Observation technique for the detection of optical counterpart of pulsars emission using an EMCCD camera

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Abstract

Pulsar signals are narrow(in time) RF bursts that occur at very stable periods ranging from seconds to milliseconds depending on the particular pulsar. It is very likely that we can obtain the optical counterpart of this signal using an EMCCD camera, which has the characteristic of being very sensitive and can acquire images faster than using a conventional CCD camera. This paper presents an observational technique for the detection of signal period of a Pulsar, using the EMCCD camera developed at the National Astronomical Observatory of San Pedro Martir (OAN-SPM).

What is EMCCD?

Unlike a conventional CCD, an EMCCD is not limited by the readout noise of the output amplifier, even when operated at high readout speeds. This is achieved by adding a solid state Electron Multiplying (EM) register to the end of the normal serial register; this register allows weak signals to be multiplied before any readout noise is added by the output amplifier, hence rendering the read noise negligible. The EM register has several hundred stages that use higher than normal clock voltages. As charge is transferred through each stage the phenomenon of Impact Ionization is utilized to produce secondary electrons, and hence EM gain. When this is done over several hundred stages, the resultant gain can be (software) controlled from unity to hundreds or even thousands of times.

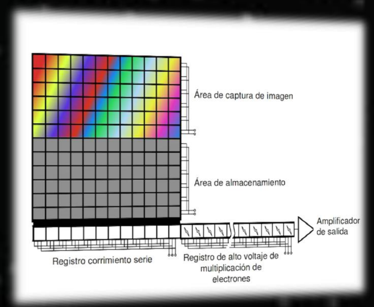


Figure 1. EMCCD Architecture.

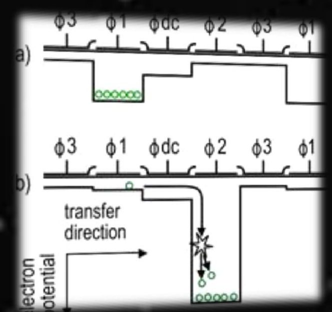


Figure 2. Multiplication Process.

Free-Run and Window modes

The generation of electrons in the multiplication register substantially improves the signal-to-noise ratio, even at higher reading speeds. Taking advantage of this feature, the Instituto de Astronomia, UNAM has developed an EMCCD camera in order to implement new astronomical observation techniques in Mexico with high temporal resolution. Two methods are proposed, the *free-run* mode, and the *window* mode (see Figures 3 to 5).

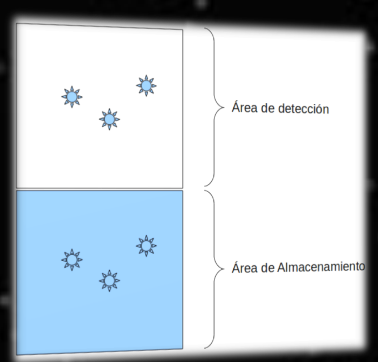


Figure 4. Conventional CCD readout.

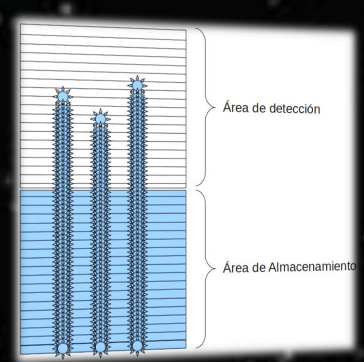


Figure 5. Free-Run mode readout.

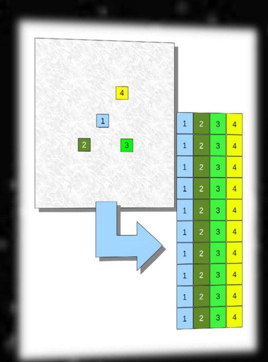


Figure 6. Window mode readout.

