Television Detector System Development at ESO

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The traditional picture of an astronomer with a long beard, gazing through his telescope and solving the riddles of the Universe, is no longer true. First of all, the beard would all too easily get mixed up with the computer terminal keys and be a definite danger near rapidly spinning magnetic tapes. And nowadays few astronomers really look *through the telescopes; the important task of detecting light from (faint) objects is more accurately and efficiently done by electronic detectors. Dr. Phillip Crane and electronics engineer Walter Nees at ESO in Geneva are developing such a detector and explain how it works and what it can do.*

We describe below the programme of developing a television-type detector system that has been going on at ESO/Geneva for about 2 years. The major emphasis of this programme has been to provide a modern detector system for the Cassegrain Echelle Spectrograph (CASPEC), so much of the following discussion relates specifically to this particular application.

Television systems have many attractive features for optical observations. They allow efficient detection of photons. In fact, many television detectors permit the detection of photons to be recorded with signal levels which are high enough that the resulting data are photon-noise limited. Another advantage of television detector systems is that they allow the observer to review his data very soon after they have been obtained. Since the data are usually recorded in digital format, the reduction by computer techniques is facilitated.

A SEC for the CASPEC

For the above and other reasons, it was decided to build a television detector system. At about the same time, the need arose for a detector to be used in conjunction with the CASPEC, cf. page 27. Apart from photographic plates and conventional image tubes, one television-type detector would fill the requirements of the CASPEC, a 25 mm magnetically focused "SEC"-Vidicon tube manufactured by the Westinghouse corporation. The term "SEC" stands for *S*econdary *E*lectron *C*onductivity and refers to the technique for storing the photon signal internally in the tube (see below for more details). For the CASPEC application, the major advantages of the SEC tube are the flat image plane, the high resolution and low distortion, and the capability of operating without significant cooling. Some technical details of the SEC tube are given in table 1. A picture of one of these tubes is shown in figure 1.

The particular tube which has been chosen was originally developed at the Princeton University Observatory through contracts with NASA for space-borne applications such as the Space Telescope (ST). The same tube with a different front window and photocathode is being flown in a balloon UV-echelle spectrograph by the Space Science Laboratory at the University of Utrecht in Holland. A very similar tube will be flown by NASA in conjunction with the Solar Maximum Mission. Although this tube will not be flown on the Space Telescope, a similar larger version was a very strong competitor for the Wide Field Camera Instrument on the Space Telescope. The basic detector on the IUE (International Ultraviolet Explorer Satellite) is also a SEC-type tube but of considerably different design.

Although the system which is being built at ESO is primarily aimed at developing the SEC-tube for the CASPEC application, the electronics have been designed in a very general way so that a wide variety of TV-type detectors could be used with the same basic electronics. For example, silicon vidicons, silicon intensified tubes (SIT) and many other tubes could be used in a wide variety of operating modes. The electronics are designed to interface through standard CAMAC bins and several special-purpose CAMAC modules have been constructed. The entire detector system is designed for completely remote control and operation.

How the SEC Works

We describe below some of the details of television tubes and some of the applications which the ESO device will

Table 1: Characteristics of SEC-Vidicon Tube

Tube type:	Westinghouse SEC-tube WX-31958
Photocathode:	Tri-alkali with S-20 spectral response. Quantum efficiency ~ 18 % at 4400 Å falling to ~ 1 % at 7500 Å.
Focus:	Image and beam section magnetically
Deflection:	Magnetically
Target storage area:	25 × 25 mm square
Resolution:	At MTF 30 % 1,000 TV-lines/picture height or 20 LP/mm equivalent
Target gain:	~ 60
Dark current integration:	~ 2 pA/min

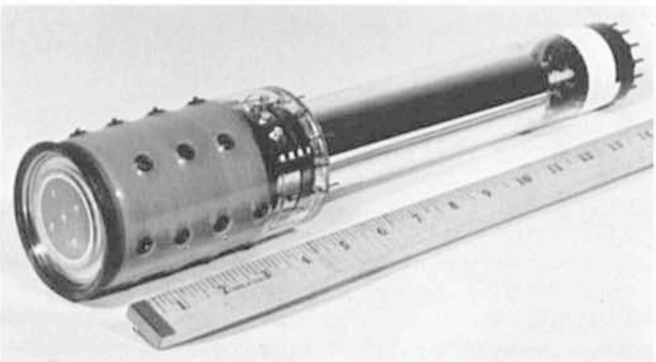

Fig. 1: *A SEC tube.*

find in the Cassegrain Echelle Spectrograph. There are, in general, two classes of television camera tubes: The vidicon plumbicons which store one electric charge per detected photon, and the SEC- and SIT-vidicon tubes which provide a prestorage gain mechanism whereby many (10–500) electric charges are stored per detected photon.

The basic parts of a SEC-type tube are: the image section, the target area, and the electron gun readbeam section (see fig. 2). Incident photons release photoelectrons at the photocathode. These photoelectrons are accelerated towards the target in an electric field and focused in a magnetic field. They strike the target with about 7,5 Kev of energy and release between 50 and 100 secondary electrons. The target consists mainly of a fluffy layer of potassium chloride (KCl) supported on an aluminium oxide (Al_2O_3) substrate, but separated from it by an aluminium signal plate. The secondary electrons are collected on this signal plate leaving behind in the KCl an electrical image of the distribution of incident photons. By scanning a finely focused electron beam across the target, it can be recharged and by detecting the recharging current, it is possible to derive a signal which is proportional to the total number of photons incident at the corresponding point on the photocathode.

