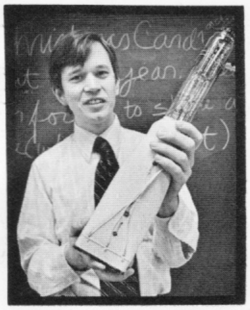
RECENT ADVANCES IN DIRECT VIEW STORAGE TUBES

Chris presented this paper at the 1977 Society for Information Display conference.



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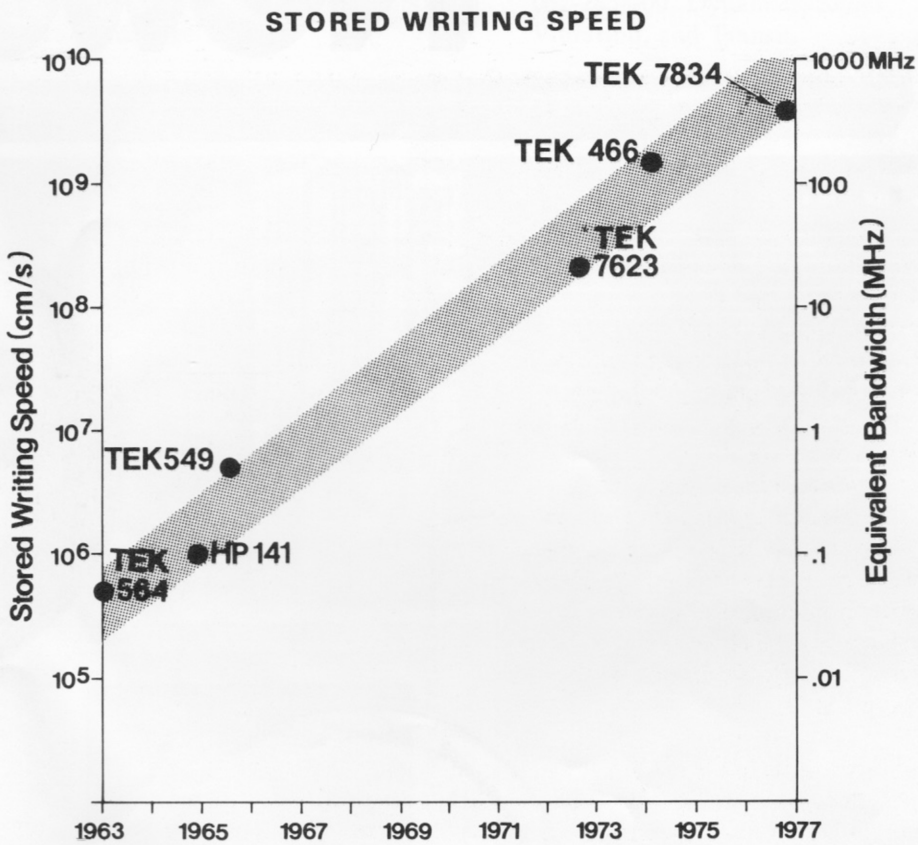

Figure 1. Dramatic improvements in stored writing speed have resulted (at Tektronix and with the HP141) from the use of the charge-transfer technique.

INTRODUCTION

Direct-view storage CRT's have been in use for many years, but significant advances have taken place in the last few years. These developments have helped to increase the CRT's usefulness and lengthen its lead over competing technologies.

TRANSMISSION STORAGE TUBES

In the field of oscillography, the **stored writing speed**, or ability to capture a single transient, is most important. Figure 1 shows the tremendous gains which have been made in the past few years as a result of the **charge transfer technique**. This technique uses a very high speed target to capture the information, which is then transferred to a low speed target for viewing [1]. Figure 2 shows the sequence of operation.

The information is first written on the high speed mesh with the writing beam (time T^1), then transferred to the storage mesh by the flood beam (time T^2), then viewed using the flood beam, storage mesh and phosphor screen (time T^3). The high speed mesh is optimized for high sensitivity, but at the price of very short retention time. The storage mesh can be optimized for long retention time rather than high sensitivity, since the high current flood beam is used to write the information.

Storage CRT's with a mesh-supported dielectric are called **transmission tubes** since the flood (viewing) current is transmitted through the target to the phosphor screen. These tubes are capable of storing halftones and operating in a variable persistence mode.

While for many years there has been a small market in radar display applications for magnetically deflected CRT's, recent developments have been seen in electrostatically deflected CRT's. Two instruments are now available which offer 50 lpi resolution in a 4″ diagonal CRT. A major use area is in medical imaging where gray levels similar to photographic film are important.

