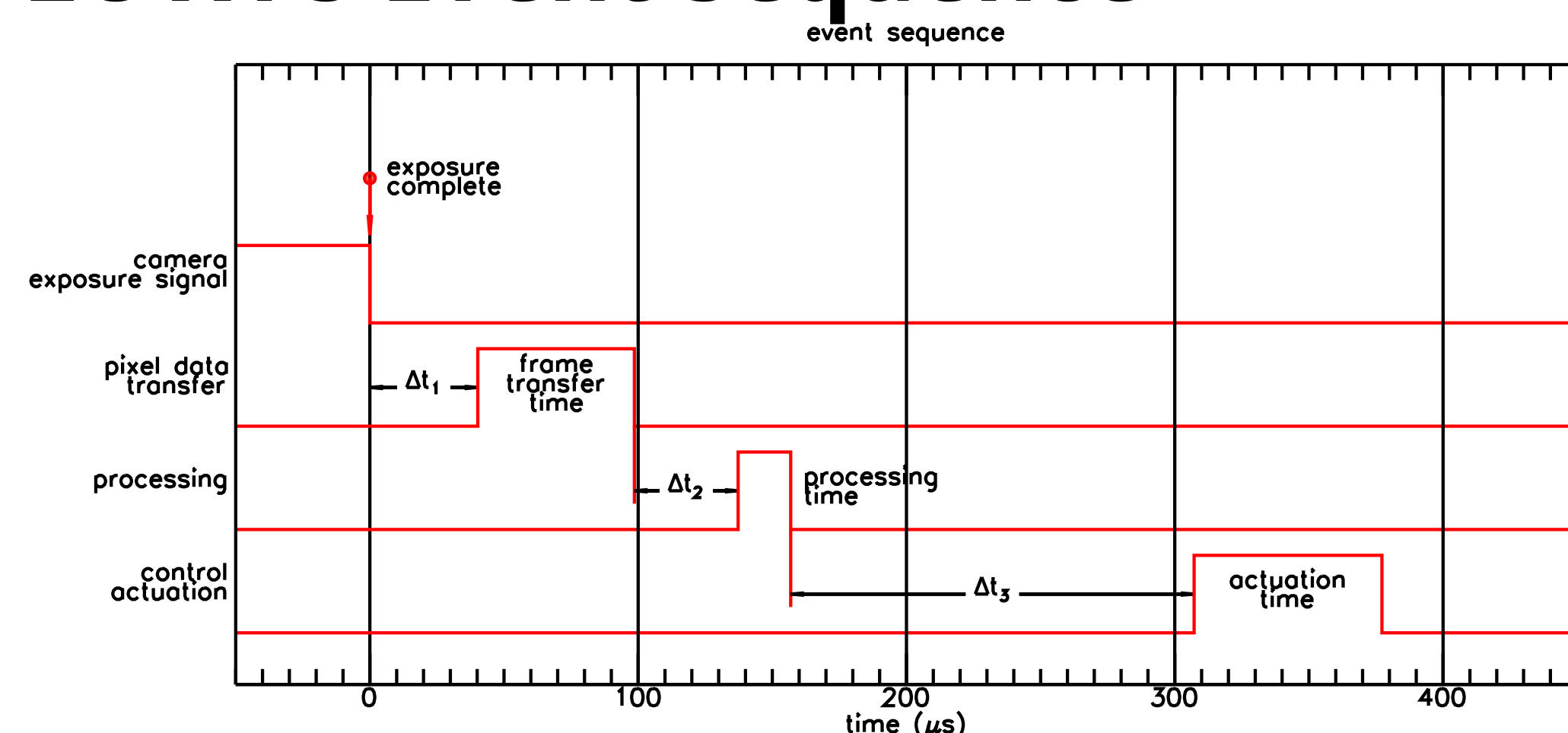


## PICTURE-C Experiment

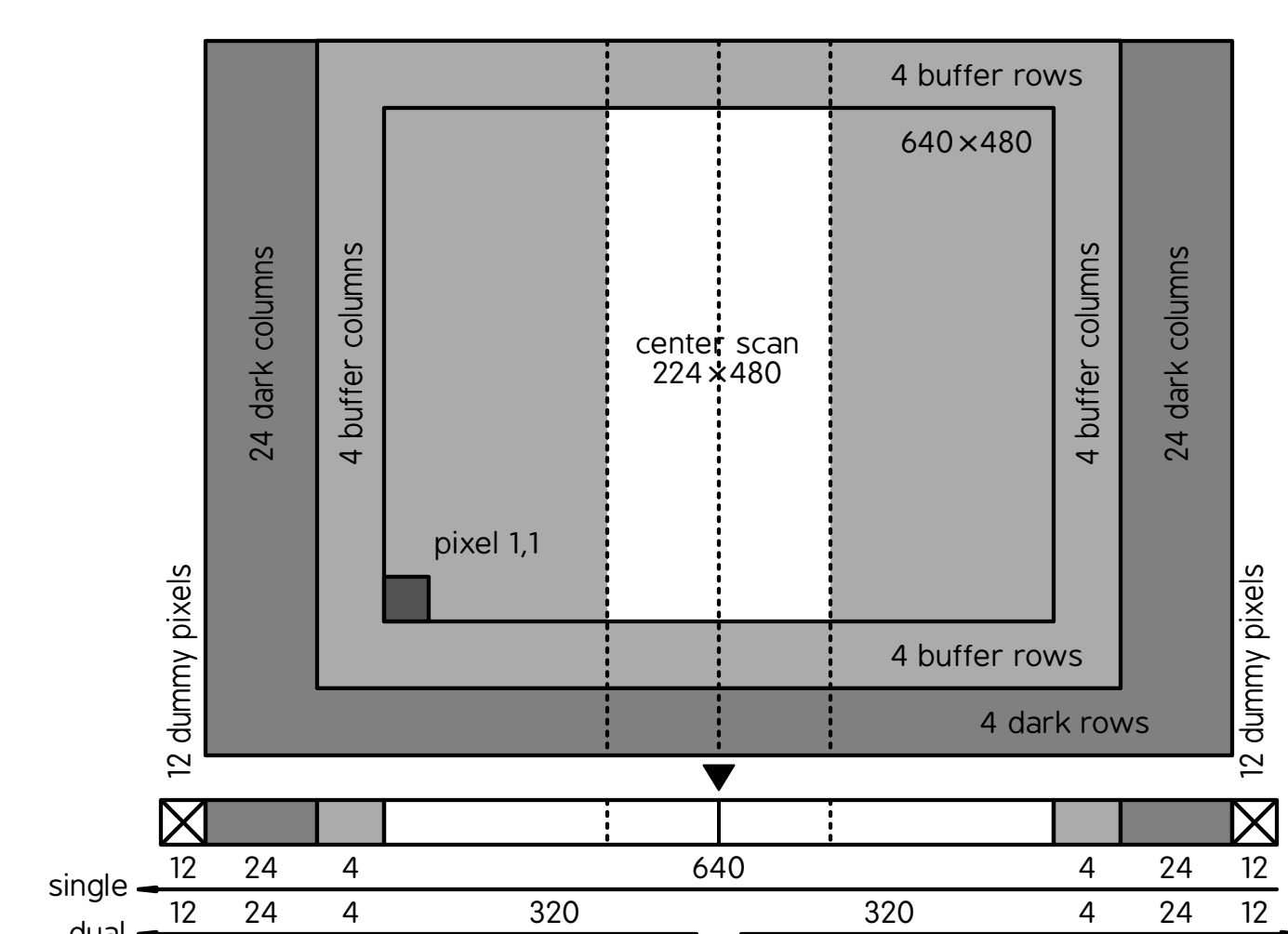
The Planetary Imaging Concept Testbed Using a Recoverable Experiment - Coronagraph (PICTURE-C) mission will directly image debris disks and exozodiacal dust around nearby stars from a high-altitude balloon using a vector vortex coronagraph operating at an inner working angle of  $1.7 \lambda/D$  in visible light (540 nm - 660 nm)<sup>1</sup>.

## LOWFS Event Sequence



Simplified timing diagram of the LOWFS events. These events occur in different devices of the LOWFS.

