

# Solid-State Video Camera for the Accelerator Environment

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**Abstract.** Solid-State video cameras employing CMOS technology have been developed and tested for several years in the SLAC accelerator; notably the PEP-II (BaBar) injection lines. They have proven much more robust than their CCD counterparts in radiation areas. Repair is simple, inexpensive, and generates very little radioactive waste.

## INTRODUCTION

Ever since SLAC was built, vacuum tube video cameras have been used to aid the machine physicists and machine operators in their endeavors. When CCD cameras were introduced, tube cameras quickly faded from the marketplace and SLAC was left with a problem.

## SOLID-STATE CAMERAS

CCD's are notoriously susceptible to accelerator radiation. They soon develop "ON" pixels (either steady or blinking) which, as far as we can tell, remain forever. Blinking pixels are especially difficult to mask using background subtraction.

CMOS cameras made a brief appearance in the early 90's but, like tube cameras, they couldn't compete with the sensitivity, resolution and compactness of CCD's.

Judging whether a video camera is good or bad is somewhat more subtle and subjective than judging, say, a fuse. In reality, a camera in the housing rarely "dies" but instead the picture degrades as the sensor is irradiated. Eventually the image becomes too useless or too annoying to watch. This pivotal point (when a good camera goes bad) is dependent upon too many factors to be truly objective. Thus the evidence presented is more anecdotal than quantitative.

Cameras degrade in different ways: Ultricons (the vacuum tubes in most cameras at SLAC) develop "streaks" which eventually wash out the desired image. CCD's may be the most annoying as they develop damaged pixels (either saturated "on" or blinking). CMOS cameras tend to fade uniformly until there is insufficient contrast to be useful. All damage described is permanent.

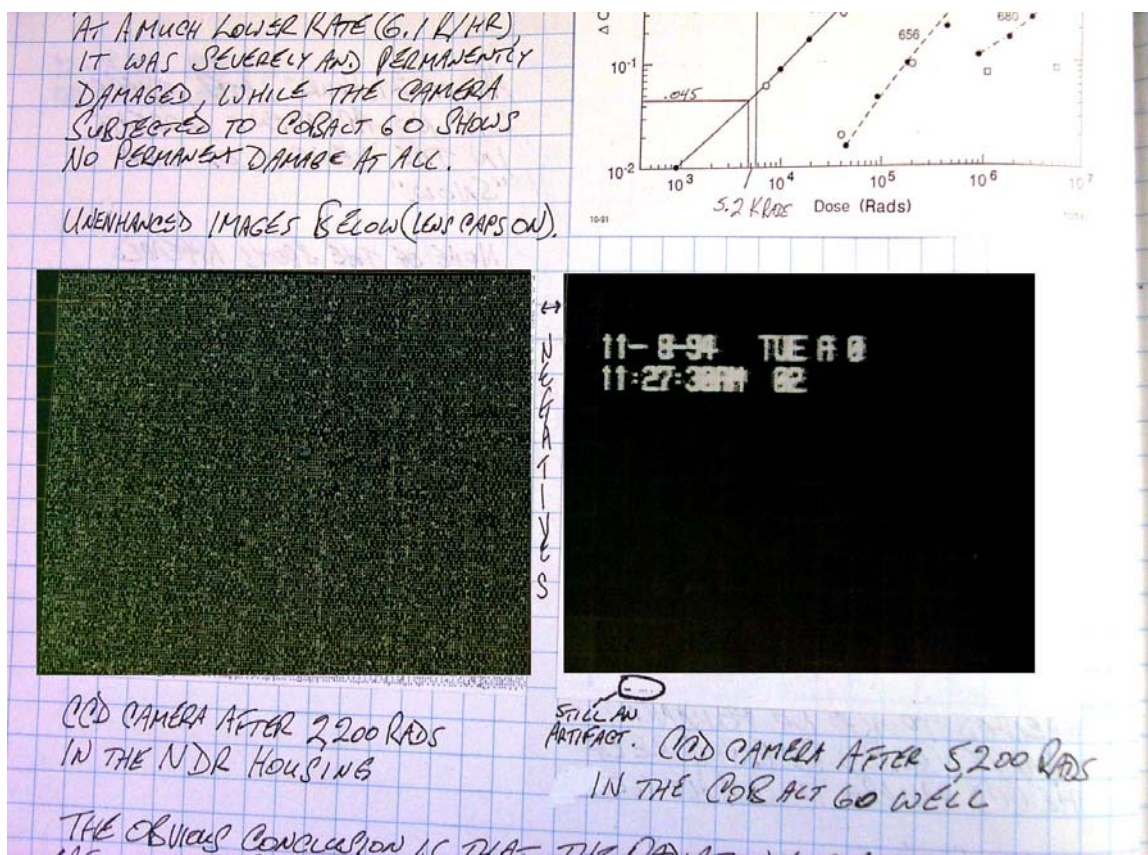
One point which is important to note is that suppliers, with the best of intentions and in the interest of abiding by some standard, sometimes rate their cameras in terms of MTBF/RAD. The important thing to remember when reviewing these numbers is

