Target imaging systems

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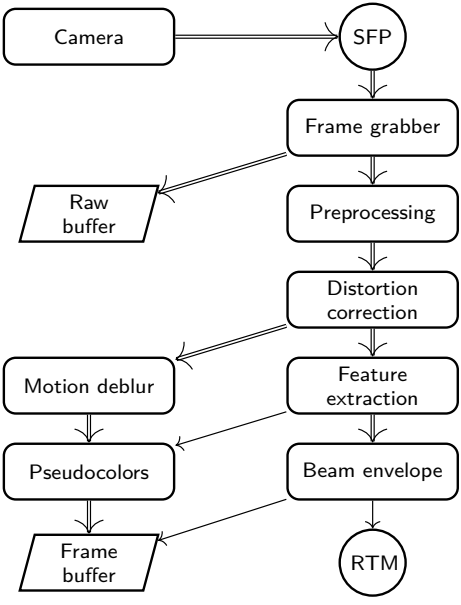
Scope of processing functionality

Functionality	SW	FW
Processing/correction		
- Median noise filter	?	?
- Background subtraction	v	
- Dead pixel mask	v	
- Vignetting correction	v	?
- Geometric distortion	v	?
- Motion deconvolution		
Parameter extraction		
- Centroid position	v	v
- Peak intensity	v	v
- Percentage outside footprint	v	v
- Normalization to beam current		
- Position of fiducials		o
- Correction for temp./yield	?	?
- Histogram and intensity contours	?	
- Beam diagnostic pulse		
Display the image @ 14 fps	v	o
- Pseudocolors		
- Store also raw data		



Expected light yield on camera

Al_2O_3 — proton stopping power

$$S_{p^+}(2\ \mathrm{GeV}) = 1.66\ \mathrm{MeV}\cdot\mathrm{g/cm^2}$$

PSTAR @ 2 GeV, NIST, 2017, URL: https://physics.nist.gov/PhysRefData/Star/Text/PSTAR.html

Coating effective thickness

$$d_{Al_2O_3} = 100\ \mu\mathrm{m}\cdot 3.95\ \mathrm{g/cm^3}$$

$Al_2O_3 : Cr^{3+}$ — light yield

$$y_{ph} = 10^4\ \mathrm{ph/MeV}$$

LHC Dump (Chromox), T Lefèvre et al., 2007, URL: https://cds.cern.ch/record/1045239

Photons per pulse

$$y_{ph} = 7.34\cdot 10^{17}\ \mathrm{ph/pulse}$$

nominal pulse: $1.12\cdot 10^{15}\ p^+$

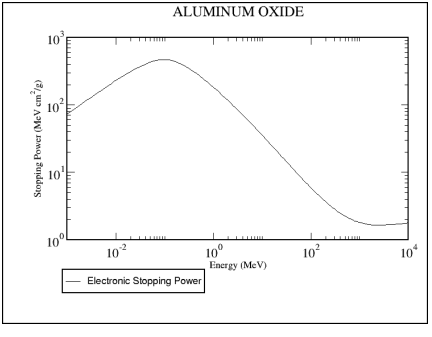


Photo-electrons on camera

$$y_{pe} \simeq 18\ \mathrm{ke/pix}$$

$\mathrm{N.A.} = 0.001$, $\langle \mathrm{T}\cdot\mathrm{Q.E.}\rangle = 20\ \%$, 2 Mpix image

Correction and normalization

Temperature correction

Temperature is known to affect Luminescence:

- spectrum broadens, lines vanish
- total light yield reduced

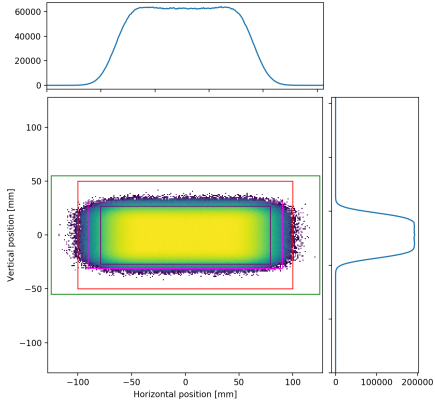
Mitigation strategy:

