional to its displacement in the x direction. For any electron lying in the vertical or horizontal plane of symmetry all forces perpendicular to that plane balance to zero.

The condition of force proportional to displacement is sufficient for an aberrationless focusing field.

Note that if the electrons are not too far from the z axis, we can replace the line charges +q and −qwith hyperbolic electrodes carrying the proper voltages. No change in the field near the axis takes place.

THE QUADRUPOLE LENS

Basics

Now we come to the quadrupole lens. In figure 3 we see a quadrupole lens formed by hyperboloids. The voltage V_0 is the voltage on the beam before it enters the field of the lens.

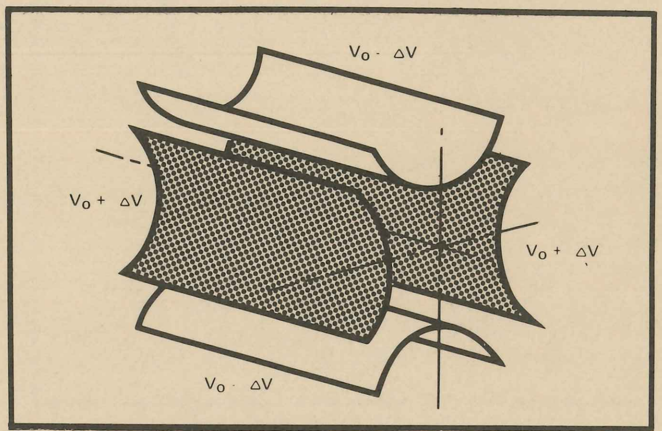


Figure 3. A basic quadrupole lens.

An electron beam entering the lens along the z axis will continue along that axis. A beam that enters the lens parallel to the z axis but displaced horizontally will be bent toward the nearer side electrode, but not at all vertically due to the symmetry of the field above and below. A beam that enters parallel to the z axis but displaced vertically will be bent away from the upper electrode toward the z axis, but due to the symmetry of the field to the left and right it is not deflected sideways. Beams that enter displaced in both the x and y directions will undergo a combination of the two deflections.

So a quadrupole lens is one which converges in one axis to which negative voltage is applied, and diverges in the other axis to which positive voltage is applied. In practice, electrode voltages are typically less than 200 volts away from the beam voltage prior to entering.

Wafers

To make quadrupole lenses that are suitable for crt production, you need three things: some appropriate hyperbolic electrodes, a way to mount them in the gun with precise symmetry about the axes, and low cost for both of the above. The first prototypes were made with machined solid parts. Machined electrodes can be accurate hyperboloids, but they are hard to align accurately in the gun and they aren't cheap. Something that is inexpensive, as well as easy to align, is a wafer with a punched aperture (see figure 4).

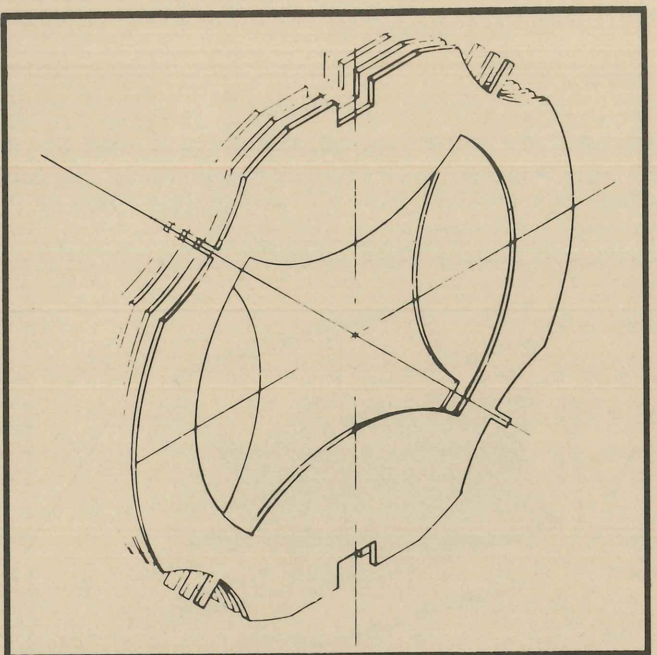


Figure 4. A quadrupole lens made with wafers.

If you make wafers like these and stack them alternately, the beam tends to "see" only the hyperbolic lobes sticking in toward the axis. Although the field is weakened slightly by chopping up the electrodes, its quadrupolarity is not appreciably altered. The penalty is that slightly more voltage must be applied. In terms of instrument cost, however, this penalty is more than paid for with lower crt costs.