Pulsars

A pulsar is a highly magnetized, rotating neutron star that emits a beam of electromagnetic radiation. This radiation can only be observed when the beam of emission is pointing towards the Earth, much the way a lighthouse can only be seen when the light is pointed in the direction of an observer, and is responsible for the pulsed appearance of emission. Neutron stars are very dense, and have short, regular rotational periods. This produces a very precise interval between pulses that range from roughly milliseconds to seconds for an individual pulsar.

Pulsar period Simulation

To demonstrate the operation of the free-run mode, a pulsar period simulator circuit has been constructed (see Figure 6), which consists of a light emitting diode "pulsing" at a certain frequency. The software for image acquisition immediately allows us to obtain a graph of the diode light (Figure 7), at a sampling frequency of 700 lines per second. Also, the software may generate a graph of the Fast Fourier Transform, which will allow us to appreciate frequencies composing the signal. We can see at figure 8 a fundamental frequency of approx 33hz.

Figure 6. Pulsar period simulator circuit.

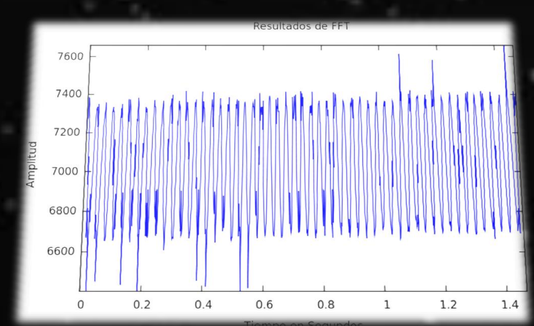


Figure 7. Diode light intensities at 700 samples per second.

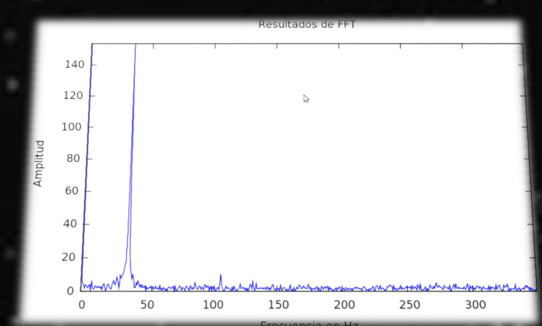


Figure 8. FFT of diode light intensities.