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that they are usually based upon exposure to Cobalt 60, which of course is a very different type of radiation than a particle accelerator has to offer.

We measure radiation dosage using liquid-filled gamma dosimeters, in pairs, with overlapping ranges. We found that exposure to 5200 Rads in the Cobalt 60 well had no lasting effects upon a CCD camera. In fact, not one “ON” pixel was created. When an identical camera with identical dosimeters was placed near a 1.2GeV electron storage ring for a short time, we measured only 2200 Rads when it was removed. This camera was severely damaged, with a large number of pixels on or blinking. We then tried a third camera in the Plutonium-Beryllium source well for twenty-four hours and observed three or four “ON” pixels when it was removed.



The above experiments do not prove that neutrons are responsible for damage to cameras in the accelerator. However it is interesting to note that, in a 1990 lecture, Sherra E. Kerns commented that “MOS devices are ‘immune’ to neutron damage.”<sup>1</sup>

The CMOS camera we developed was designed to live a relatively moderate but useful lifetime in low to medium radiation areas. In high radiation areas we actually pipe the photon image to the surface and watch from there.<sup>2</sup> This is an expensive and complex solution.

SLAC is approximately synced to the power grid. Strange things happen when observing a 1 Hz beam with a crystal-controlled camera running at 59.9 Hz. The beam seems to fade in and out, sometimes prompting the operator to search for problems in the accelerator. It is only an electro-optical illusion, however, and one solution is to line-lock the camera to prevent the beat-frequency effect. We chose to pick off the ripple voltage from the AC adapter, amplify it with a 120 Hz active filter, apply it to a comparator against its own average, divide the 120 Hz by 4, trigger a variable time delay (controllable either locally or remotely by DAC), and then create a 30 Hz TTL pulse which line-locks the camera. This is all done in the interface box.

The cameras we built have a Delrin™ housing, a CS mounting (C mounting with a 5mm spacer), and a single S-Video cord for power and signals. Oversized walls of Delrin permit replacing existing cameras. They are tripod mountable and can support relatively heavy lenses. The chips are wholesaled by Omnivision (OVT.COM) and products using these chips are retailed by (SMARTVISIONPRODUCTS.COM).

We repair our cameras in-house, since they may have been activated in the accelerator and cannot be sent off-site. With Ultricon cameras the cost of repair was nearly \$1000. The last Ultricon tube sold by SLAC Stores cost over \$650. In addition the sync and video chips were always replaced at every opportunity. Add in labor for a moderately difficult repair job, then labor for calibration and alignment, and it might seem more sensible to buy a new camera. However, a new camera meant about a Kilogram of mixed waste added to our collection. (970 gms). We chose to repair them ourselves, generating about 50 gms of waste.

Repairing the CMOS cameras generates about 7 gms of waste, and the entire camera weighs about 150 gms. This allows us to mount the camera on a mechanically anchored lens rather than the other way around. Repair is well under \$100 per B&W.

The NTSC chips we use are true-interlaced and are also available in Color, PAL, VGA, Scientific Square Pixel, etc with a wide variety of packaging choices. There are other vendors available; a search engine will be useful to help locate a CMOS device which meets your specific needs.

## **SUMMARY**

CMOS Cameras outlast CCD Cameras when installed near the SLAC beam lines.

## **ACKNOWLEDGMENTS**

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1. Kerns, Sherra E., "Radiation Effects on Electronics," Vanderbilt University and University Consortium for Research on Electronics in Space, 1990.
  2. Decker, Franz-Josef, "Improved Controls and Optics for the Linac Off-Axis Profile Monitors," SLAC Internal Memo, 9 July, 1990.
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