Applications

Now to the actual application. The simplest approach is to expand just the first axis of deflection, which is usually the vertical. This is done by inserting between the vertical and horizontal deflection plates a quadrupole lens which is divergent in the vertical axis and convergent in the horizontal axis. (This, of course, neither helps nor hinders horizontal deflection.) See figure 5.

If nothing further were done, the beam would leave this interdeflection quadrupole with a highly oval shape and arrive at the screen thoroughly defocused. Also shown in figure 5 is the preconditioning of the beam by the focus and astigmatism lenses which produce a focused round spot. Note that the astigmatism lens is depicted with the properties of a quadrupole, which in fact is what it amounts to.

This simple scheme is useful for applications up to 1.2 times vertical expansion. Above about 1.25 times, horizontal deflection defocus becomes severe because of the great width of the beam entering the horizontal plates. The spot becomes severely eliptical due to unequal vertical and horizontal merging. Near 1.5 times expansion, the beam can not be focused at all.

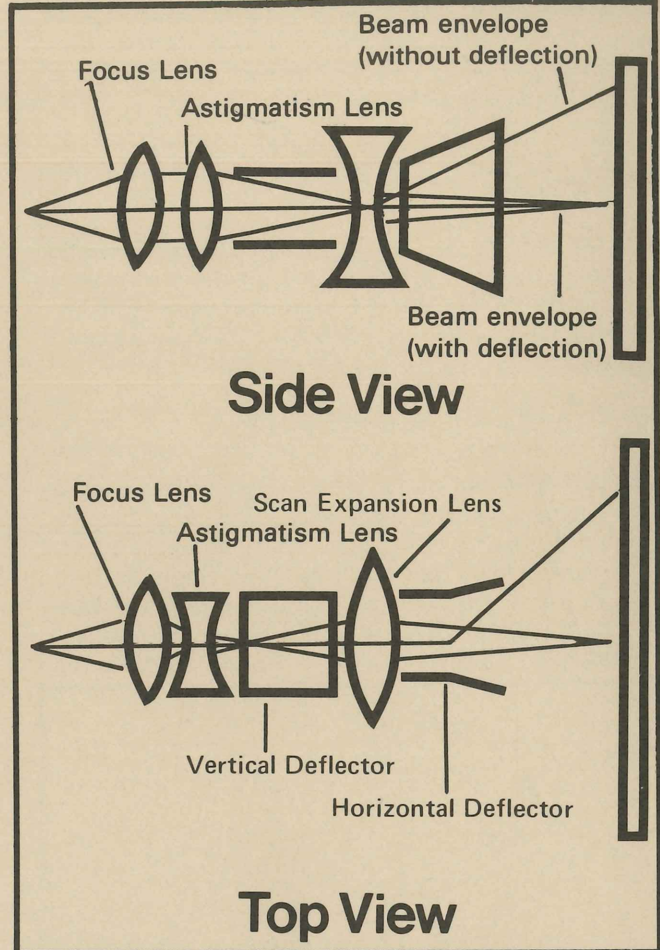


Figure 5. In a quadrupole lens system, focus and astigmatism lenses can be used to precondition the beam to produce a focused round spot.

Three-Quadrupole with Vertical Expansion

For greater expansion it is better to replace the focus and astigmatism lenses with two successive quadrupoles acting in opposite directions.

This scheme yields round spots at expansions of about 1.8 times in the vertical. It was developed for the tube for the 7834 Fast Storage Oscilloscope. See figure 6.