PHOSPHOR STORAGE TUBES

In the information display field, information capacity is one important requirement. Using the screen area as an indication of capacity, figure 3 describes recent trends in bistable **phosphor storage CRT's**. Since the screen is not quantized, the amount of information displayed depends upon the quality required, with some users storing 34,000 characters on a 19″ diagonal CRT. This capacity is equivalent to 18 characters per inch as shown in figure 4.

Initial users of bistable CRT's for computer output utilized a 5″ diagonal CRT which had been built for oscilloscopes [2]. This was obviously too small, but due to the low cost was a practical method of displaying computer messages. Because of the inherent simplicity of this device [3] compared to mesh storage (transmission) tubes, the scale-up (shown in figure 3) was accomplished at a reasonable cost to the user. The rapid growth in computer graphics is primarily a result of the very high resolution, stable display offered by these CRT's.

The operation of a bistable CRT using a phosphor storage target is diagrammed in figure 5. The writing beam deposits a positive charge image by bombarding the dielectric (phosphor) target with a secondary emission ratio greater than one (time T[1]). The flood electrons bombard the positively charged areas, with a secondary emission ratio equal to one (time T[2]). No net charging occurs, and a continuous light image is emitted by the phosphor.

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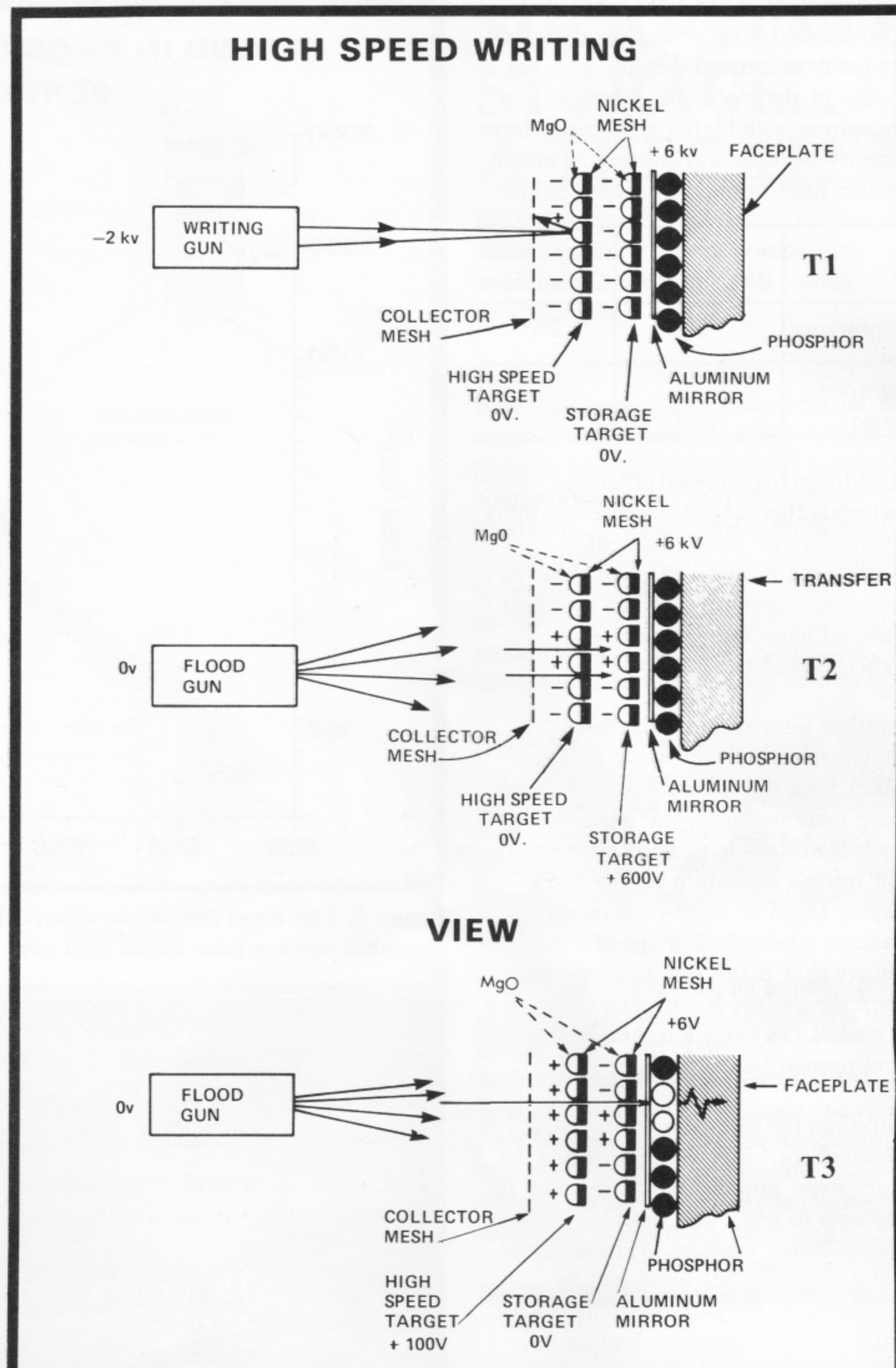

