A Tale of Two Camera Tubes

By James E. O'Neal
Technology Editor, TV Technology Magazine and Member
BTS AdCom History Committee

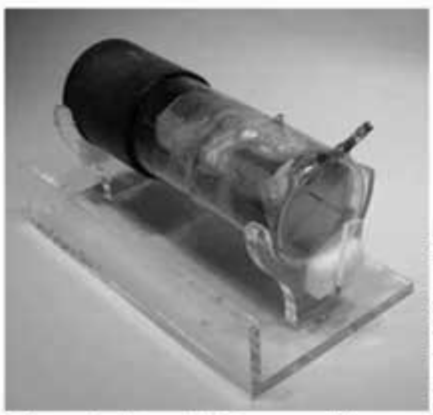
A new Broadway play called "The Farnsworth Invention" opened in New York in October and purports to tell the story of the interactions between television pioneer Philo Farnsworth and RCA president David Sarnoff, who was a driving force in the development of television. The production is one of the few stage plays written about an inventor, and the first dealing with a television inventors.

To make the storyline comprehensible to a general audience, playwright Aaron Sorkin has "dumbed down" the technical elements of what both Farnsworth and RCA research camps were doing in the 1920s and 30s—especially that which led to litigation over priorities and patents. Theatre audiences are given the impression that the television secret (and reason for litigation) was somehow contained in a technique for sealing an optically flat faceplate to the barrel of the camera tube. RCA's director of television research, Vladimir Zworykin supposedly "reverse engineered" this seal technique after a visit to Farnsworth's lab.

Actually, the issue was much more complicated than a glass seal.

In this day and age of inexpensive and readily-available solid-state imaging devices, conversion of a light pattern to an electronic signal is largely taken for granted. However, this was certainly not the case at the beginning of the electronic television age. Probably the most difficult single item to develop was the camera pickup tube. Both Farnsworth and Zworykin succeeded to a degree in producing workable tubes. As their inventions were the first-ever devices for generating live television images without mechanical scanning, it's interesting to look back 75 years or so and examine these first-generation devices.

In the 1920s—the beginning of the modern or electronic television era—there were essentially just two players: Farnsworth, with his seriously under-



Smithsonian Institution collection

Figure 1: An early Farnsworth image dissector

O'Neal collection

Figure 2: A small Zworykin iconoscope

Smithsonian Institution

Figure 3: Philo Farnsworth holds an image dissector used in his early television camera

funded and understaffed television program, and Zworykin, who had the blessing, resources and mandate from Sarnoff's Radio Corporation of America to bring television to the marketplace.

Display devices produced by both inventors were very similar—cathode ray tubes. Farnsworth's was known as the "oscilite" and Zworykin dubbed his the "kinescope." However, their approaches to converting images into electrical signals were markedly different.

ZWORYKIN'S ICONOCSOPE

In Zworykin's tube, the scene to be televised is focused on a target that he called the "mosaic." This was constructed around a fairly large mica substrate coated with a photo-emissive material that had been treated in such a way as to form minute and isolated cells or "globules." Each of these cells is capacitively coupled to a common conductive surface on the rear of the mica substrate. When light strikes these cells, an electrical charge is built up, proportional to the number of photons hitting each cell. The tube also contains an electron gun, similar in design to that employed in a CRT, and mounted below and at an angle to the mosaic. The electron beam produced in the gun is electromagnetically deflected, and scans the mosaic from side-to-side and top-to-bottom. The result is that of a "commutator" discharging the minute "globule" capacitors in sequence. A video signal results directly from the action of this electron beam.

About the only similarity between Zworykin's iconoscope and Farnsworth's tube, the image dissector, was that each was contained within a glass vessel and required a moderately high vacuum for operation.

THE IMAGE DISSECTOR

In the image dissector, light from the scene being televised is focused on a thin transparent "photocathode" coated with a photo-emissive material. This produces an electron "field" at the rear of the photocathode representing the optical pattern presented to the tube.

The image dissector was designed to electrostatically accelerate this "charge field" to the rear of the tube. There, through the actions of external electromagnetic scanning, the field is presented to and made to pass through a very small aperture, literally one picture element at a time. Electrons passing through the aperture are collected on the tube's rearmost element, the signal plate. A video signal is taken from this plate.

