# A Television System for Auroral Cinematography at Sanae, Antarctica

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A television system has been developed which incorporates a silicon-intensifier target camera tube for cinematography at very low light levels. Operated at exposures of 0,02 second this system has the necessary sensitivity, angular resolution and dynamic range to record fine temporal, spatial, and subvisual features of auroral displays.

*'n Televisiestelsel wat van 'n beeldversterker met 'n silikonskyf en kamerabuis vir kinematografie by baie swak lig gebruik maak, is ontwikkel. Hierdie stelsel beskik vir opnames van auroras by blootstellingstye van 0,02 sekonde oor die nodige sensitiwiteit, hoekoplossing en dinamiese bereik om geringe subvisuele veranderinge in fyn ruimtelike en tydafhanklike detail te registreer.*

## Introduction

Different techniques used to study precipitating electrons of various energies have different degrees of ability to distinguish between temporal and spatial fluctuations. For example with balloon-borne detectors one can study purely temporal variations of higher energy electrons by detection of the bremsstrahlung X-rays which they produce during their deceleration in the atmosphere, but since the effective target area is ~ 100 km diameter, smaller spatial changes cannot be examined. With satellite-borne detectors that move at some 8 km $s^{-1}$ it is extremely difficult even to distinguish between temporal and spatial changes. A similar problem is generally encountered in rocket-borne measurements.

The morphology of low-energy electron precipitation patterns can be studied from ground-based recordings of the auroral optical emissions which they produce. Although photometers have been used successfully, any data obtained must be interpreted in terms of the field of view employed, since photometers can measure only the average luminosity within this field. For example if the photometer sees several pulsating surfaces within its field of view and if the pulsations from adjacent patches vary in phase or frequency then the record would become confused and short-period fluctuations of the weak features would be lost. Again if a sub-visual patch, which is not pulsating, drifts through the field of view of the photometer this could be interpreted from the output of the photometer as being a pulsation of an auroral form.

The spatial and temporal ambiguities discussed above do not arise in systems employing very sensitive photoelectric devices for high-speed imaging of auroral emissions with exposures of a fraction of a second *(Davis*, 1966; *Scourfield & Parsons*, 1969). The system described in this paper is based on such a device, namely a silicon-intensifier target tube.

## Photoelectric and Photographic Image Detection

Failure to reach ideal picture quality is partly due to sources of noise, e.g. statistical fluctuations resulting from the quantum nature of light, detector dark current and emulsion fog in the case of photography. However, a large contribution to this failure is the fact that not all of the incident photons produce a recorded event, i.e. the quantum efficiency of the detection process is considerably less than unity. A typical photographic emulsion efficiency is 0,16% *(Webb*, 1948) whilst good photocathodes give efficiencies of from 10% to 20%. Therefore, for the same optical image falling upon an emulsion and a photocathode the latter should retain approximately 100 times the information retained by the emulsion.

Furthermore, the only energy available for emulsion exposure is that of the incident photon. A photon incident on a photocathode however, liberates a photoelectron which can, by acceleration, be given an energy much greater than that of the incident photon. This amplification of the incident energy allows a corresponding reduction in the integration time required to produce a usable image, and is in fact the basis on which the tube, described below, operates.

## Silicon-Intensifier (SIT) Camera Tube

The SIT tube, which is responsible for the high light gain in the TV system under consideration, is an Amperex S5OXQ. A cross-sectional view of this tube is shown in Fig. 1.

An optical image is brought to a focus upon a flat image plane (useful diameter 25 mm) which is optically coupled to an S-20 photocathode by high quality fibre-optics. The flux of photoelectrons from the photocathode is energized