- measure temperature in situ
- apply calibration curves

Worst-case scenario:

- significant variation across luminous field
- predict response map from simulation

Cost: anther full pixel map

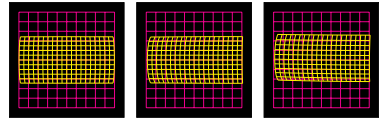


Distortion correction

Projection distortion

Analytic composition of two projections:

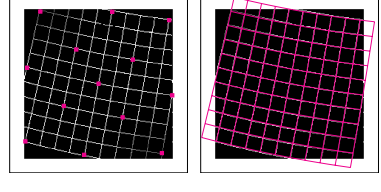
- Beam-normal system projects onto target wheel
- Wheel rim projects thru off-axis pinhole camera matrix



Curved mirror distortion

In-situ calibration:

- Use actual or simulated image of rectilinear system
- Fit with 2nd degree xy-binomial

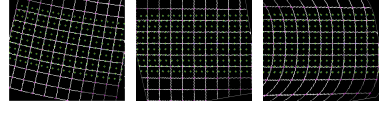


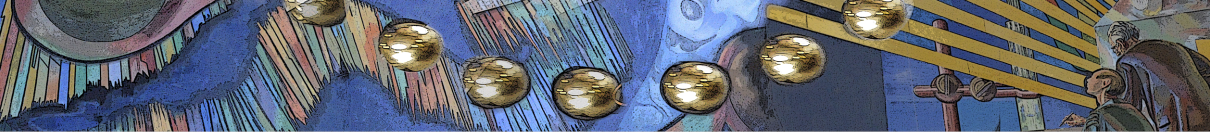
Combined correction

Combination of two distortions

- Projection distortion
- Curved mirror distortion
- Fit with 4th degree xy-binomial

Explicit 2D correction map





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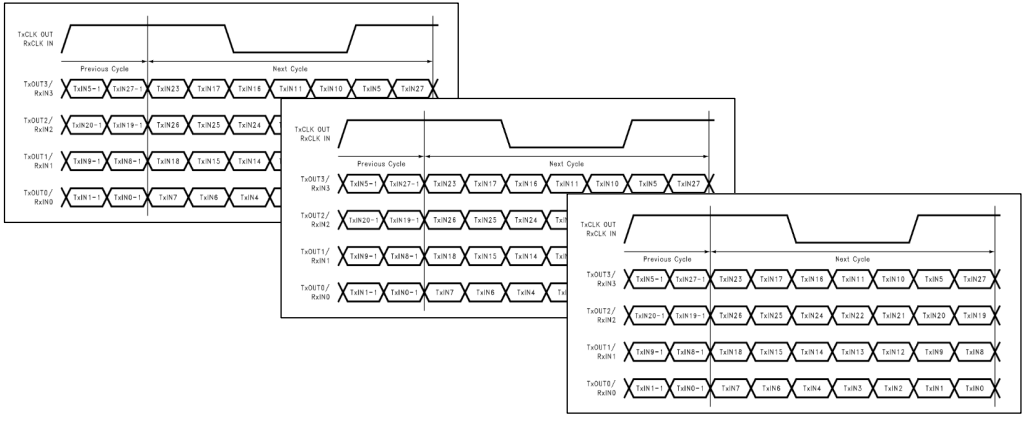
Camera Link Frame Grabber

