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Synchronous shutter, PSN limited, HDR image sensor

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Outline

- Need for HDR, Synchronous Shutter Imaging
- “Consumer” HDR imaging
- 3-Level TG method
  - Pixel - Topology
  - Pixel - Principle
  - Merging of pixel gains
- Measurements
- Conclusions

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Need for HDR Imaging

Why we need HDR imaging?

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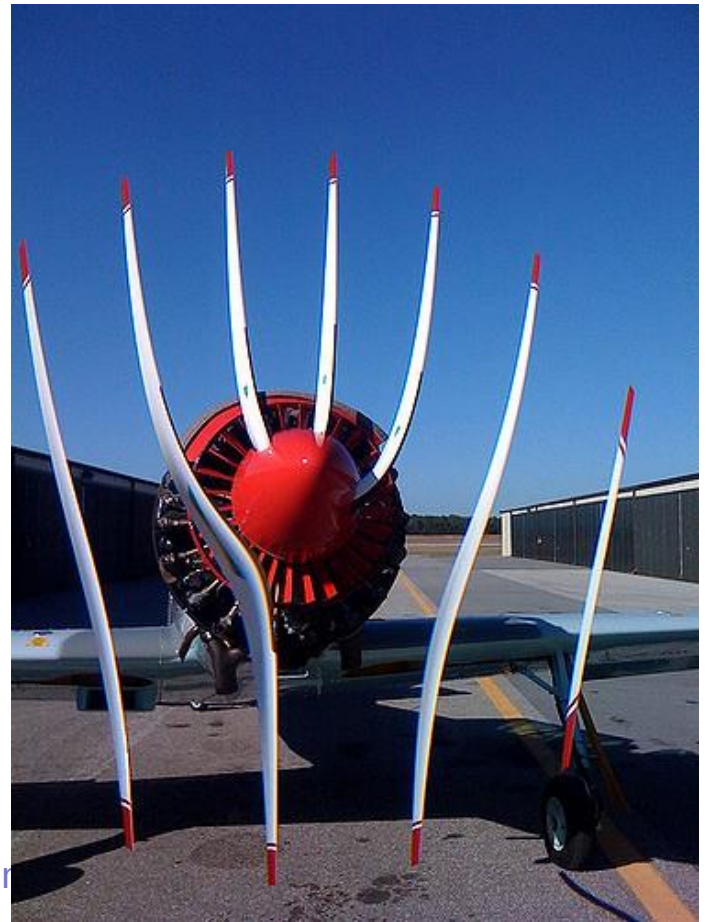
Most natural scenes contains intensities varying from >100000 lx to <1lx