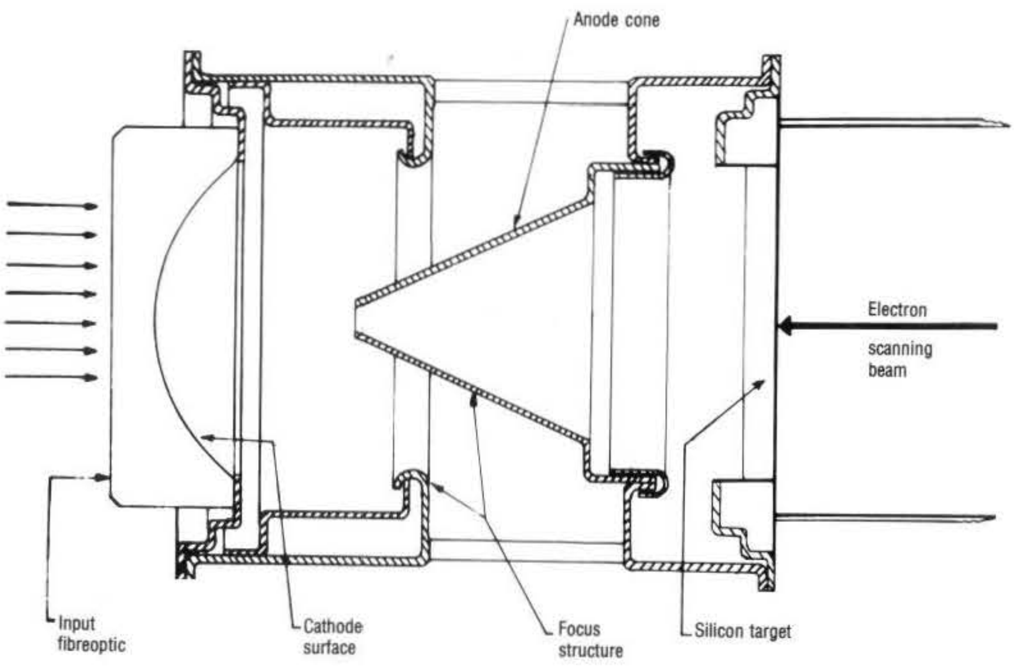


Fig. 1. Schematic diagram of the SIT tube.

by an applied voltage (variable from 3 to 9 kV) and electron-optically imaged onto the silicon target.

The target consists of a two-dimensional array of diodes formed in an n-type silicon wafer which is made thin in the active region. Diodes are positioned with the p-region of each diode facing the electron scanning beam. An insulator covers the exposed n-region appearing between the p-regions to prevent the scanning beam from reaching the substrate. In operation, the diodes are reverse-biased when the n-type substrate is held at a positive potential and the scanned side is maintained near cathode (earth) potential. Each diode constitutes an elemental storage capacitor on account of the insulating properties of the depletion layer. The n-region serves as a signal plate and the individual depletion regions form the dielectrics of the elemental storage capacitors. Energetic electrons, focused on the n-type substrate, produce a multiplicity of hole-electron pairs for each primary electron. Holes, generated in the valence band, diffuse to the depletion layer and, by traversing this region, discharge the storage capacitors. An amplified charge pattern, being a replica of the original optical image, is stored in this fashion and the output signal is generated by the capacitive displacement current during the recharging of each elemental capacitor by the scanning beam. The recharging in one scanning period is sufficient to maintain the reverse-bias for a period of time greater than one frame period with normal levels of light illumination.