Figure 2. Transfer tube operation begins when the information is first written on the high-speed mesh with the writing beam (in time T[1]), then transferred to the storage mesh by the flood beam (in time T[2]), then viewed using the flood beam, storage mesh and phosphor screen (in time T[3]).

The intensity of the light emitted is proportional to the phosphor efficiency, the incident current density, and the energy of the electrons. Newer phosphors with higher efficiencies have recently been used, resulting in much greater light output, as shown below:

	Zn_2SiO_4:Mn	Rare Earth Oxysulfides
Luminance	8fl	20fl
Contrast Ratio	10:1	8:1

In addition to increased efficiency, these materials also exhibit increased stability under electron bombardment. Reductions in aging rates of three to four times compared to the standard material have been measured in accelerated tests.

Another improvement has been implemented by the circuit designer rather than the device designer. With some local memory, the **write-thru** mode is utilized to provide both storage and refresh operation on the same display [4]. The write-thru mode presents a refreshed image at a current density that is too low to store, and when the picture is correctly formatted or placed, the current is increased to the level needed to store.

Although the phosphor storage CRT is intended for bistable applications, its widespread popularity has resulted in attempts to use it as a halftone display device. Some workers [5] have found that acceptable halftones can be generated by varying the written area and hence the apparent luminance.

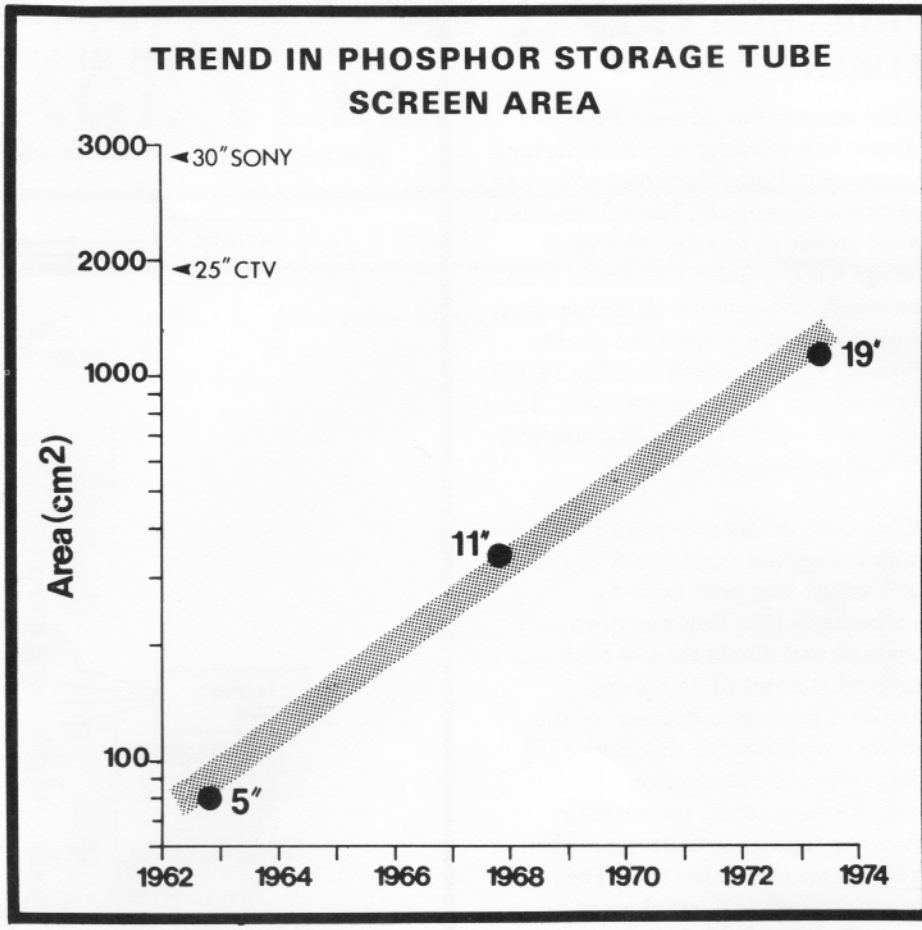

Figure 3. The trend line shows clearly that there has been a ten-fold increase in phosphor storage tube screen area over the last decade.

