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Performance of the low light level CCD camera for speckle imaging

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Abstract. A new generation CCD detector called low light level CCD (L3CCD) that performs like an intensified CCD without incorporating a micro channel plate (MCP) for light amplification was procured and tested. A series of short exposure images with millisecond integration time has been obtained. The L3CCD is cooled to about $-80°$ C by Peltier cooling.

Key words: interferometer, speckle imaging, L3CCD camera

1. Introduction

High resolution imagery requires a high quality sensor that helps in obtaining snap shots of very high time resolution, depending on the dwell time of the speckle pattern, of the order of either (i) frame integration of 50 Hz, or (ii) photon recording rates of a few MHz. Recent development of a non-intensified low light level charge coupled device (L3CCD) which effectively reduces the readout noise to less than one electron rms has enabled substantial internal gain within the CCD before the signal reaches the output amplifier (Mackay et al. 2001). Such a detector shows promise for quantitative measurement of diffraction-limited stellar images with suitable instruments, such as a speckle interferometer. We have procured recently, one such system, from Andor technology, U.K., for recording specklegrams of a few interesting objects, viz., close binary stars, active galactic nuclei (AGN) etc., at the 2.34 meter Vainu Bappu Telescope using the speckle interferometer developed by Saha et al. (1999).

2. Salient features of L3CCD

In general, an intensified CCD (ICCD) detector consists of an image intensifier (MCP) coupled to a CCD camera. The major disadvantages of ICCD is the high voltage operation which affects its usages at high humidity and its susceptibility to damage when

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more light is allowed to fall on to the intensifier. Another drawback of such a system is the poor gain statistics results in the introduction of a noise factor between 2 and 3.5.

In the L3CCD camera, no safety measures are required under bright light. The system is provided with Peltier cooling that operates to - 65°C with air-cooling and with further additional water circulation, it reaches -80°C. The performance of this cooling system is comparable with a liquid nitrogen cooled cryostats. The L3CCD is a frame transfer device where the image store and readout register are of conventional design that operates typically at 10 volts. But there is an extended section of gain register between the normal serial register and the final detection node which operates at much higher amplitude (typically at 40-50 volts). This large voltage creates an avalanche multiplication which thereby increases the number of electrons in the charge packets, thus producing a gain. Adjustment of the gain is possible with fine control of the voltage. All the output signals above a threshold may be counted as photon events provided the incoming photon flux is of a sufficiently low intensity that no more than one electron is generated in any pixel during the integration period, and the dark noise is zero, and the gain is set at a suitable level with respect to the amplifier read noise.

The L3CCD camera system that we have procured has 576×288 pixels of size $20\times30\mu m^2$ in the image area. The storage section contains 591 columns and 288 rows. The physical area of the chip is 11.52 × 8.64 mm. It has the provision to change the gain from 1 to 1000 by software. The noise at 1 MHz read rate is 0.1 e. Each pixel data is digitized to 16 bit resolution. The system has full vertical binning mode suitable for spectroscopy, single scan for regular astronomical imaging with long integration time, kinetic series acquisition, and the frame transfer mode with region of interest that can have short integration time in the order of milliseconds. Several hundreds of frames in a series can be recorded in this mode. For speckle observations, the kinetic mode acquisition mode was used.

3. Performance

We have tested this L3CCD both at the laboratory, as well as at the 2.34 m VBT, VBO, Kavalur. The performance was found to be satisfactory. The dark count was found to be 0.001 e/pixel/second at $-80°$ and the saturation signal was about 52,000 counts/pixel. Without external power supply and using the internal PC power, the Peltier cooler reached the set temperature of $-50° C$ from the ambient temperature of $20° C$ within 11 minutes.

On 15th December, 2001, we have recorded an image of the star, HD36151 (m_v 6.5) at the Cassegrain focus of 2.34 m VBT, VBO, Kavalur, with an exposure time of 10 msec, with the software gain set to 150, and a CCD sensitivity of 6.14 e per A/D count. The recorded image shows 50,000 counts. It may be noted here that the software gain can be varied from 1 to 255, which nonlinearly corresponds to an actual gain of 1 to 1000. A 12th magnitude star with an integration time of 10 msec. has been recorded as well. The count was found to be about 2000; software gain was set to 200.

4. Discussion

For experiments like speckle imaging (Labeyrie, 1970) and adaptive optics where the integration time is dictated by the atmospheric coherence time, which is normally of the order of a few milliseconds, this L3CCD may be more suitable than the MCP-based detectors. For the selective image reconstruction technique (Dantowitz et al. 2000), where a few sharpest images are selected from a large dataset of short-exposures images, L3CCD detector will provide important advantages (Baldwin et al. 2001).

References

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