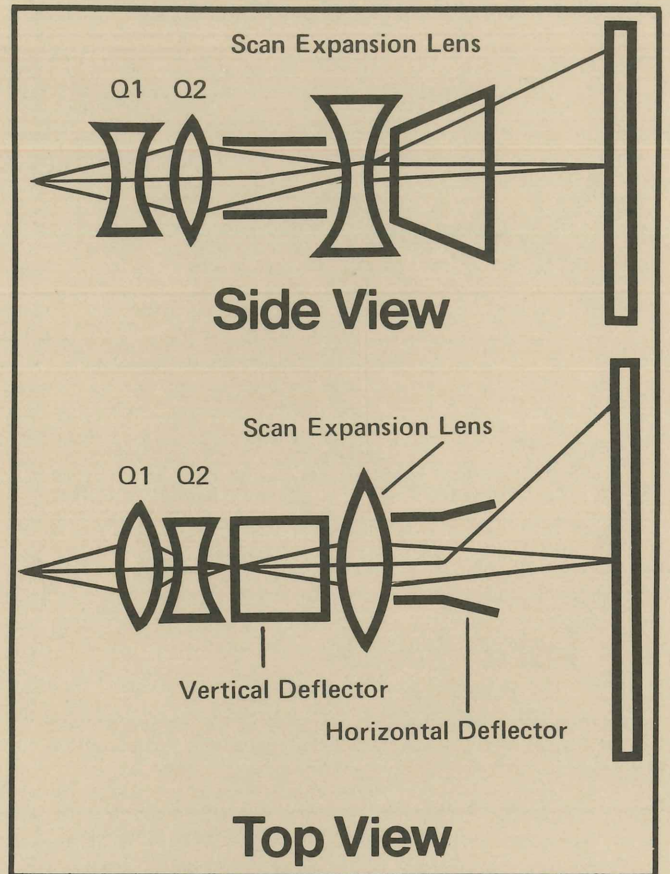


Figure 6. Three-quadrupole scheme, with vertical expansion.

Four-Quadrupole with Vertical and Horizontal Expansion

To get expansion in both axes, you can add another quadrupole lens (after the horizontal deflection) which is strongly divergent in the horizontal and strongly convergent in the vertical (see figure 7).

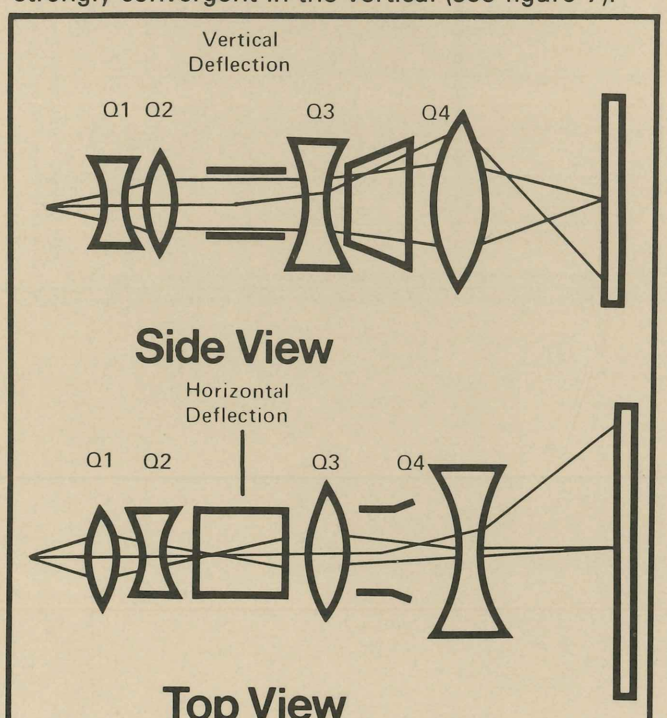


Figure 7. Four-quadrupole scheme, with vertical and horizontal expansion.

Storage CRT Engineering has examined such a lens made from large wafers to pass the larger scan envelope present after the horizontal deflector. Results to date indicate this lens combination may be of benefit only in crt's longer than about 16 inches.

BOX LENS

A lens for which development has passed the design completion milestone in its first application is shown in the crt top view in figure 8.

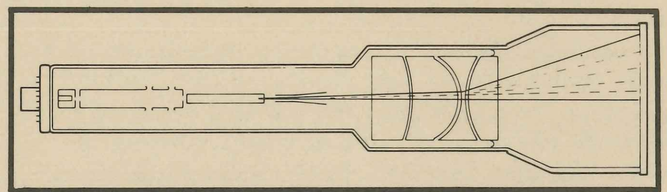


Figure 8. Top view of crt with box lens.

It is called a box lens and will be used in the 7104 1 GHz scope. Although it does not resemble a classic quadrupole lens in construction, its action is similar. In figure 9, the voltages are referenced to the cathode.