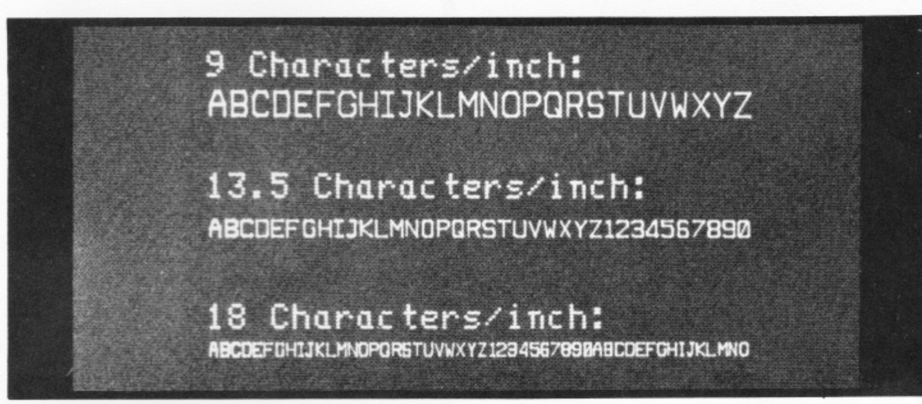

Figure 4. This photo shows examples of different character spacings.

CATHODOCHROMIC CRT'S

Another class of DVST which features dark trace storage, rather than bright trace, is the **cathodochromic CRT**. CCRT's utilize a screen material which darkens under electron beam bombardment. The dark trace is retained until the material is heated to 300° C. Recent material developments [6] allow erasure with the writing beam rather than external sources. A 3 x 3 inch screen can be erased in six seconds using a 20 kV electron beam. These improvements should increase the usability of this very simple and potentially inexpensive storage CRT.

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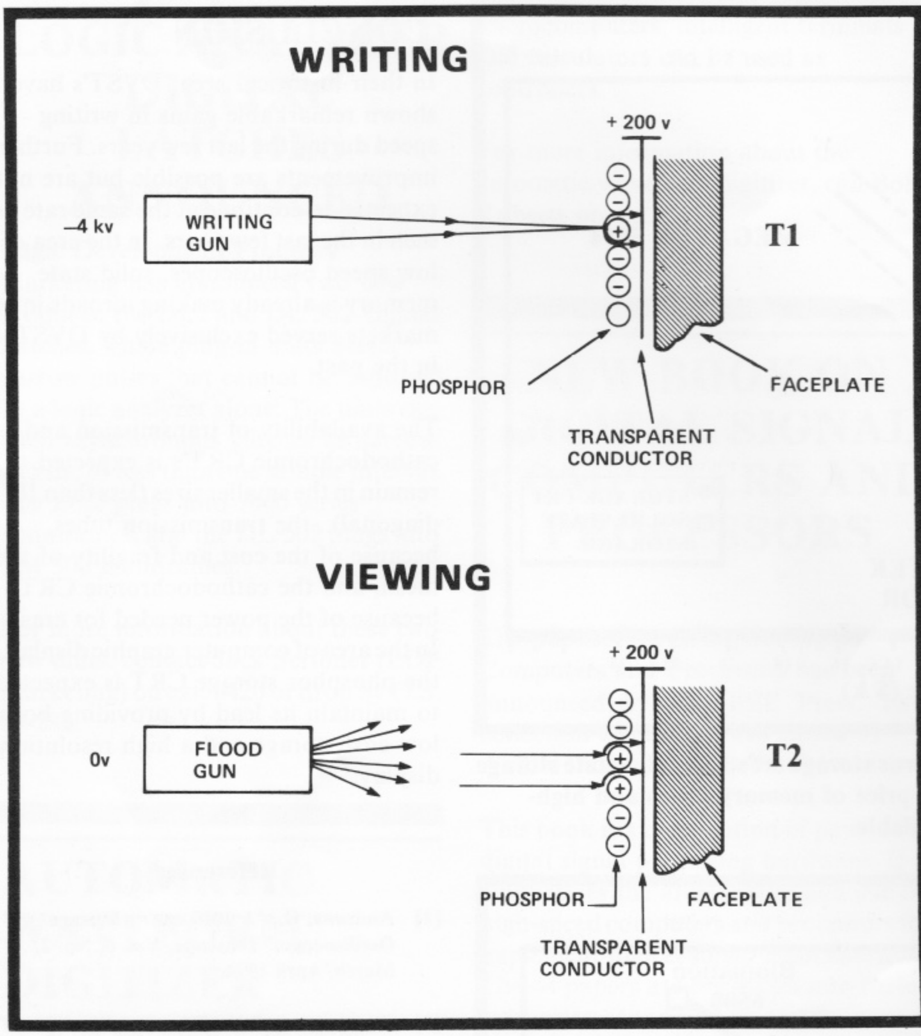