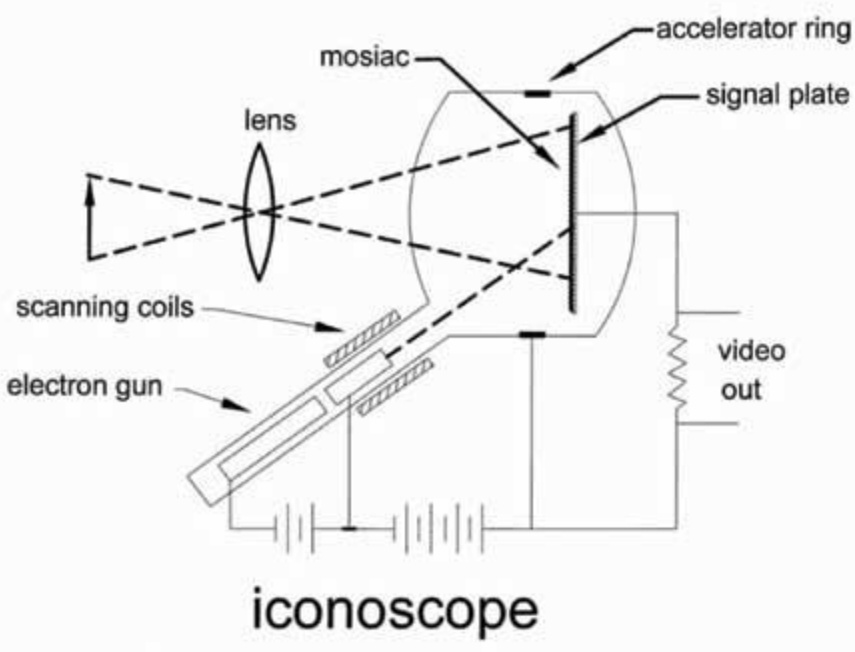


Figure 4: schematic representation of the iconoscope

By today's television imaging device standards, both tubes are very insensitive to light. When the iconoscope was used in studio cameras, the amount of base light needed to generate an acceptable picture was around 1,000 foot candles. (Modern television studios operate with light levels a tenth of this or less.)

As demanding as the light requirements were for the iconoscope, the image dissector required even more light in order to deliver a moderately noise free picture.

This reason for this difference in sensitivity is readily apparent.

The iconoscope is a "storage" type of pickup tube in that the photons striking the mosaic keep building up a charge on the small photo-emissive globules (capacitors) until this charge is removed by the electron beam. Depending upon the amount of light striking the tube and the speed at which the scanning beam is swept over the mosaic, a fairly large number of electrons can be produced.

The image dissector possesses no such storage mechanism and suffers from this. The removal of the electrons through the small aperture is basically an instantaneous process. Fewer electrons yield a considerably weaker (noisier) signal than that from an iconoscope.

PUTTING SECONDARY ELECTRONS TO WORK

Farnsworth was able to overcome this limitation to a degree by substituting an electron multiplier stage for the signal plate electrode. This multiplier (once a common vacuum device) consisted of a series of plates or "dynodes," with each more positively charged than the one preceding it. Physical construction is such that an electron striking one dynode produces additional electrons from secondary emission. These are electrostatically accelerated to the next dynode, with even more electrons produced. Depending on the design of the tube, considerable electron gains are possible, and this results in a much stronger video signal for a given amount of illumination.

Even though the iconoscope was considerably more "sensitive" than the image dissector, it was by no means a perfect device for converting visual information into electricity. Due to the high velocity of electrons scanning the mosaic, a considerable number of secondary electrons were developed. Unlike the image dissector multiplier stage, these were unwanted and had a tendency to settle back on the mosaic, producing uneven shading in the video signal. Also, the resolution of the iconoscope was poorer that that of the image dissector. The photo-emissive "globules" were not infinitely small and also the electrical charge produced on them tended to leak to adjacent cells, thus slightly smearing the captured image.

A FATAL PATENT FLAW

By the mid 1930s the development of the iconoscope could go no further without changing several aspects of the tube. While it could be developed into a television camera, it was just not sensitive enough to become the workhorse that the nascent television industry needed. RCA would have to move in another direction to produce a really practical camera pickup tube. However, this was precluded, as that the original patent application filed by Zworykin in 1923 for television system contained a fatal flaw.

(To keep the record straight, Farnsworth filed a patent application for his television system in 1927; a patent was granted in 1934. Zworykin's patent was not granted until 1938.)

One of the Farnsworth's patent claims—the 15th—was the production of an "electric" or electronic image within the pickup tube. Zworykin made no such claim. This was indeed a costly oversight and ultimately led to a major reversal of policy at the Radio Corporation of America, which had become the assignee of Zworykin's patents.

For RCA to develop a camera tube beyond Zworykin's initial iconoscope, having an "electric" image to move around was a necessity. The concept was Farnsworth's and he could do this. Legally, Zworykin could not. This resulted in a challenge to the Farnsworth patent and a patent "interference" that made its way through the legal system.