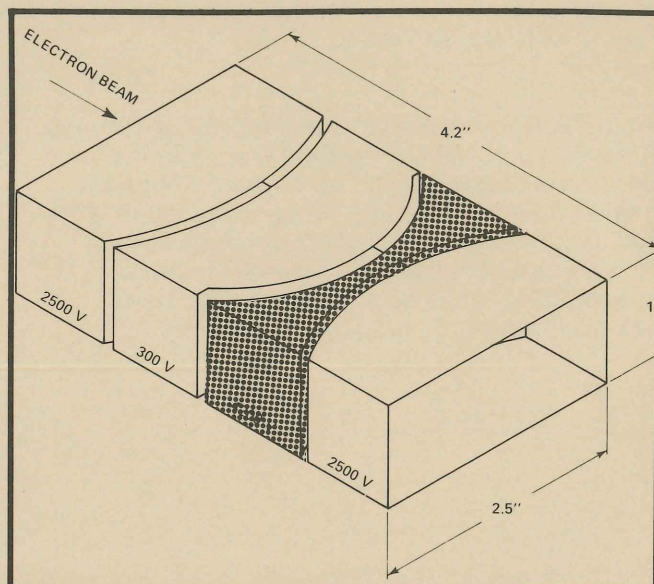


Figure 9. Close-up view of the box lenses shown in figure 8 with voltages referenced to the cathode.

The beam enters and leaves the lens with an energy of 2500 eV. The combination of the D-shaped electrode at negative voltage (with respect to the beam) and the double-convex-shaped electrode at positive voltage (with respect to the beam) causes the beam and the scan to cross over the axis in the vertical and diverge in the horizontal.

The vertical focal length is affected more by the z axis dimension of the D-shaped electrode, and the horizontal focal length is affected more by the x-y aspect ratio of the box. This permits tailoring the box lens to allow the crt to be made with ordinary focus and astigmatism lenses and still have a reasonably round spot for all grid drive levels.

The scan expansions for this lens are 4 times in the horizontal and 4.5 times in the vertical. This nonaccelerating version of the box lens could be of great value in storage crt's if the flood electrons were shielded from the lens field.

An advantage of the box lens is that with a modified design of the cuts in the box lens, it can be made to operate in a PDA mode instead of the nonaccelerating mode.

The voltages (shown referenced to the cathode in figure 9) indicate the bias requirements for PDA operation. In both modes the box lens requires an electrode which is operated at a value above the screen voltage. However, the current requirement for that electrode is negligible.

MAGNETIC LENSES

As a parting shot, I would like to mention that quadrupole lenses may be formed with magnetic fields as well as electrostatic fields.

In figure 10, if electrons were moving out of the page through various parts of the field shown by the long curved arrows, they would be diverted from their paths as shown by the short arrows. This action is the same as it is in an electrostatic quadrupole with positive side electrodes. Our research in this area is just beginning. We can probably expect some practical results in 1 to 2 years.

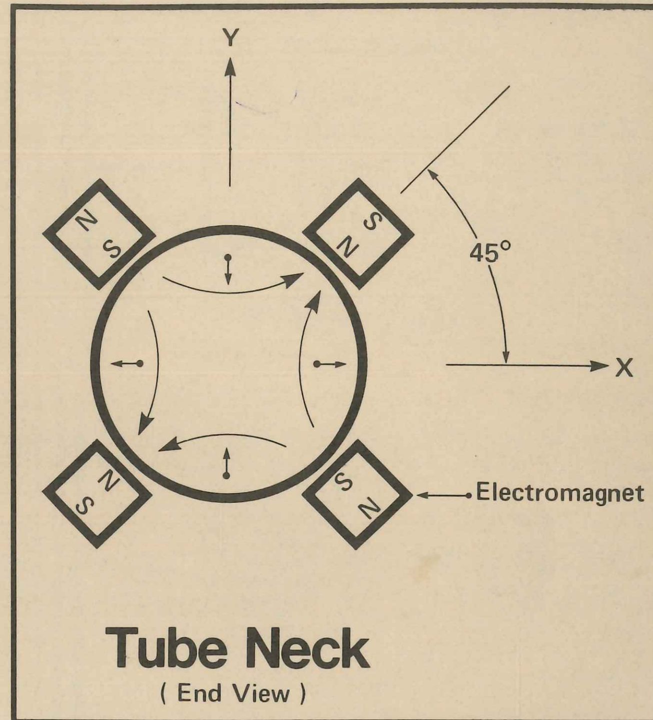


Figure 10. A magnetic quadrupole scan-expansion scheme.

	Vertical Expansion	Horizontal Expansion	Chief Advantage	Chief Disadvantage
Domed Mesh	2.5X	2X	Experience	Lens Let Aberration
3-Quad(vert.)	1.8X	1X	Simplest Mono.	Only 1 Axis
4-Quad(vert. & horiz.)	4X	3X	Storage Compatible	Large Spot Size
Box	4.5X	4X	Mono Or PDA	Bulky
Magnetic Quad	Not Known, Under Evaluation			