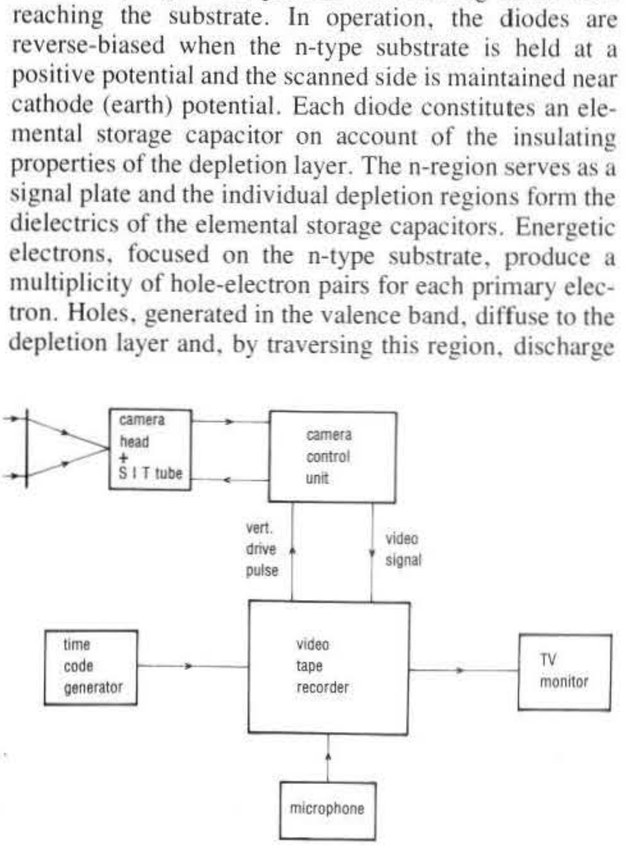


Fig. 2. Block diagram of the TV system.

By varying the applied voltage to the image section of the tube the impact ionization-gain in the target can be increased from ~ 100 to a maximum value of several thousand.

## The TV System

### General Description

The SIT tube is installed in a closed-circuit TV chain (Philips LDH-150) with the camera head and control unit modified to accept the tube and its associated high-voltage circuitry. A block diagram of the complete system is shown in Fig. 2.

The scanned area of the silicon target is arranged to fit just within the circular field of view provided by the front optics. With the TV chain operated in the 50 Hz, 625-line scan mode, video information is finally stored on half-inch tape with a video tape recorder (SONY AV342OCE). This recorder is driven by 12 v d.c. and is thus not subject to mains frequency fluctuations at Sanae base. Furthermore, the vertical drive signal from the recorder is used to trigger the vertical and horizontal drives in the camera control unit making the latter also independent of the mains frequency. A time code, together with read-outs of elevation and azimuth bearings of the camera head mount, are recorded on the audio channel of the video tape recorder.

In field operation the camera is mounted beneath a dome in a light-tight enclosure and the operator views the video data on a TV monitor. Experience with the system

**Table 1**

Variation of resolution with light intensity

| Light intensity at 4200 Å | | SIT high voltage setting (0-8) | Resolution (TV lines) | | Dynamic range |
|---|---|---|---|---|---|
| kR | lux | | horizontal | vertical | |
| 135,0 | $1,8 \times 10^{-2}$ | 2,0 | 450 | 350 | |
| 68,0 | $8,8 \times 10^{-3}$ | 2,1 | 400 | 320 | 150 |
| 33,5 | $4,4 \times 10^{-3}$ | 2,2 | 380 | 300 | |
| 17,0 | $2,2 \times 10^{-3}$ | 2,5 | 340 | 280 | 150 |
| 8,5 | $1,1 \times 10^{-3}$ | 3,0 | 320 | 260 | |
| 5,5 | $7,1 \times 10^{-4}$ | 3,5 | 280 | 240 | 100 |
| 3,0 | $3,9 \times 10^{-4}$ | 3,8 | 260 | 220 | |
| 1,0 | $1,3 \times 10^{-4}$ | 4,0 | 220 | 200 | 100 |
| 0,5 | $6,5 \times 10^{-5}$ | 5,0 | 200 | 170 | |
| 0,2 | $2,6 \times 10^{-5}$ | 6,0 | 180 | 160 | |

has shown that the dynamic range allows it to be operated for the major portion of time with fixed settings of the controls of the SIT tube and TV chain. When the dynamic range is exceeded this is taken care of by a suitable change in the high voltage applied to the SIT tube. A photograph of the mounted camera head appears in Fig. 3.

