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Sec7.4-End of Sec7

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Contents

7.4.1 Slow-scanning, cooling, and optimization

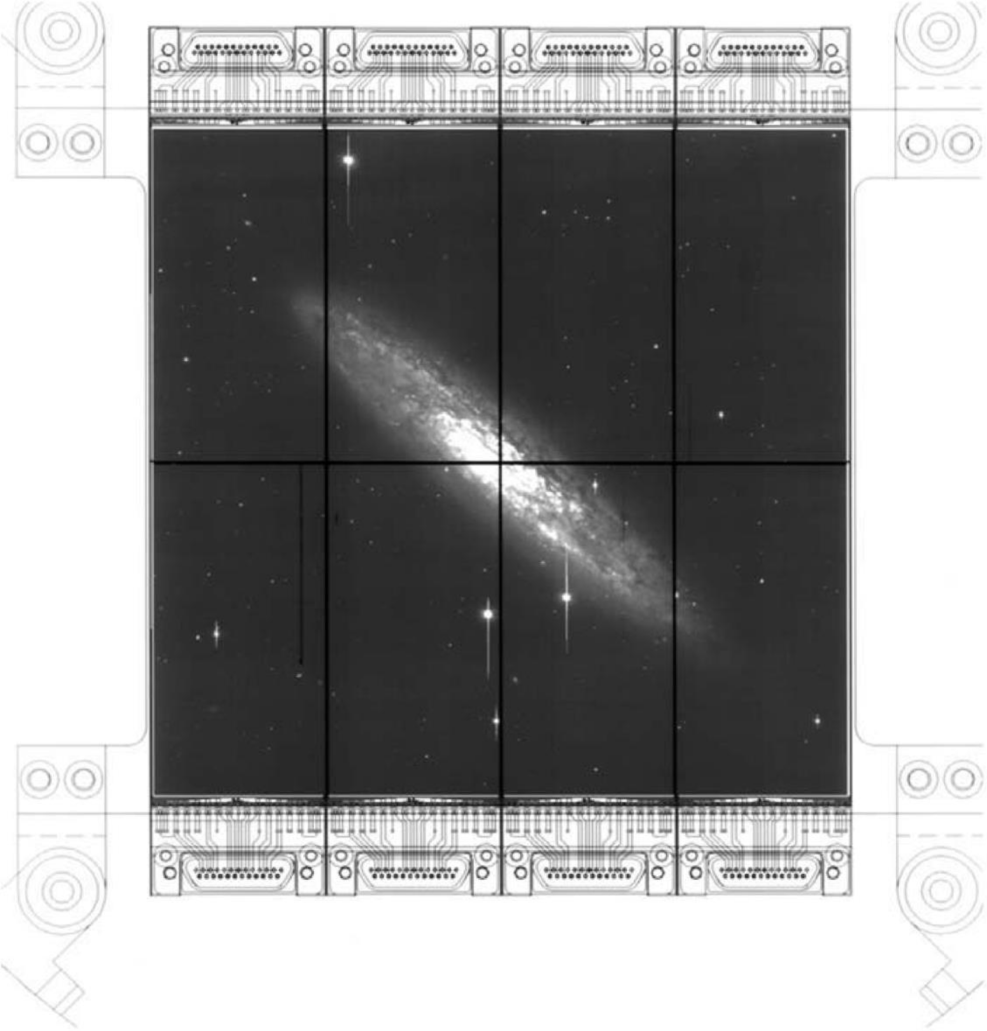
- For astronomy applications, long exposure time is needed to build up a faint source image.
- Also, astronomical CCDs must be read out very slowly because the electronic noise is greater at higher read-out rates.

→This mode is called “slow scan”.

- When long exposures are taken, dark current matters.
- To permit long exposures, astronomical CCDs must be cooled enough.
- most CCD cameras at professional observatories use modified liquid-nitrogen cooling systems.

7.4.2 CCD mosaics

- To obtain cameras with much larger numbers of pixels the general approach has been to construct “mosaics” of CCDs.
- CCD mosaics provide a larger field of view, which leads to shorter time required to complete a survey.
- To construct multi-CCD mosaics, considerable effort has gone into both the packaging of the CCD itself and the design of the camera head to make these systems practical.



