Technical Note 106

New CCD Readout Mode (Low Smear Drift Mode) with Absolute Time Stamping.

Derek Ives (RGO), Tony Bennett (RGO), Frank Gribbin (LPO)

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A new CCD readout mode is available for use on the WHT. It enables a reasonably sized windowed (1124 x 10) frame to be readout continuously at approximately one windowed frame per second or slower. A novel clocking scheme has been implemented, in conjunction with the ISIS dekker mask, to ensure low level smearing of the image data while the image is being clocked with the shutter open, thus the name, LSD Mode or Low Smear Drift Mode. Absolute time stamping of the image has also been implemented although it has still to be decided if this feature will be offered in the future.

Introduction

The LSD Mode is a new CCD readout mode of operation specifically implemented to allow very fast continuous readout of a windowed area of the CCD with minimal dead time. For example, the user may want to observe an object which may be varying in some way over a few seconds time period. The user may thus want to take a snapshot image of the object once per second over a long observing period. The user is now able to perform this type of observation at the WHT using the LSD Mode. In the example given the one second readout sequence would consist of a 700 ms integration period of the object followed by a 300 ms clocking period, then followed again by the next integration period and so on for the required duration. The observing period is limited by the memory in the DMS which is limited by the window size selected and the required number of windows to read out. Since the frame readout bandwidth is much higher than can be achieved by opening and closing the ISIS shutters, it is therefore an essential requirement that the shutter remains open for the whole of the continuous run. The problem with this is that it may cause optical smearing of the image giving the arc lines distinctive tails because light is still collecting on the CCD as it is being clocked out. Therefore a new method of clocking the CCD, which tries to reduce this smearing to a minimum, has been implemented.

LSD Clocking

This new mode to reduce image smearing is called Low Smear Drift Mode. It consists of a novel clocking scheme used in collaboration with a dekker mask to ensure that the smearing is reduced to a very low level, of the order of <1% for a 1s run. The requirements to ensure that this feature work efficiently is that the window width is chosen to be just greater than or equal to the width of the aperture mask. The start position of the window in the y direction (assuming the serial readout register lies in the x direction) is also extremely important as well. This clocking scheme is explained in much more detail with reference to figure 1. shown below. Consider the readout sequence for a window I described as follows:-

1. The user specifies the window size and its X and Y offset from (0,0). In our very simple example the window is 1000 pixels in X and 10 pixels in Y and starts at X=0, Y=40. The Y start position is very important and must be some multiple of the window Y size away from the serial register. More will be said of this later. In our simple case the window has a Y size of 10 and is 40 pixels away from the serial register.

2. The user specifies all of the other usual parameters, e.g. readout speed, integration time and the number of times that the readout sequence is to occur. Consider the example where the user requests a 700 ms integration time on the integration window.

3. The CCD is cleared and the shutter is then opened and left in the open state. The first 700 ms integration occurs on the CCD window **I**. This is state 1 as shown in figure 1.

4. The CCD controller then clocks vertically very quickly (in the Y direction) by 10 times moving the image **I** into the region below the aperture. Light is still integrating onto the CCD in this situation but because the vertically clocking is very fast compared to the integration then the effects of smearing on the image **I** are minimal. In this case very much better than 0.1%. This then takes us to state 2 in our figure 1. The region **S1** above the image **I** has now moved into the aperture area originally taken up by image **I**. This clocking also moves the preceding image **I-1** to the edge of the serial register ready for readout. This image **I-1** does not contain any valid data since it never lay under the aperture at any time.

5. We now do a normal readout sequence for window **I-1**. For example this will take approximately 22 us per pixel in TURBO speed. This will take us to state 3 in which the region **S1** is moved out of the aperture area and the region **S2** is moved into the aperture area. Because this readout sequence is slow, of the order of 300 ms for our window then the region **S1** under the aperture would be very highly smeared as it moved out of the aperture area and the region **S2** will also be highly smeared as it moved into the aperture area. We therefore do another series of fast vertical clocking to move this smeared region **S2** out of the aperture area. This brings us to state 4 in figure 1. The next window **I+1** is now position under the aperture is then integrated for the 700 ms.

6. There would then follow another fast V clocking which would bring our original integrated image area **I** to the serial register, that is state 5. This is then followed by the normal readout sequence allowing the area **I** to be read into the computer and stored, this brings us to state 6. This whole sequence of clocking and readout is repeated until aborted or the requested number of windowed frames have been readout. When finished the shutter is then closed.