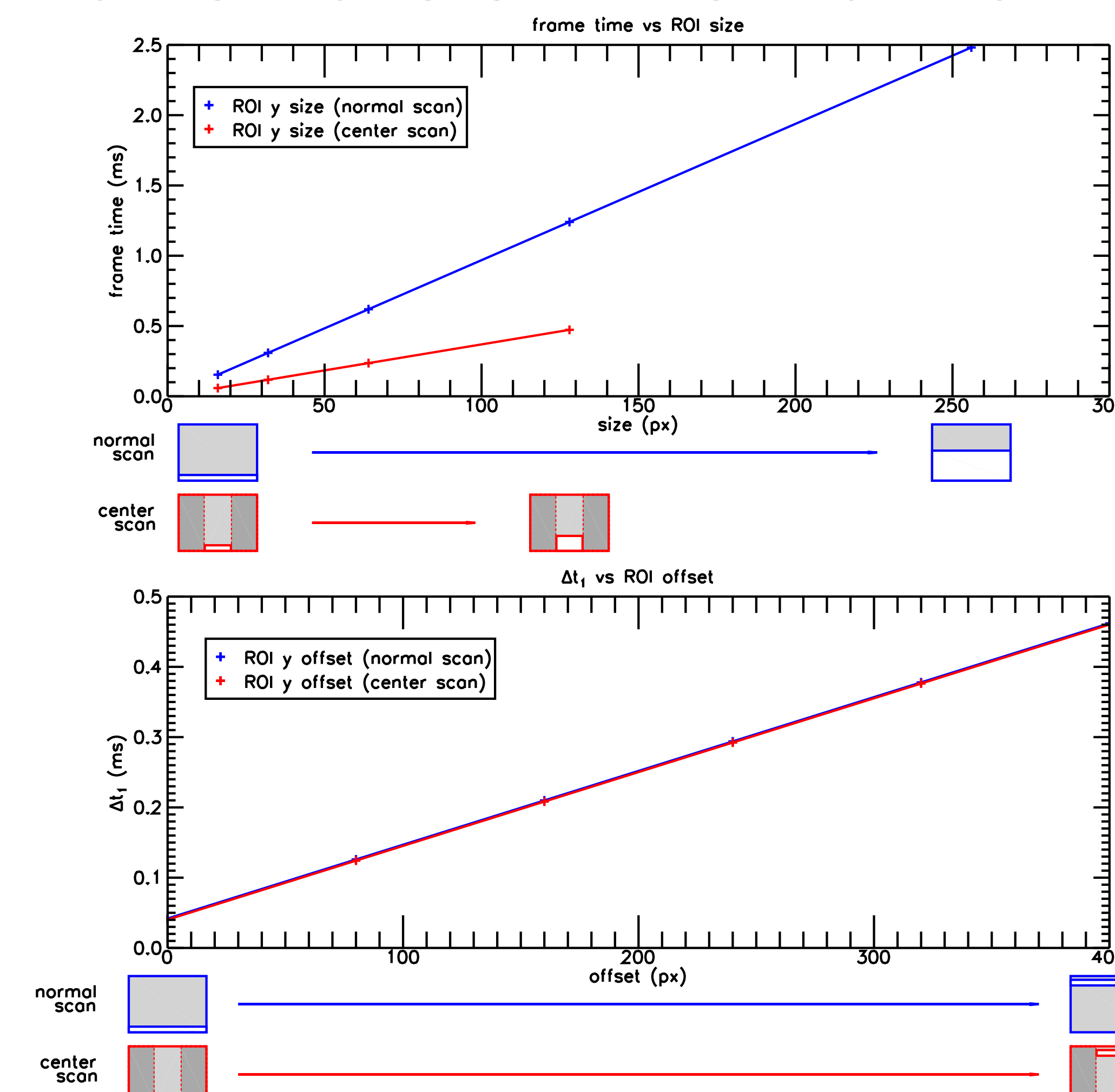
## Sensor Architecture



The CCD KAI-0340 on the LLOWFS camera (Bobcat B0620M) consists of an active pixels region, a buffer region and a light shielded region.