7.4.3 Drift scanning

- Drift scanning is one alternative to a large mosaic of detectors to obtain large swaths of sky, especially suitable for non-tracking telescopes designed to point at one location in the sky.
- Instead of trailing stars, the charge image from previous pixels is added to the next one and the current position of the charge pattern will move along the column to keep up with the current optical image position.

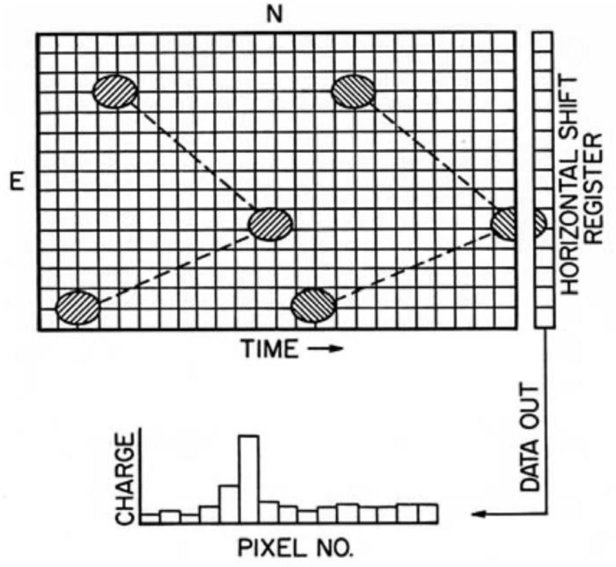


Figure 4.7. The principle of "drift-scanning" in which the unique charge-coupling property of a CCD allows the image charge to be moved along columns from pixel to pixel at any rate. This technique is used to produce the Sloan Digital Sky Survey.

7.5.1 High-speed CCDs with on-chip gain

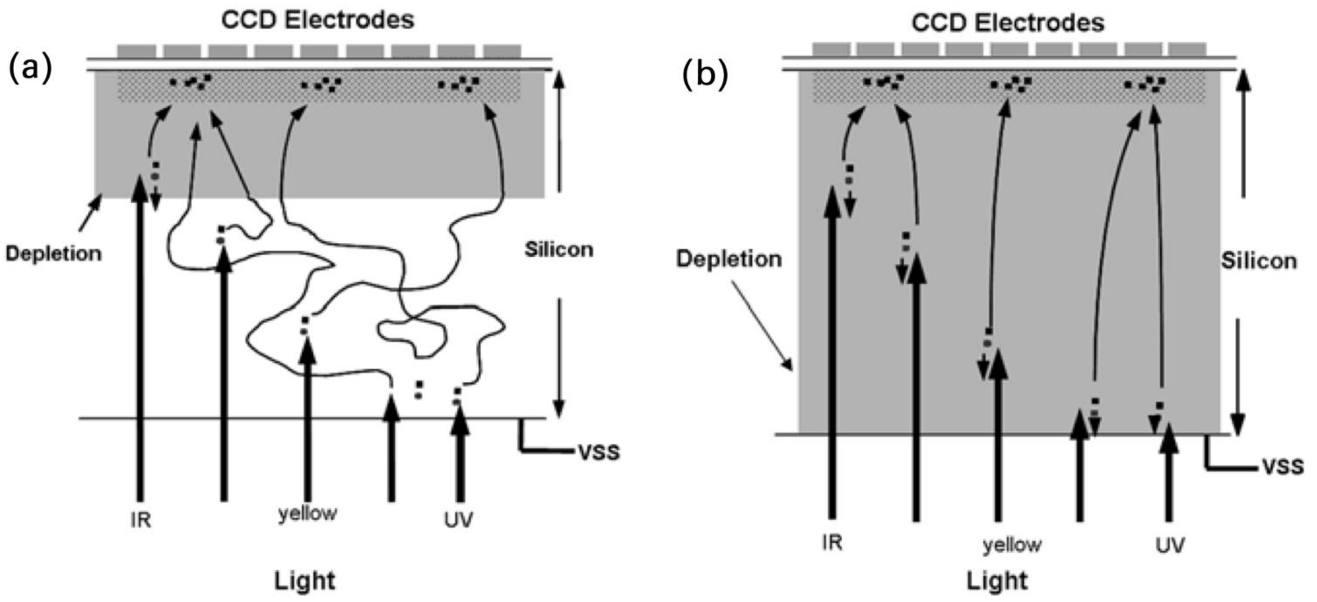
- A new technology developed by *e2v technologies* provides a way to reduce the readout significantly and increase the readout rate.
- This normally causes the readout noise (R) to rise, but a large gain factor (G) makes a small equivalent readout noise (R/G) .
- A large gain is possible by the repetition of avalanche multiplication, a phenomenon in which an electron transferred into an electrode will create a second electron with a few percent probability.
- For example, for a 1% probability of an extra electron released and 600 elements the gain is $1.01^{600} = 392$.
- Because of the reduction of the readout noise these CCDs can be used in photon-counting mode in which usual CCDs can’t be used.