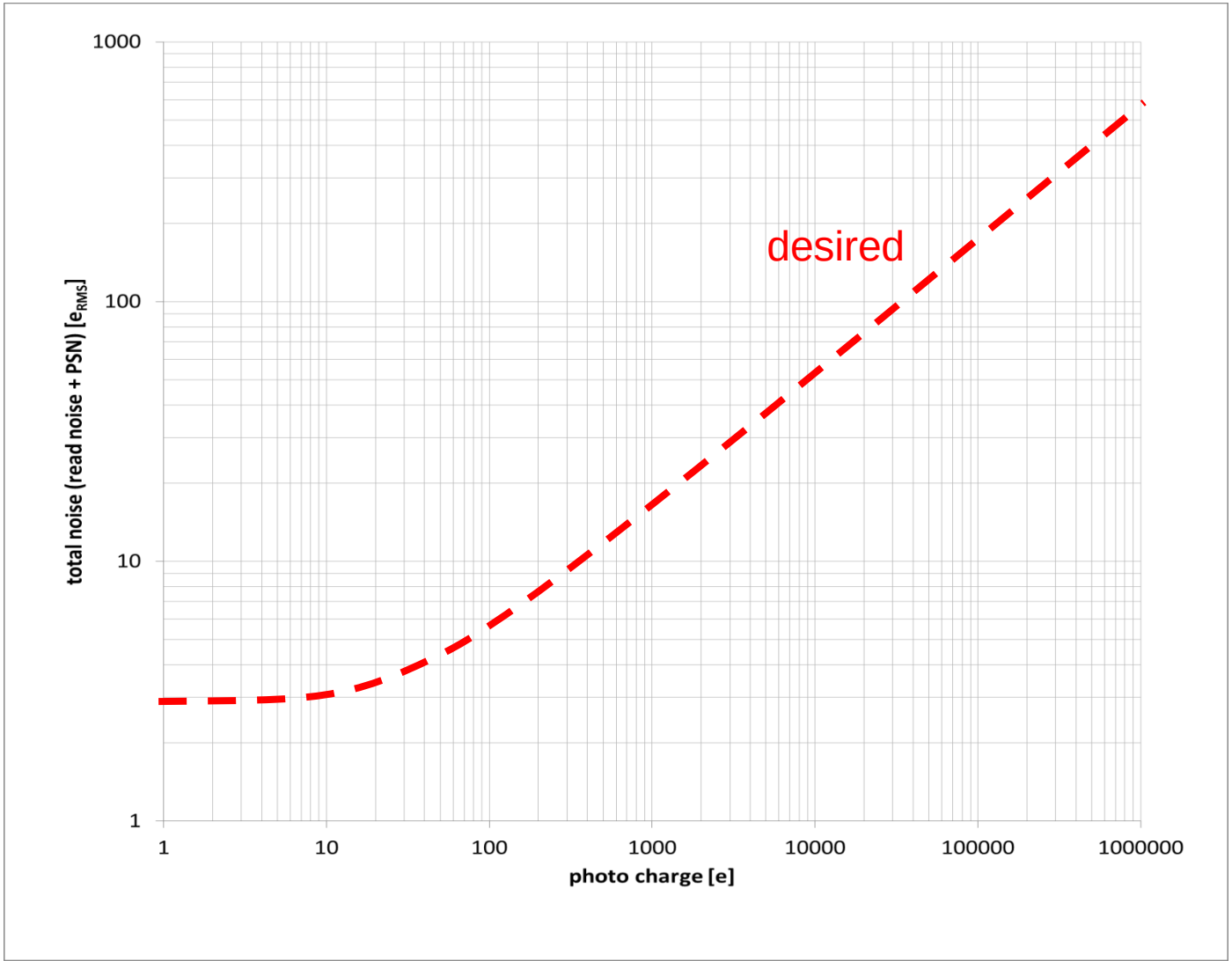
Why we need Synchronous shutter?

Synchronous shutter (“Global” shutter) is required for capturing images without motion artifacts



Noise – State of the art

CDS limited read noise at dark and PSN limited performance at higher light levels



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Need for HDR imaging
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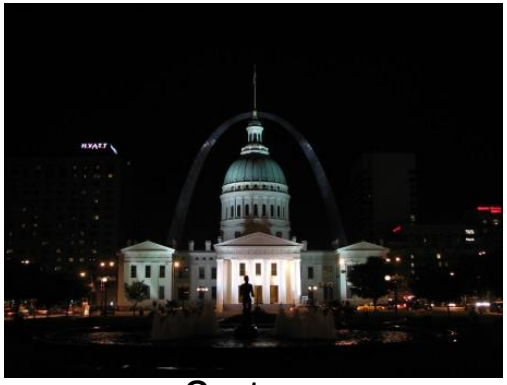
Consumer HDR Imaging

“Consumer” HDR imaging

- Most methods are based on bracketing (capturing images for different exposure time) or other equivalent methods
- Pro - Can capture high dynamic range static scene
- Con - Cannot capture high dynamic range moving scene without artifacts