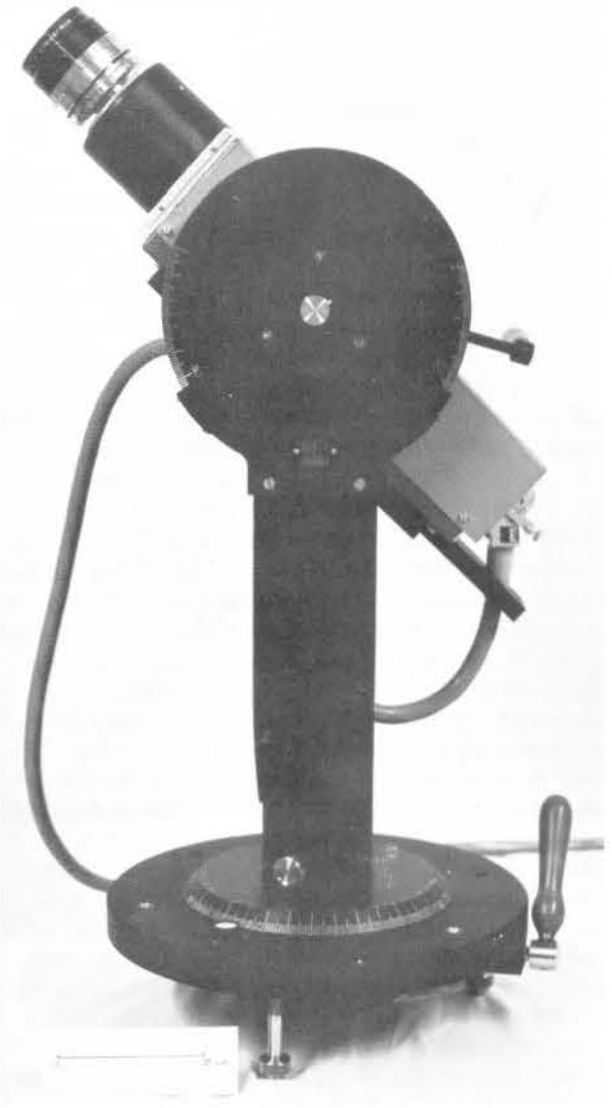

Fig. 3. The mounted TV camera head.

**System Evaluation**

Variation of resolution with incident light intensity is investigated by viewing with the system a transparent TV chart placed in front of a calibrated low brightness source, the brightness of which can be varied in steps. Since this source is calibrated in kilorayleighs (kR) per angstrom, a filter (the same one that is used with the system during field operation) is placed over the front-end optics. The TV test chart consists of resolution wedges, the greatest resolution being 600 TV lines per picture height.

Table 1 shows the results of these observations for light intensities (at 4200 Å which is the peak wavelength response of the filter) decreasing from 135 kR. In column 2 is given the equivalent photocathode illumination in lux, a more commonly used unit. For each intensity step the high voltage applied to the SIT tube (in column 3, setting 8 represents the maximum permissible voltage) is adjusted to give the best resolved picture on the TV monitor.

Below 0,2 kR picture degradation becomes most pronounced but it is still possible to make out the general shape of the test pattern. It should be noted that when the system is viewing a source intensity of 0,5 kR the TV test pattern cannot be seen directly with the unaided, dark-adapted eye. Resolution falls off with decreasing intensity but for auroral work it is still quite acceptable below 1 kR. If the system field of view is 20°, say, then a resolution of 200 TV lines is equivalent to an angular resolution of 0,1°.

At a given applied voltage to the SIT tube and fixed settings of the TV chain, the dynamic range varies between 100 and 150. This range is sufficient to ensure infrequent adjustment of system controls by the operator.

The exposure time involved with this system is 0,02 s which is the time taken for one complete TV field. During analysis the playback of the video tape may be slowed down until it is possible to view individual TV fields and thereby to obtain time changes to an accuracy of 0,02 s.

**Field Operation**

The TV system will be operated with selected fields of view between 25° and 60° using the filter centred on 4200 Å chosen to include the $N_2^+$ ING emission and to exclude the 5577 Å line emission. The latter originates from a forbidden oxygen transition with upperstate lifetime of ~ 0,7 s, and its inclusion would introduce undesirable time lag effects.

## Acknowledgments

It is a pleasure to acknowledge the financial and logistic support of the South African Department of Transport.

*The Editor acknowledges the assistance of Dr I.W.H. Robertson of the Department of Physics, University of Calgary, in evaluating this paper.*

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(Received 15 August 1974)