Ultimately, it was ruled that Farnsworth had priority to the claim of an "electronic image" and that anyone wishing to employ this concept in their camera tubes would be required to license such technology from Farnsworth. Quite reluctantly, RCA did so.

NEW TUBES FROM OLD

With a redesign to produce a true "electron image," Zworykin's iconoscope morphed into a much more sensitive "image iconoscope," allowing it to make a greater contribution in creating a practical television system.

Pickup tube development did not stop at this point, as the high velocity scanning problems were still present.

Others at RCA eventually developed a tube with low velocity scanning that overcame such difficulties. This was the orthicon. It underwent wartime improvement and eventually had an electron multiplier stage added, becoming the "image orthicon" or simply the "IO." This tube became the industry standard for live television until it was displaced by photoconductive tubes beginning in the late 1960s.

THE ORIGINAL TUBES LIVE ON

The original iconoscope was not immediately relegated to the scrap heap, however.

As long as there was a bountiful supply of light, the tube worked fairly well (shading issues notwithstanding). As it is possible to push a very large amount of light through motion picture film, the iconoscope was the tube of choice for televising movies and slides. As it was considerably cheaper and had a longer useful life than the image orthicon (whose enhanced light sensitivity wasn't really needed), the

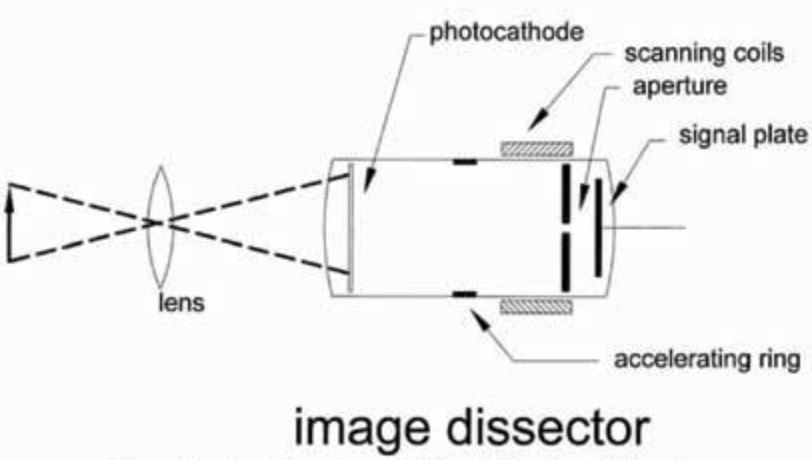


Figure 5: schematic representation of the image dissector

Figure 6: Vladimir Zworykin

iconoscope served in film-to-television applications well into the 1960s.

Farnsworth's image dissector, even with the enhancement of an electron multiplier stage, still required more light than was practical for most television studio or field applications. However, it did possess one element that kept it viable for specialized applications.

All of the RCA tubes—iconoscope, orthicon, image orthicon—depended upon an electron gun for operation. As with any thermoionic device, the gun structure wore out with time.

The image dissector, on the other hand, did not have an electron gun. It was based entirely on light-induced emission of electrons from a photochemically reactive compound—a cold cathode emitter. In essence, the tube had a nearly unlimited useful life. This made it an ideal pickup device for imaging very bright scenes in conditions that precluded regular maintenance, i.e. industrial applications such as looking into a blast furnace. The image dissector continued to be used for such purposes until it was eclipsed by more modern imaging technologies.

Today the iconoscope and image dissector would be considered large, clumsy and totally impractical beasts. However, 75 years ago they were quite revolutionary electron devices and paved the way for television's future.

References:

[1] U.S. Patent no. 1,773,980 (Television System, P.T. Farnsworth)

[2] U.S. Patent no. 2,141,059 (Television System, V.K. Zworykin)

[3] Anner, George E., "Elements of Television Systems," New York; Prentice-Hall, Inc., 1951.

[4] Everson, George, "The Story of Television," New York; W.W. Norton & Co., 1949.

[5] Farnsworth, Elma G., "Distant Vision," Salt Lake City, Utah; PemberlyKent Publishers, Inc., 1990.

[6] Helt, Scott, "Practical Television Engineering," New York; Rinehart Books, Inc., 1953.

[7] Morton, G.A. and Zworykin, V.K., "Television," second edition – New York; John Wiley & Sons, Inc., 1954

[8] Showalter, Leonard C., "Closed-Circuit Television for Engineers & Technicians," Indianapolis, Ind.; Howard W. Sams & Co., 1969.

About the Author

James O'Neal graduated from the University of Arkansas. He retired from the Voice of America in 2005 and has more than 36 years of experience in broadcast engineering. He is now technology editor for the TV Technology Magazine.