HAMAMATSU
ORCA-Flash4.0 V3 Digital CMOS Camera
C13440-20CU

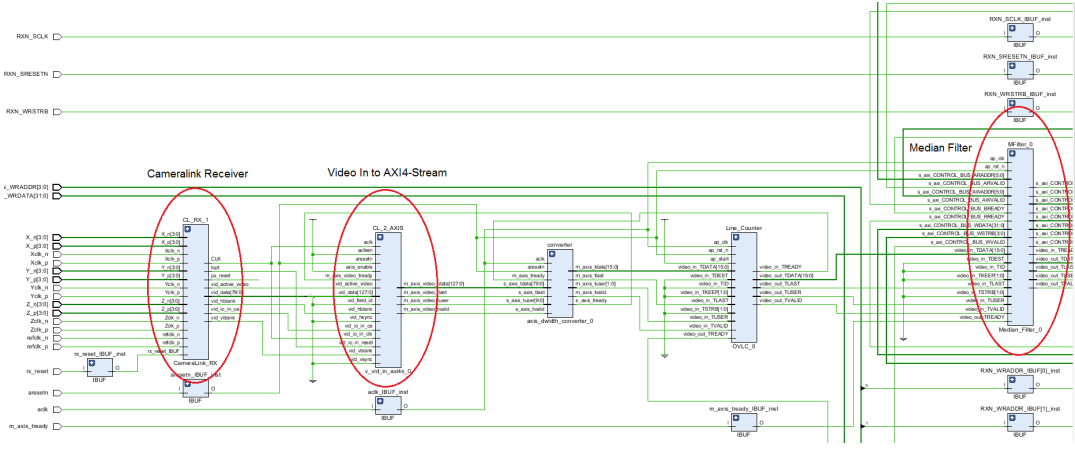
- Effective no. of pixels: 2048×2048
- A/D converter 16/12/8 bit
- Max Readout Speed:
  100 frames/s (Full res., std. scan)
  49 frames/s (Lightsheet mode)
- Readout noise:
  Std. scan: 1.6 electrons rms
  slow scan: 1.4 electrons rms
- Lens Mount: C-mount
- Interface: Camera Link (80 bit) /USB 3

Camera Link 80 bit (10 ports x 8 bit)

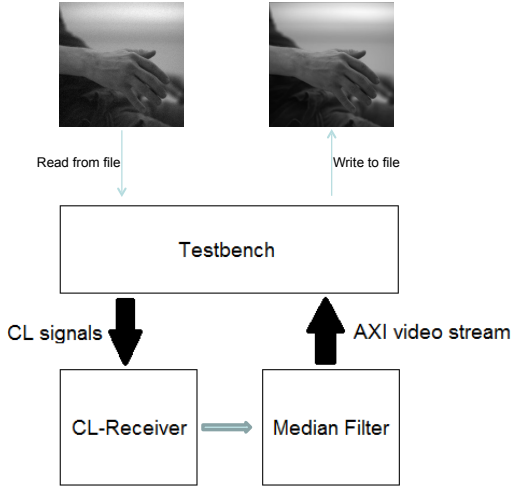
ORCA FLASH: Five 16 bits pixels per clock @ 85 MHz
100 Frames/s → 850 MB/s



Camera Link Frame Grabber simulation (Gate Level)

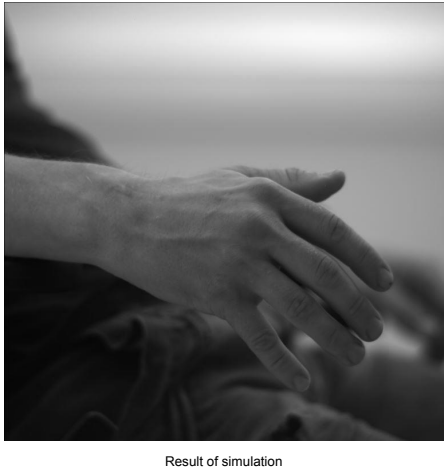


Camera Link Frame Grabber simulation



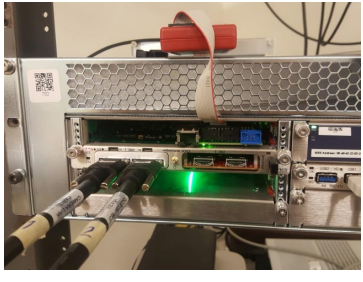
Camera Link Frame Grabber simulation

Orca Flash CL-link camera frame with Salt & Pepper noise added.