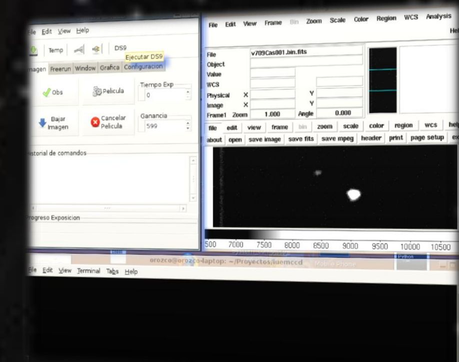
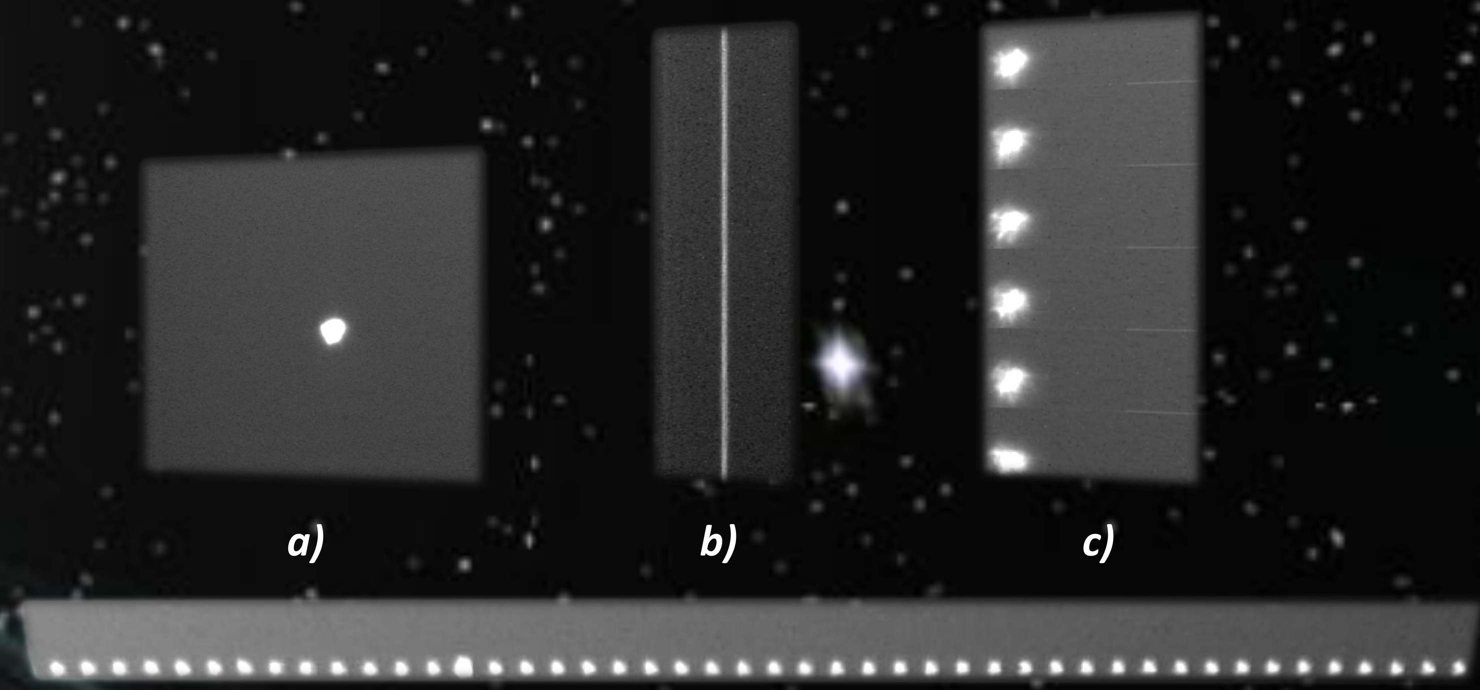


Figure 9. User interface of the EMCCD camera.

Figure 10. EMCCD camera mounted on telescope.



d)

Figure 11. Observation of the variable star V600 using: a) Direct image, b) Free-run mode, c) & d) Window mode.

Results

We obtained a good performance of the camera and its acquisition system, although not demonstrate its total potential, since it requires to perform many more tests to fully detail the proposed methods. It seems to be very useful to obtain directly from the user interface the light curve and its FFT, so we can see any frequency of interest almost in real time. We see that the system is able to obtain pulsar period directly if the signal is strong enough.

References

Basden, A., Haniff, C., and Mackay, C. (2003). Photon counting strategies with low light level CCDs. Monthly Notices of the Royal Astronomical Society, 345(Nov.):985–991.

Jerram, P., Pool, P., Bell, R., Burt, D., Bowring, S., Spencer, S., Hazelwood, M., Moody, I., Catlett, N., and Heyes, P. (2001). The llccd: low-light imaging without the need for an intensifier. Sensors and Camera Systems II, 4306:178–186.

Mackay, C., Tubbs, R., Bell, R., Burt, D., Jerram, P., and Moody, I., editors (2001). Subelectron read noise at MHz pixel rates, volume 4306 Sensors and Camera Systems II.

Orozco, B., Carramiñana, A., Michel, R., Zazueta, S., and Fordham, J. (2007a). A fast photon counting camera for -ray pulsar astronomy. The First GLAST Symposium. AIP Conference Proceedings, 921:436–437.

R.Michel, S.Zazueta, E.Colorado, F.Quiros, F.Murillo, G.Sierra, M.Pedrayes, F.Lazo, B.Orozco, J.Murillo, B.Garcıa, and B.Martınez (2008). Cámaras para visión nocturna Basada en los nuevos CCDs multiplicadores de electrones y pedestal de estabilización para su uso en las unidades de superficiede la Armada de México. Documentación interna de Secretaría de Marina. Instituto de Astronomía, UNAM.