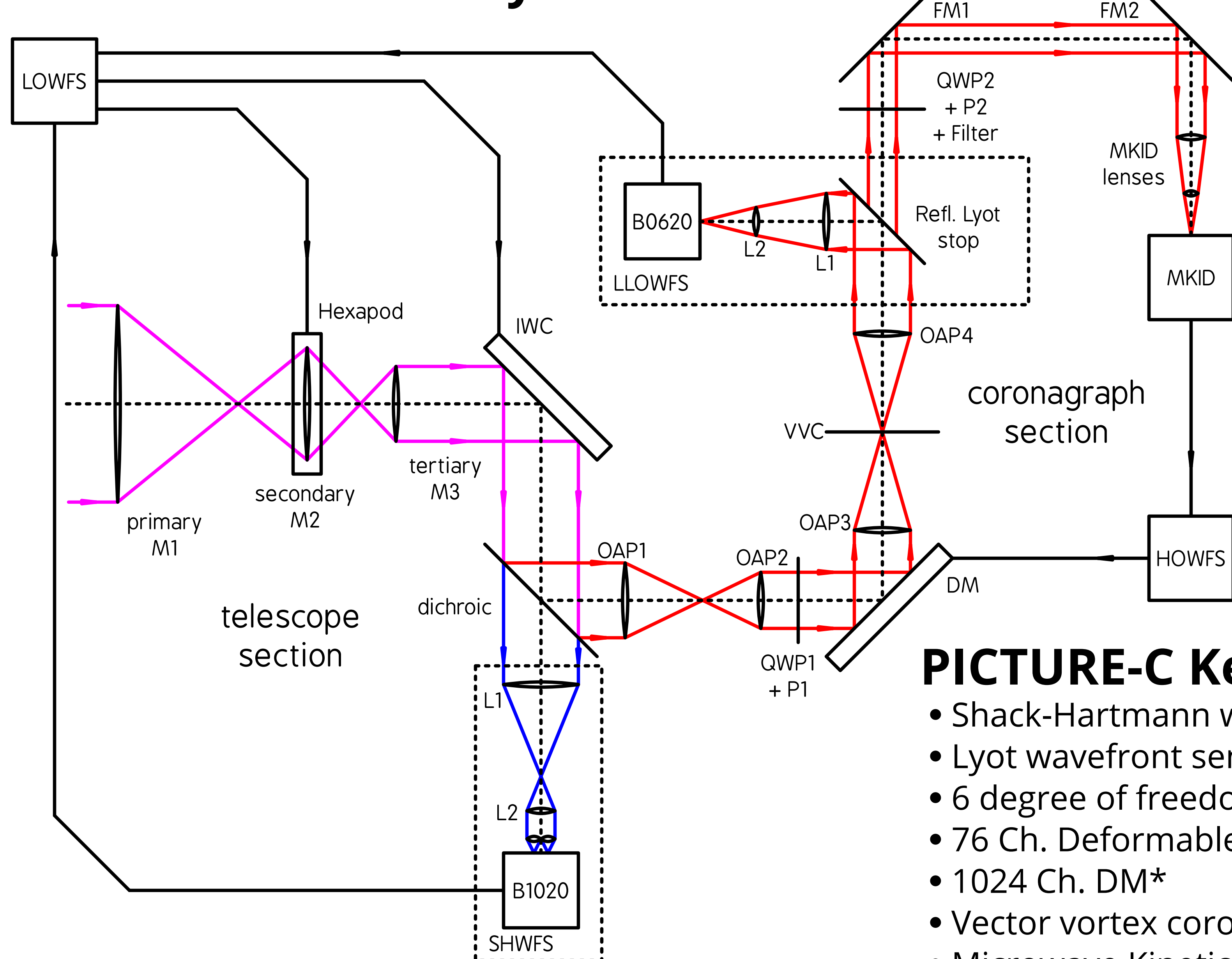
Bobcat 1020M camera on the SHWFS has a KAI-01050 CCD with a similar architecture but with 1084x1064 total pixels and 1024x1024 active pixels.

## Frame Transfer Time with ROI



The frame transfer time and  $\Delta t_1$  of the B0620M camera can be changed by altering the size and the position of the ROI on the sensor. The center scan mode decreases the frame transfer time by a factor of 3.

## PICTURE-C Control System



Schematic of the PICTURE-C instrument (convex shapes denote powered optics\*). The SHWFS and the LLOWFS provide wavefront data to the LOWFS that in turn applies corrections to the wavefront via the hexapod and the IWC.