7.5.2 Deep-depletion CCDs for no fringing

- The depth at which an incident photon generates an electron-hole pair in a silicon CCD depends on wavelength. Longer wavelength photons penetrate deeper into the silicon before charge generation occurs.
- For backside-illuminated devices the total thickness of silicon is usually less than 20 microns and the longest wavelengths ($\lambda > 800$ nm) can pass right through without absorption. Some of these photons can reflect back and cause interference fringes.
- To eliminate these problems and get the best far-red performance one can adjust the anti-reflection coatings and increase the active thickness layer of the CCD.

7.5.2 Deep-depletion CCDs for no fringing

- Even if the device is thick enough to absorb photons beyond 800 nm, it will poorly collect photons of shorter wavelengths with normal depletion (left figure) .
- A deep depletion region ensures that photons of all wavelengths are collected correctly (right figure) .

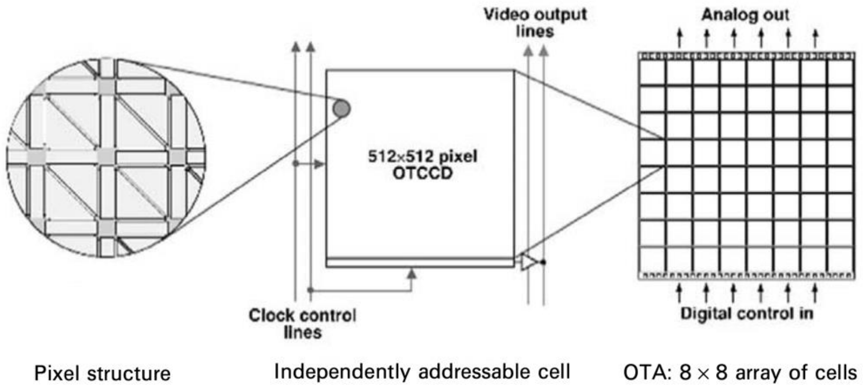


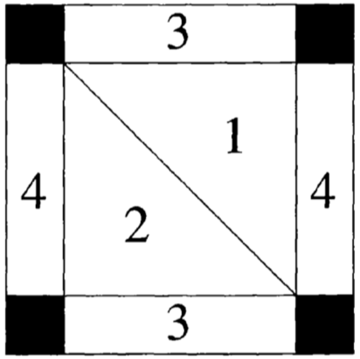
7.5.2 Deep-depletion CCDs for no fringing

- The actual depth of the depletion is proportional to V/N_A , where V is the channel potential, and N_A is the doping concentration of the silicon below the buried channel.
- By optimizing the deposition conditions it is possible to produce a silicon layer with much lower N_A , hence higher resistivity (ρ), which in turn means a deeper depletion region.
- These devices are called “high-rho” or “deep-depletion” CCDs, and have a much improved response which in turn results in much less fringing.

7.5.3 Orthogonal transfer CCDs

- Orthogonal transfer (OT) devices are a unique kind of CCD technology developed at MIT/Lincoln Labs for Pan-STARRS.
- With this architecture, the collected charge can be moved up, down, left, or right.
- A blurred image in a long exposure due to atmospheric turbulence can be compensated by move the charge already stored from the previous moment in the same direction as the image was moving.