Since the recharging currents are often extremely small, it is of utmost importance that the first stage of the video amplification chain have an extremely low noise. The system being built at ESO will have an equivalent noise level of less than about 5 photoelectrons per resolution element referred to the photocathode.

The television tube will be used in the integrating mode where the read beam is turned off during the time an exposure is being made and the image section is turned off during the time the tube is being read out. The tube will also be run in the "slow-scan" mode in which it takes roughly 20 seconds to scan and read out a complete 1,000 element by 1,000 line frame. This operating mode can be compared to the continuous scan 25 frames per second operation of a commercial-type television camera. Clearly the electronics to control an integrating slow scan system will not be very similar to a commercial television camera. A typical operating sequence would be:

1. PREPARE, the target is erased of any previous residual exposure and prepared to a fixed charge state;
2. EXPOSE, the read beam is off, and the photocathode high voltage (~ 7,5 KV) is on. Photoelectrons are storing up a charge image on the target;
3. READOUT, the electron beam scans the target. The measured target recharge signal is, after amplification, sampled and converted into 12 bit binary words at intervals of about 15 microseconds each. (1,000 words per scan line and 1,000 scan lines per complete frame). For further processing the digital image data 1,000 × 1,000 or 10^6 words are stored on computer disc, or magnetic tape.

The Cassegrain Echelle Spectrograph will make full use of the 25 mm square active area of the SEC tube. The optical system of the CASPEC has been designed to take advantage of the resolution of the SEC, so that a 1.3 arc second slit will project into 30 microns on the SEC photocathode, when the R = 17,000 grating is used. Figure 3 shows a typical vidicon frame (simplified) as it would appear to the CASPEC user.

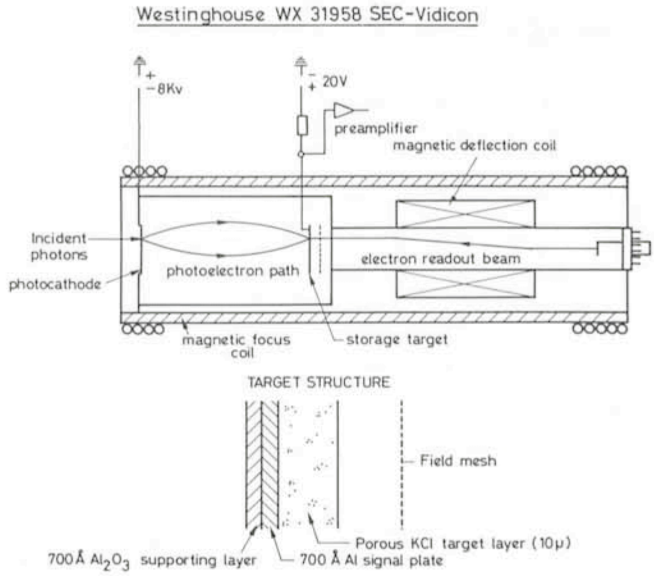

Fig. 2: *Schematic drawing of the main parts of a SEC tube.*

What the SEC May Do

The data coming from this detector-spectrograph combination will provide new information at high resolution on faint objects. Thus, for example, the chemical composition of galaxies and the stars and nebulae which make up these galaxies can be studied to even greater distances. Maybe these data will provide clues to evolutionary processes in galaxies? Other observations might include the study of absorption-line systems in quasars with higher spectral resolution than previously possible.

These applications require extremely sensitive and efficient instruments such as the one described here. Of course it is too soon to be sure, but we hope that the combination of a modern detector, an efficient telescope and spectrograph and fast efficient data-reduction techniques will make this into one of the most productive astronomical instruments on La Silla or elsewhere.

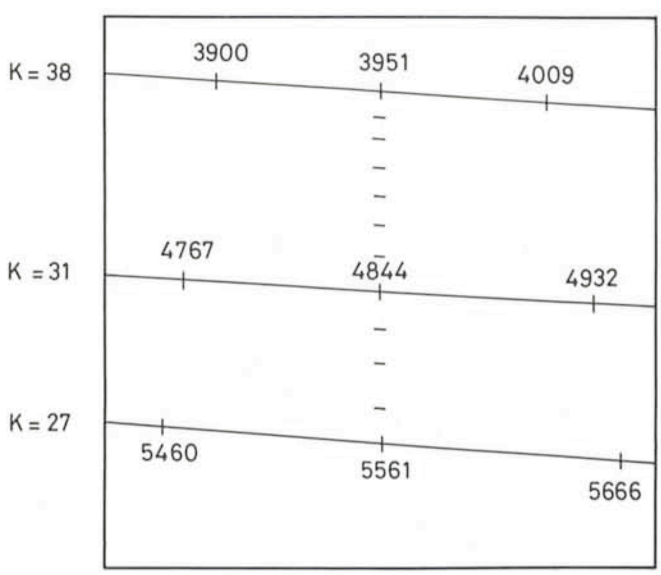

Fig. 3: *Schematic of an echelle spectrum. K is the echelle grating order. Wavelengths are shown in Ångströms. Intermediate orders are shown by tick marks. The circumscribed square is the 25 mm × 25 mm target area of the SEC Vidicon.*