\* not to scale  
Details of the optical design in these proceedings (Mendillo et al.10400-34)

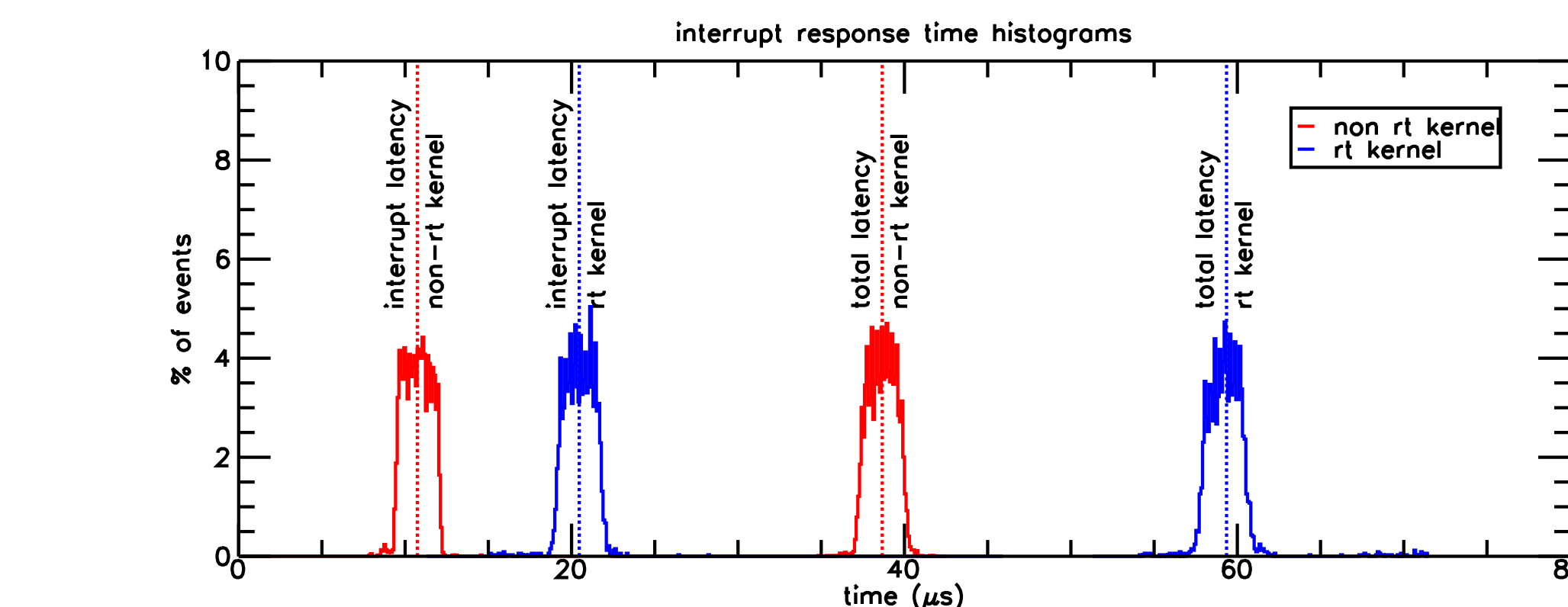
## LOWFS Requirement

- Calculated empirically
- Rate - 200 Hz
- Total latency - 1 ms

## PICTURE-C Key Features

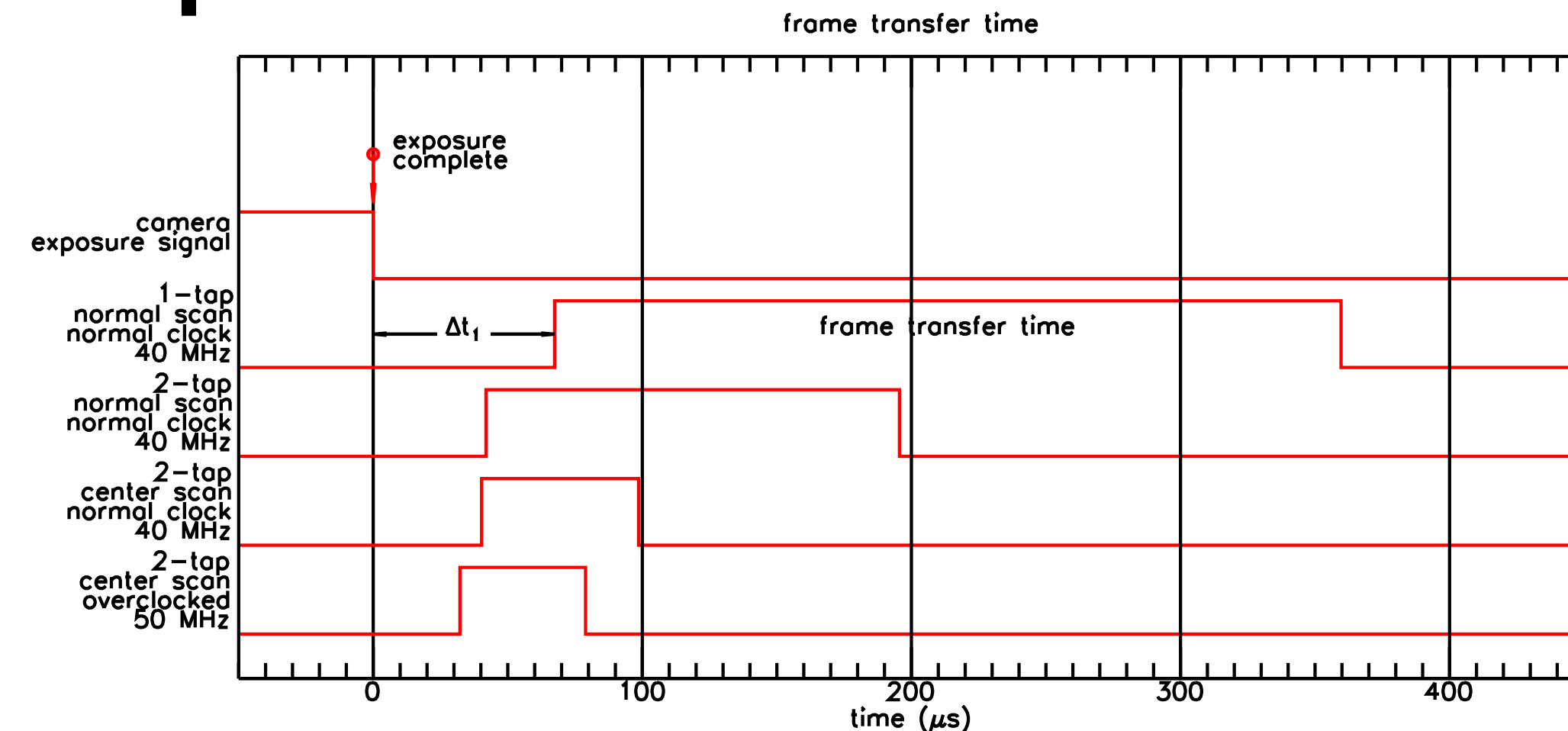
- Shack-Hartmann wavefront sensor (SHWFS)
- Lyot wavefront sensor<sup>2</sup> (LLOWFS)
- 6 degree of freedom hexapod
- 76 Ch. Deformable Mirror (DM) with Tip-Tilt (IWC)
- 1024 Ch. DM\*
- Vector vortex coronagraph<sup>3</sup> (VVC)
- Microwave Kinetic Inductance Detector<sup>4</sup> (MKID)\*