This is a very simplified description and easy example of how the Low Smear Drift Mode functions. In the real world the image area would never be an exact multiple of windows away from the serial register and the window size may not be the same as the aperture size. The CCD controller therefore contains a complex algorithm in software which looks at the user's window requirements for size and position and then tries to fit these onto the CCD in question. It may for example add extra fast vertical clocking sequences to the sequences required to move regions **S1** and **S2** making these clocking sequences longer than that required to move the image **I** down, or it may actually start the window at a slightly different place than requested or make the window size slightly different than requested. This is done to ensure that when the window size and position are chosen then the image data **I** arrives at the serial register at the right time for the readout sequence. This guarantees that the required pixels are always digitised and stored.

	S1+1	**S2+1**	**I+2**	**S1+2**	**S2+2**	**I+3**
	I+1	**S1+1**	**S2+1**	**I+2**	**S1+2**	**S2+2**
	S2	**I+1**	**S1+1**	**S2+1**	**I+2**	**S1+2**
	S1	**S2**	**I+1**	**S1+1**	**S2+1**	**I+2**
Dekker Mask Aperture	**I**	**S1**	**S2**	**I+1**	**S1+1**	**S2+1**
	S2-1	**I**	**S1**	**S2**	**I+1**	**S1+1**
	S1-1	**S2-1**	**I**	**S1**	**S2**	**I+1**
	I-1	**S1-1**	**S2-1**	**I**	**S1**	**S2**
Serial Register	**S-2**	**I-1**	**S1-1**	**S2-1**	**I**	**S1**
State	**1**	**2**	**3**	**4**	**5**	**6**

Time →

Figure 1

To ensure that the user is happy with the actual window which has been selected by the controller, a C program is now available at LPO which mimics the window calculation algorithm in the CCD controller. The user can run this program and input the required window size and co-ordinates and then see what the CCD controller would produce for the best fit window to the LSD mode. If the user is happy with the results from this program the window details can then be entered into the CCD controller.

Other set-ups are also possible. For example, two window operation is also available in LSD mode. There is a limit on how far the windows can be apart on the real CCD for this to function. For further information contact the CCD Detector Group at RGO for its use.

Binning is available as normal in both X and Y in LSD mode.

The commands required to implement the new mode are available from the ICL prompt on the astronomer's system computer. Ther user should contact LPO for more information on the high level commands.

Readout Speed.

The fastest frame rate possible in this mode will of course depend on the speed chosen for operation with TURBO speed being the fastest astronomically and STANDARD speed the slowest. It will also depend on the size of the window, the integration time required and if binning has been enabled. A readout speed of greater than 1 windowed frame per second has been achieved in the lab. This would typically be made up of 300ms clocking and pixel processing which in effect is dead time with the rest being the integration period. For detailed calculations of the exact timing please contact the authors. The first real astronomical use of the new mode was to observe the system Sco X-1 which is a neutron star binary. These observations were made using the following set-up with great success:-

ISIS blue with TEK2 CCD
spectral binning of 2 (1124/2 data pixels)
spatial binning of 4 (36/4=9 data pixels)
each spectrum was exposed for 1.06s,
0.32 dead time with standard mode (noise 4.8e-), giving a time resolution of 1.4s.

There has been at least one other successful observing run made since this one (Welsh,University of Keele).

Each of the images readout are input into one large file. For example if the user requested a 1s integration time and 3600 exposures then the resultant data output would be a single file which contained each of the 3600 images stacked on top of each other in the Y direction. There is a physical limit on how many windowed images can be stacked up like this. This limit depends on the sizes of the requested windows, the binning factor and the amount of memory available in the DMS. For more information about this and about the header information which is stored with the image please contact the authors or island staff.

Time Stamping

This new mode of operation was originally produced for an astronomical run by a group at St. Andrews. Their original requirement was also for each of the integrated images to be absolute time stamped to better than 10 ms. This was because that group wanted to correlate the WHT data with that produced by an X-ray satellite. To this end a GPS system was borrowed (from Ashtech Ltd) to enable the absolute time of each image to be acquired and stored with each image. The absolute start time of each windowed frame was acquired and stored to an accuracy of about 1 ms. This time stamping is not now available as the GPS was only borrowed for the one run. We await decisions from LPO staff to see if they would like absolute timing accuracy to be implemented on our CCD systems in the near future. If this is the case then a GPS will have to be purchased and interfaced to the WHT system. Contact the authors or LPO staff for more details about this.

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