Determining the timeline of Ultra-High Speed Images of the Cordin 550-32 camera

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Abstract

A method to determine the timeline of captured images of the Cordin 550-32 Ultra-High Speed Camera has been developed. The method is aimed at applications that require photographic diagnostics, with the Cordin camera, in conjunction with other diagnostic instrumentation. In such cases the synchronisation of the diagnostics is paramount. Here, the camera generated info.txt file is utilised to determine the time of each frame with respect to the system trigger, enabling synchronisation of images with other diagnostics such as Flash X-Ray, Light Gate Outputs, Data Acquisition Equipment, etc.

Introduction

Photographic diagnostics at very high frame rates (>200,000 frames per second) utilising rotating mirror cameras such as the Cordin 550 Ultra-High Speed Camera (UHSC) play an important role in the research into rapid energetic events. During this research, various instruments (e.g. Flash X-Ray, Data Acquisition Equipment (DAQ), etc.) may be integrated into an experimental arrangement which is controlled by a single trigger event. For the purpose of accurate post-processing, the diagnostics need to be synchronised on a single timeline with the system trigger as reference. The Cordin 550-32 camera generates an info.txt file, containing the Frame Rate, number of Frames, Index to Trigger Displacement, First Bank and Pixel bit section, which can be used to synchronise such an experimental arrangement.

Experimental Procedure

During experiments performed by the CSIR Landward Sciences into energetic events, experimental arrangements for *e.g.* Argon Bomb characterisation, EFP surrogate characterisation and other research activities are conducted. These studies require the integration of various scientific equipment and instrumentation. A typical arrangement with various recording apparatus is shown in Figure 1.

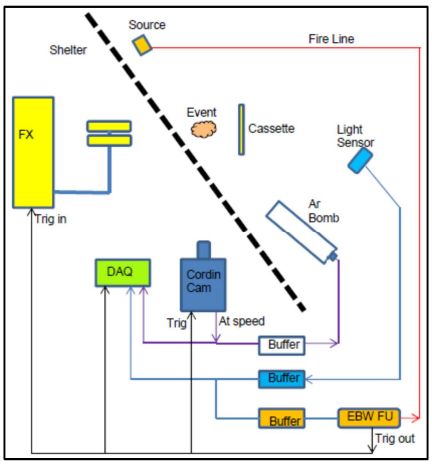

Figure 1: Typical arrangement where synchronisation of various recording apparatus, e.g. Camera, Flash X-Ray and DAQ, is required.

In the set-up in Figure 1, the camera is the controlling device and sends a trigger to the Argon Bomb when the camera reaches "At Speed". As soon as the lighting level from the Argon Bomb reaches an adequate level, determined by the light sensor, a firing pulse is sent to the detonator on the test sample. This is considered as time zero (T_0) for the camera, FX and DAQ. The FX and DAQ will trigger almost immediately, with a known instrument delay. However, due to the nature of rotating mirror cameras, the mirror can be anywhere between two internal imagers (F_x *and* F_{x+1}) at time T_0. In addition, the first image displayed by the camera is not the first image after trigger, but rather the first image in a specific bank of images. Figure 2 below shows some of the mechanics of the Cordin550-62 (same as the Cordin550-32, except that the Cordin550-32 has 4 CCD's per bank).

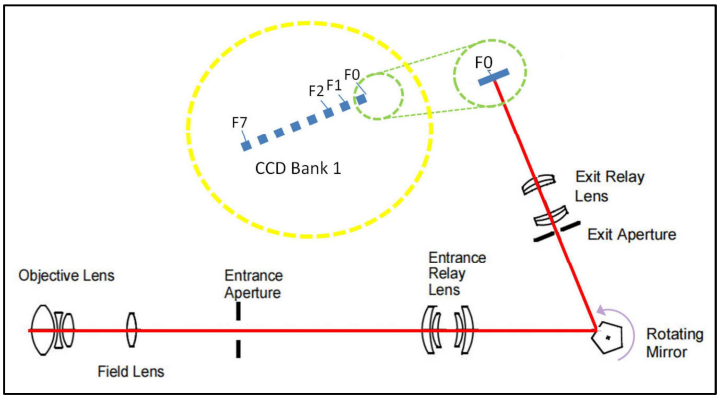

Figure 2: Schematic illustrating the key optical elements along the Cordin550-62 optical path (Conneely et al [1], Fig 1)

It is evident that a standard way of determining the timeline of the captured images would be helpful in combining recorded events on various apparatus.

Results

In addition to images, the Cordin550-32 generates an info.txt file with every captured event as shown in Figure 3 below.

```
                                        Info
Frame Rate= 162437 fps
Frames = 32
Index to Trigger displacement =  105
First Bank =  0
Pixel Bit section -- High byte with overflow compensation
```

Figure 3: Cordin550-32 system generated info.txt file

The Frame Rate (FR) is the exact framing rate at the time of the trigger signal: in general this is near but not exactly the framing rate set by the operator. The Index to Trigger Displacement (ITD) indicates the mirror position relative to the camera's "zero point" at the time of the trigger signal. The First Bank (FB) is the CCD bank number in which the trigger occurred. The ITD value is used to calculate the timeline of the captured images with respect to the system trigger. This is the subject of this paper.