Figure 5. The operation of a bistable crt using a phosphor storage target begins when the writing beam deposits a positive charge image by bombarding the phosphor with a secondary emission ratio *greater* than one (in time T^1). The flood electrons bombard the positively charged areas with a secondary emission ratio *equal* to one (in time T^2). No net charging occurs, and a continuous light image is emitted by the phosphor.

SOLID-STATE STORAGE... A THREAT?

With the price of solid-state memories declining rapidly, their competitive threat to storage crt's is becoming serious.

In the information display market, Hewlett-Packard and Tektronix have recently announced terminals which provide refreshed graphics at a price comparable to our storage-tube products. Although their resolution is marginal for complex graphs (see figure 6), solid-state storage will provide increasing competition as the price of memory drops and high-resolution refreshed monitors become available.

In the single-shot oscillography field, the situation is different. Solid-state memory systems become competitive today only for signals below 1 MHz because of the severe speed requirements at higher frequencies (see figure 7).

This technological barrier appears to be more resistant than the price, but it will slowly yield with continued development. Products like the 466 Portable Storage Oscilloscope and 7834 Fast Storage Oscilloscope which store 100 and 250 MHz single-shot waveforms appear to be reasonably secure for a few more years.

WRITING A PAPER?

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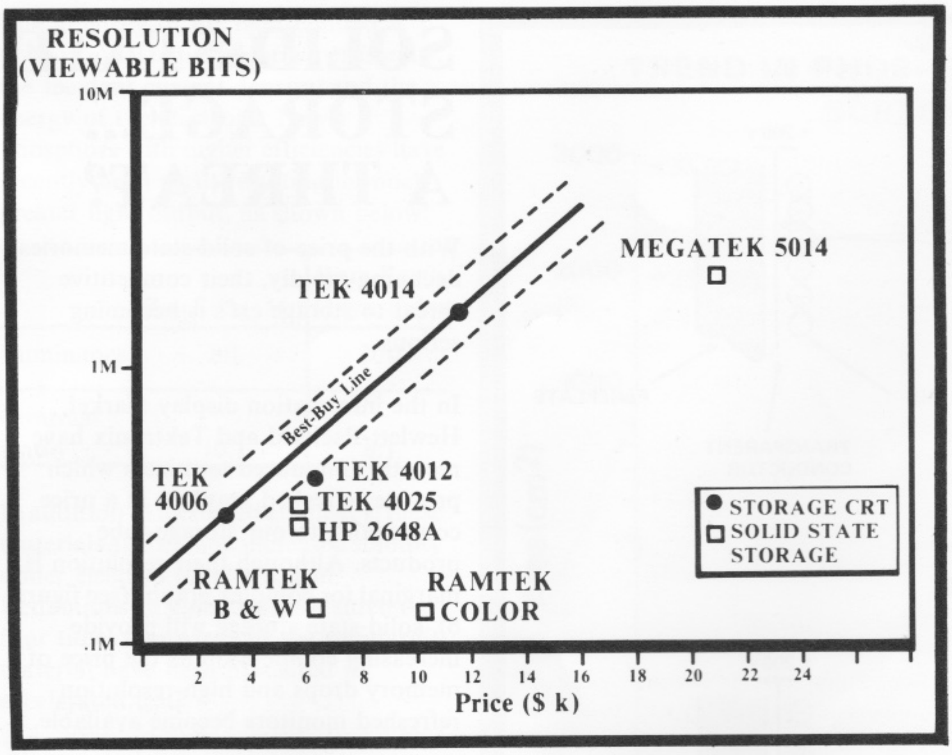

Figure 6. Price/resolution trade-offs still favor storage crt's, but solid-state storage will provide increasing competition as the price of memory drops and high-resolution refreshed monitors become available.