## Linux Kernel Real Time Patch



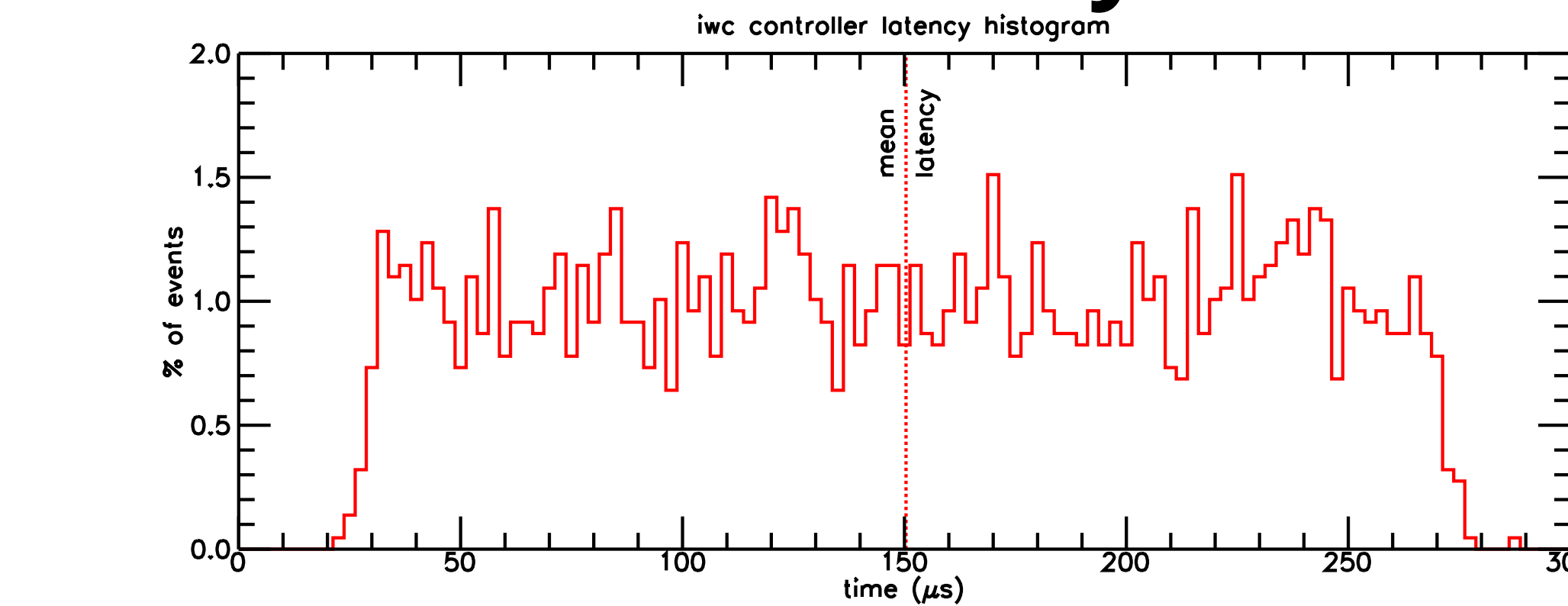
Distribution of ~6000 interrupt latency measurements and total latency (interrupt latency + scheduling latency) measurements of the Linux kernel (version 3.2.21) and the same kernel with the real-time patch (version 33).

## Acquisition Modes



Frame transfer times for a 16x16 pixel image in four different configurations of the acquisition system.

## IWC Controller Latency



The distribution of latency measurements for ~2000 IWC commands.

## MKL vs. OpenBLAS

Frame size (pxxpx)	Matrix size	OpenBLAS (μs)	Intel MKL (μs)
16x16	256x24	42.2 (±0.3)	19.6 (±1.5)
32x32	1024x24	145.6 (±2.6)	53.6 (±1.4)
64x64	4096x24	545.6 (±3.7)	190.5 (±2.0)

Calculation times for different frame sizes for MKL and OpenBLAS.

## Final System Total Latency

Final system configuration is as follows,

- 2-tap
- Center scan mode at 40 MHz px. clock
- ROI at bottom left corner
- 64-bit Linux mainline kernel (version 3.2.21)
- MKL 2017 update 3

Frame size (pxxpx)	Mean total latency (μs)	Worst case total latency (μs)
16x16	378	517
32x32	471	611
64x64	726	866

## References

- [1] Cook, T., Cahoy, K., Chakrabarti, S., Douglas, E., Finn, S. C., Kuchner, M., Lewis, N., Marinan, A., Martel, J., Mawet, D., Mazin, B., Meeker, S. R., Mendillo, C., Serabyn, G., Stuchlik, D., and Swain, M., "Planetary imaging concept testbed using a recoverable experiment-coronagraph (PICTURE-C)," *Journal of Astronomical Telescopes, Instruments, and Systems* 1(4), 044001 (2015).
- [2] Singh, G., Martinache, F., Baudoz, P., Guyon, O., Matsuo, T., Jovanovic, N., and Clergeon, C., "Lyot-based low order wavefront sensor for phase-mask coronagraphs: Principle, simulations and laboratory experiments," *Publications of the Astronomical Society of the Pacific* 126, 586 (June 2014).
- [3] Mawet, D., Serabyn, E., Moody, D., Kern, B., Niessner, A., Kuhnert, A., Shemo, D., Chipman, R., McClain, S., and Trauger, J., "Recent results of the second generation of vector vortex coronagraphs on the high-contrast imaging testbed at JPL," *Techniques and Instrumentation for Detection of Exoplanets V* 8151, 81511D (Sept. 2011).
- [4] Mazin, B. A., Bumble, B., Meeker, S. R., O'Brien, K., McHugh, S., and Langman, E., "A superconducting focal plane array for ultraviolet, optical, and near-infrared astrophysics," *Opt. Express* 20, 1503-1511 (Jan.2012).

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