Discussion

The ITD is of interest, however, the value presented in the info.txt file was of little immediate meaning. The Cordin 550-32 manual [2] offered no explanation, and requests to the Cordin Company for clarification of the ITD rendered little additional information.

However, the comparison of many *ITD* and *FB* values of different tests revealed that the *ITD* value actually represents the time x 10 (in µs) between the camera "zero point" and the trigger occurrence: In the Cordin 550-32 manual [2], Index Pulses are described as being generated when the rotating mirror passes Frame 0 (camera "zero point"). It followed that the *ITD* (Index to Trigger Displacement) had something to do with the time between the Index Pulse and the Trigger – the increasing *ITD* value for higher *FB* values and decreasing *ITD* value for higher *FR* confirmed this. Dividing the *ITD* value by the inter frame time consistently led to the number of images being larger than 32, in fact 10 times more. This led to the realisation that the *ITD* value is in µs x 10 format. In **Figure 3** above the *ITD* is given as 105: this means that the trigger occurred 10.5µs from the camera's position zero. With this knowledge, the timeline of the images w.r.t. the system trigger could be calculated (using the information in **Figure 3** as example):

Using the *FR*, the timing between frames can be calculated as $= {}^{1}/_{FR} = 6.16\mu s$, and the number of frames (images) to the trigger point as $F\# = {}^{ITD}/_{10.Tf} = 1.705$. The number of frames (*F#*) will almost always not be an integer, with the fraction being the timing of the trigger signal between 2 frames (F_0 and F_1 in this example). Since the imagers in the Cordin 550-32 camera are in banks of 4 each, the $= {}^{F\#}/_{4} = 0.43$. The FB is thus 0 (rounded off downwards). With *F#* =1.705, it means that the trigger occurred 0.705 x *Tf* = 4.34µs after the first frame (F_0 - frame 0).

To simplify these calculations, a tool in the form of an Excel Sheet is presented in figure 4:

			Displayed Frame Number	Captured Frame Sequence (Actual)	Timing from T0 (s)	Timing from T0 (µs)
Enter Values from .txt file			0	16	-1.8314E-06	-1.8314
File Name:	info.txt		1	17	2.1374E-06	2.1374
Frame Rate:	251969		2	18	6.1061E-06	6.1061
Index to Trigger:	693		3	19	1.0075E-05	10.0748
First Bank:	4		4	20	1.4044E-05	14.0436
			5	21	1.8012E-05	18.0123
Trigger Frames Calculations			6	22	2.1981E-05	21.9811
Interframe Time:*Tf*	3.9687E-06		7	23	2.5950E-05	25.9498
Total Time:	1.2700E-04		8	24	2.9919E-05	29.9186
Frames from Frame 0:	17.4614517		9	25	3.3887E-05	33.8873
Trigger between Frames:	16	17	10	26	3.7856E-05	37.8560
Decimal of Frames:	0.4614517		11	27	4.1825E-05	41.8248
Time to trigger after X:	1.8314E-06		12	28	4.5794E-05	45.7935
			13	29	4.9762E-05	49.7623
Trigger Bank Calculations			14	30	5.3731E-05	53.7310
Bank:*FB*	4	CORRECT BANK	15	31	5.7700E-05	57.6997
X (frame in bank):	1		16	32	6.1668E-05	61.6685
First Frame in Bank:	16		17	1	6.5637E-05	65.6372
Trigger after Frame (actual):	16		18	2	6.9606E-05	69.6060
Time T0 of First Frame:	-1.8314E-06		19	3	7.3575E-05	73.5747
			20	4	7.7543E-05	77.5435
			21	5	8.1512E-05	81.5122
			22	6	8.5481E-05	85.4809
			23	7	8.9450E-05	89.4497
			24	8	9.3418E-05	93.4184
			25	9	9.7387E-05	97.3872
			26	10	1.0136E-04	101.3559
			27	11	1.0532E-04	105.3247
			28	12	1.0929E-04	109.2934
			29	13	1.1326E-04	113.2621
			30	14	1.1723E-04	117.2309
			31	15	1.2120E-04	121.1996

Figure 4: Cordin550-32 timeline tool

By simply entering the frame rate, index to trigger displacement and first bank data from the info.txt file, the timeline of the captured images w.r.t. the system trigger is calculated and displayed per frame (image). The displayed frame number and actual frame sequence are usually not the same – only if the first bank is 0.

Conclusion

From the previous it is clear that the info.txt file created by the Cordin 550-32 camera gives valuable additional data, which can be used to synchronise various recording apparatus onto a single timeline of events. An Excel Tool has been developed and proven to assist in the calculations of such a timeline, and same will be advanced to become a Graphical User Interface.

References

1. Michael Conneely, Hans O. Rolfsnes, Charles Main, David McGloin, and Paul A. Campbell (2011). On the accuracy of framing-rate measurements in ultra-high speed rotating mirror cameras. Vol. 19, No. 17 / OPTICS EXPRESS 16432

2. Cordin 550 Users Manual, Cordin Company Inc. (Salt Lake City, Utah, USA) (2004)