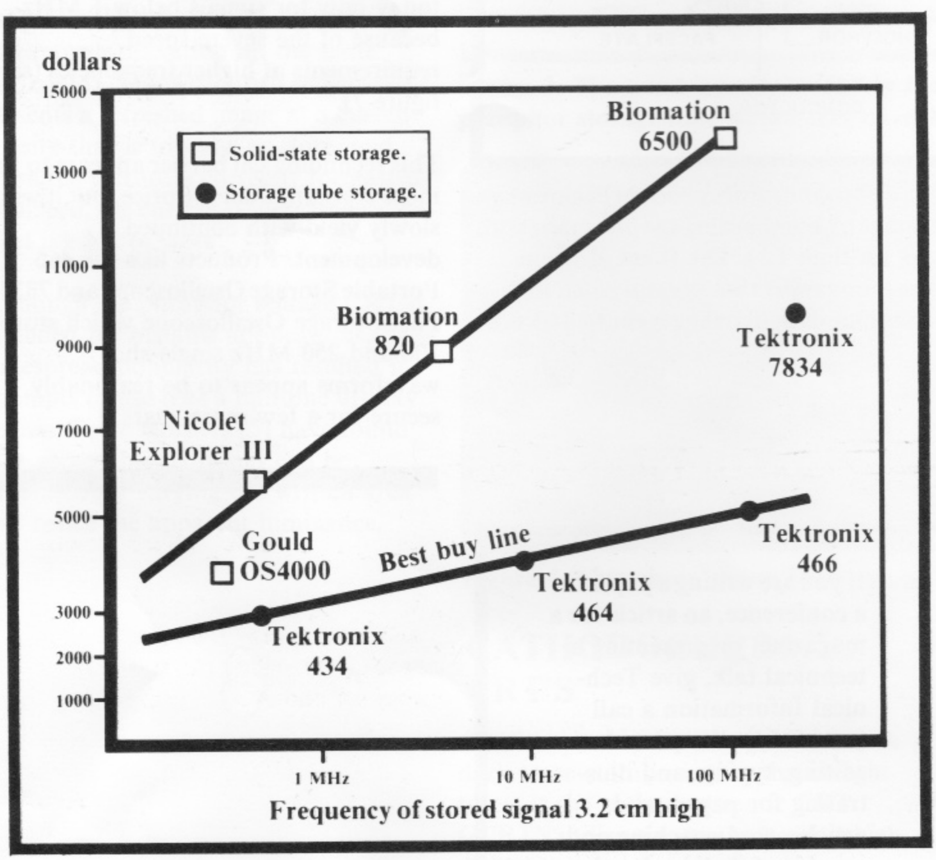

Figure 7. Today solid-state storage systems become competitive with storage tubes only for signals below 1 MHz because of the severe speed requirements at higher frequencies.

CONCLUSION

In their historical area, DVST's have shown remarkable gains in writing speed during the last few years. Further improvements are possible but are not expected to continue at the same rate as seen in the last few years. In the area of low speed oscilloscopes, solid state memory is already making inroads into markets served exclusively by DVST's in the past.

The availability of transmission and cathodochromic CRT's is expected to remain in the smaller sizes (less than 10″ diagonal)...the transmission tubes, because of the cost and fragility of the mesh, and the cathodochromic CRT because of the power needed for erase. In the area of computer graphic display, the phosphor storage CRT is expected to maintain its lead by providing both low cost storage and a high resolution display.

References

[1] Andrews, G., "A 1000 cm/ s Storage Oscilloscope," Tekscope, Vol. 6, No. 2, March/April 1974.

[2] Winningstad, C.N., "The Simplified DVST in Computer Output Applications," SID Digest, May 1967, p. 129.

[3] Anderson, R.H., "A Simplified DVBST," IEEE Transactions on Electron Devices, Vol. ED-14, No. 12, December 1967, pp. 838-844.

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[5] Gordon, R., et. al., "Halftone Graphics on Computer Terminals with Storage Display Tubes," Proceeding of the Society for Information Display, Vol. 17, No. 2, 1976.

[6] Todd, L.T., et. al., "Cathodochromic CRT Employing Faceplate Deposited Sodalite and Electron Beam Erase," IEEE Transactions on Electron Devices, Vol. ED-22, No. 9, September 1975.