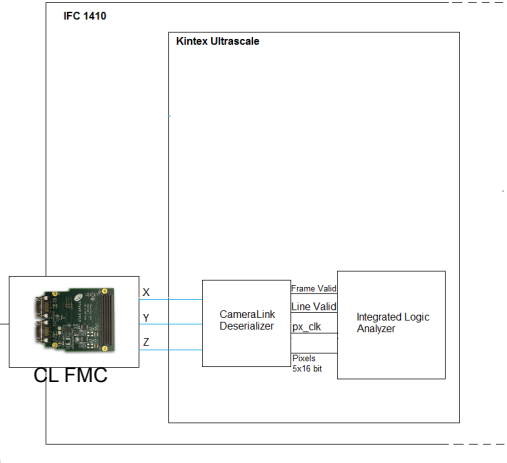


Result of simulation

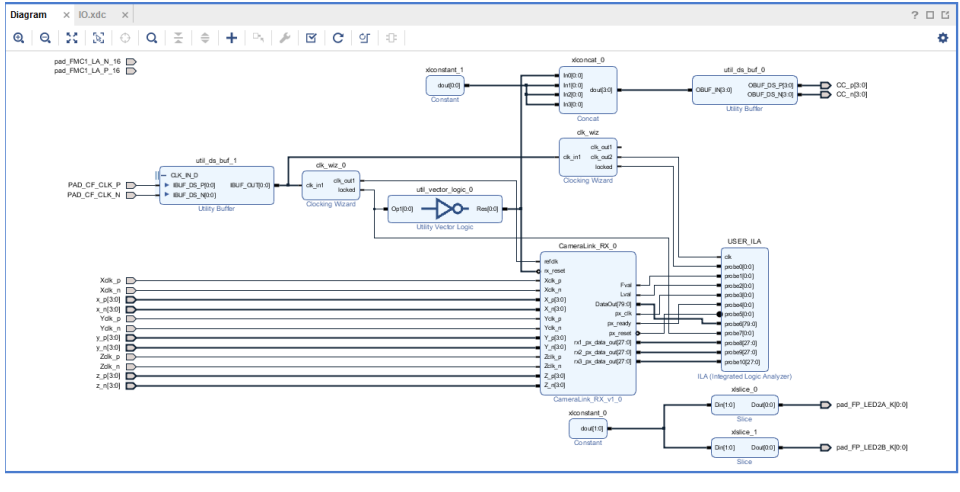
IFC1410 Implementation



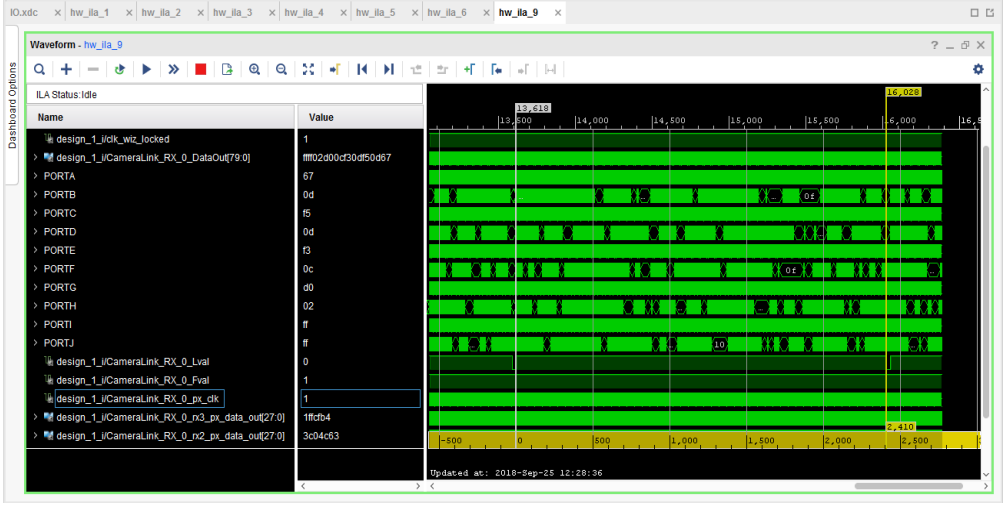
Hamamatsu Orca FlashV4.0



IFC1410 Implementation

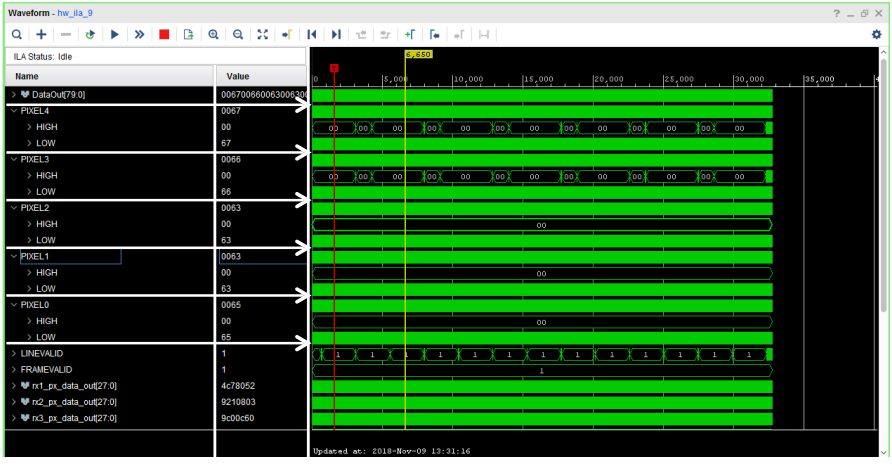


Camera Grabber Input

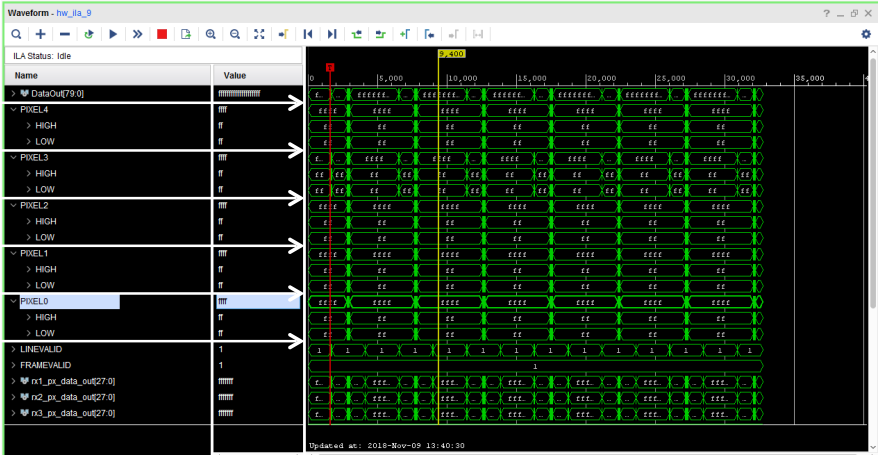


2410 samples@500MHz → 410 clocks@85MHz

Camera Grabber Input (Darkness)

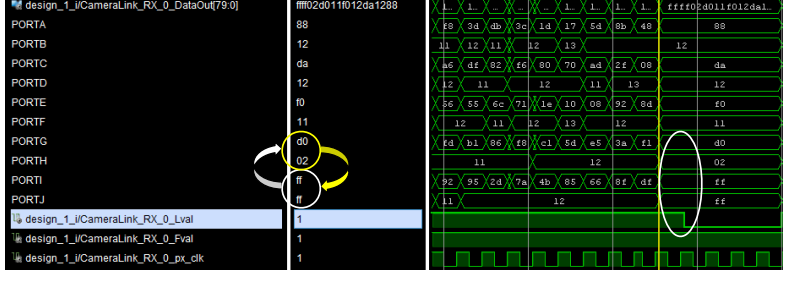


Camera Grabber Input (Saturated)



Port issue

According to datasheet port G and H should be 0xFF at end of each line (last clock cycle before lval goes low). Port I and J should be a fixed value (Line info). Seems like G and H are swapped with I and J.



Ongoing and future Work

- Tosca IIb/III implementation
- Camera configuration over Camera Link
- Display frames through HDMI FMC