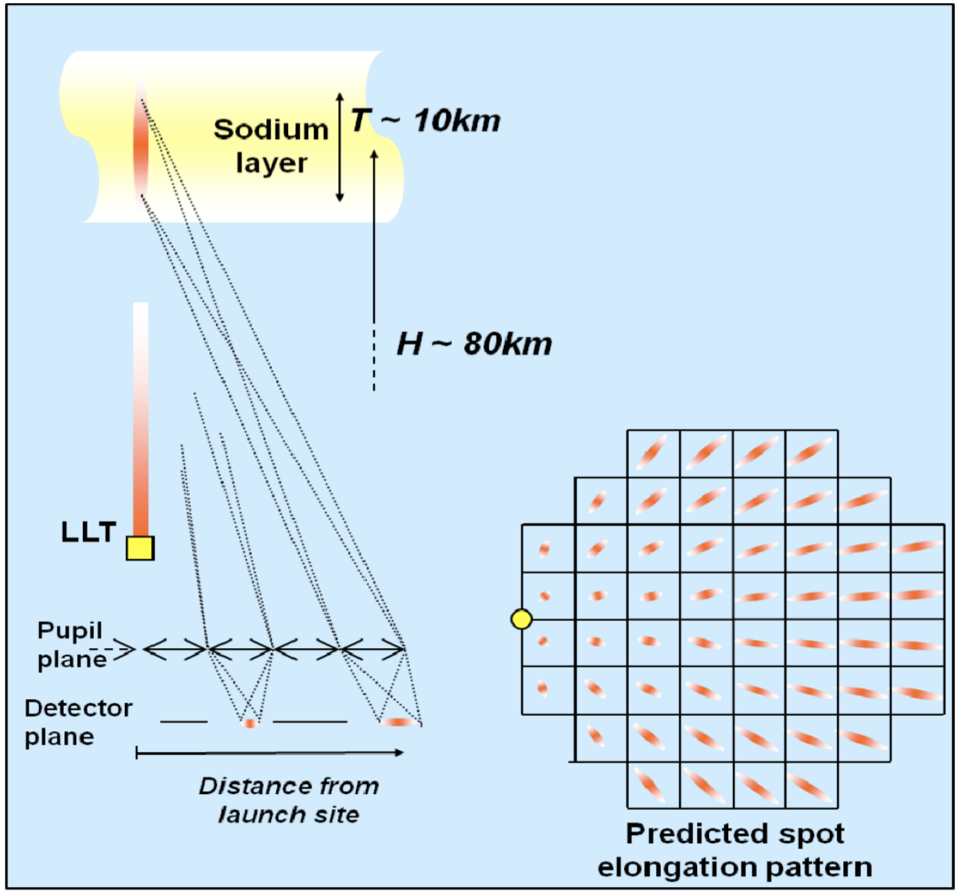




Tonry et al. (1997)

7.5.4 Customized CCDs

- In addition to orthogonal transfer CCDs, there are other customized CCDs for special applications.
- One customized CCD (Beletic et al., 2005) can clock the charge along a radius vector from the center.
- This handles the observed elongation of a laser guide star spot caused by the large separation between the launch axis and the edge of the primary mirror, and the finite thickness of the sodium layer.



https://www.eso.org/sci/meetings/2009/dfa2009/Writeups/WR-Downing_A0WFS_DfA2009.pdf

7.6 Summary

- The basic structure of a CCD is a 2D grid of semiconductor pixels controlled by overlying metallic electrodes arranged in strips. Charges accumulate where the light falls on the CCD and build up an image.
- For astronomy applications, CCDs must be cooled and operated in “slow-scan” readout mode, but with on-chip gain circuits (electron-multiplied) , CCDs can show low-noise performance at very high speeds.
- Different types of CCDs can be designed for special applications such as electronic tip/ tilt control.
- Although individual CCDs with 4Mpxl~16Mpxl are readily available, many observatories combine CCDs to create much larger mosaics.