- 4 stops



- 2 stops

2 stops

4 stops

Local tone mapped image

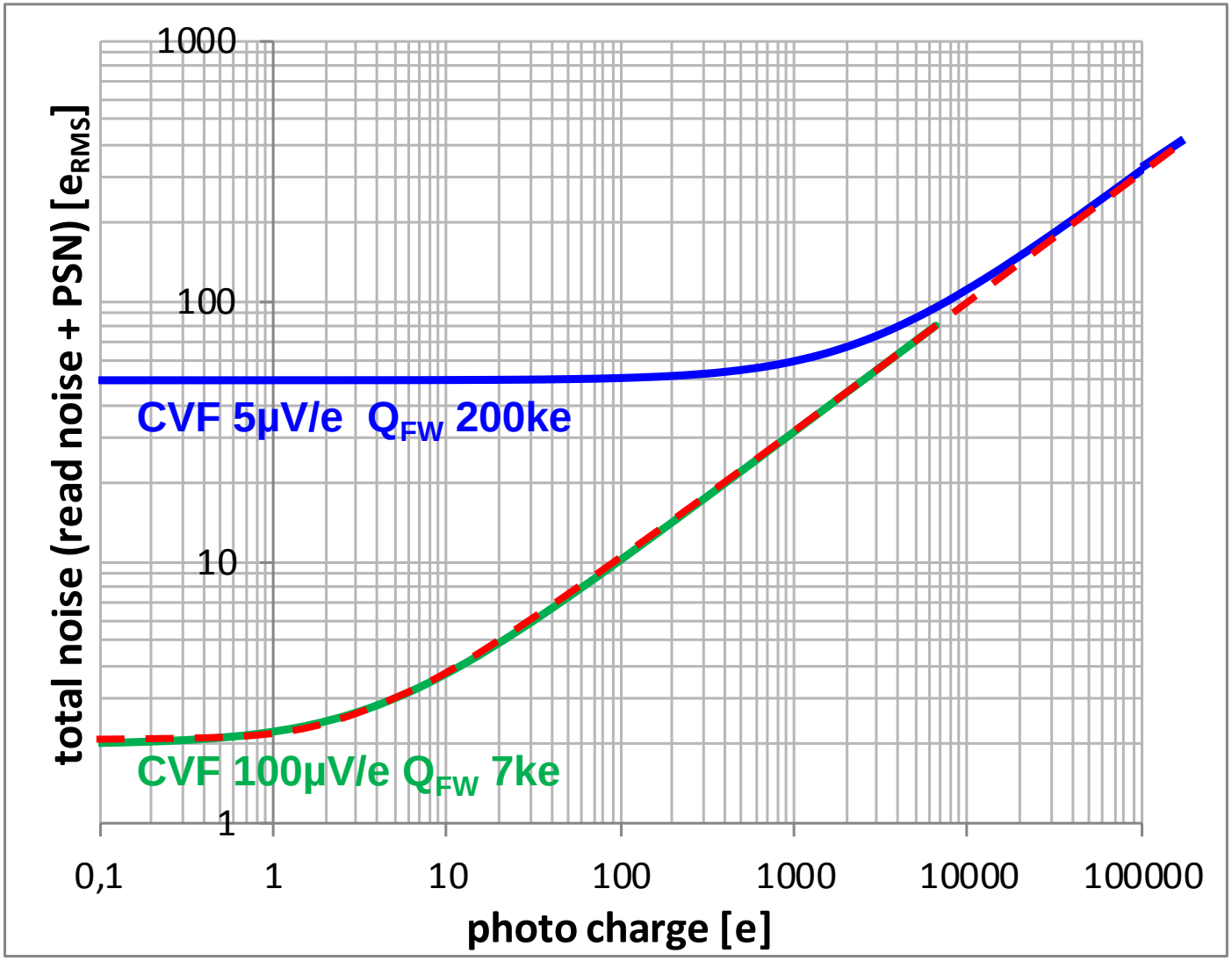
(source - https://en.wikipedia.org/wiki/High-dynamic-range_imaging)

Desirable features

	Caeleste Device A	Caeleste Device B	Caeleste Device C	Caeleste Device D
Pixel pitch (µm)	8	8	50	15
Pixel array	4Kx2K	4Kx4K	200x600	4Kx4K
Full well (e^-)	250K	350K	2.2M	170K
Read noise (e^-)	< 2	<6	<15	<10
Non-Linearity (% of FW)	< 1	< 2	< 0.2	< 1
Shutter/ Integration modes	IWR	IWR	IWR	IWR

*IWR: Integrate While Read

Desirable features



High Q_{FW} range:
DR=200000/50=4000:1

Low Q_{FW} range:
DR=7000/2=3500:1

Combination
DR=200000/2
=100000:1 **100dB**

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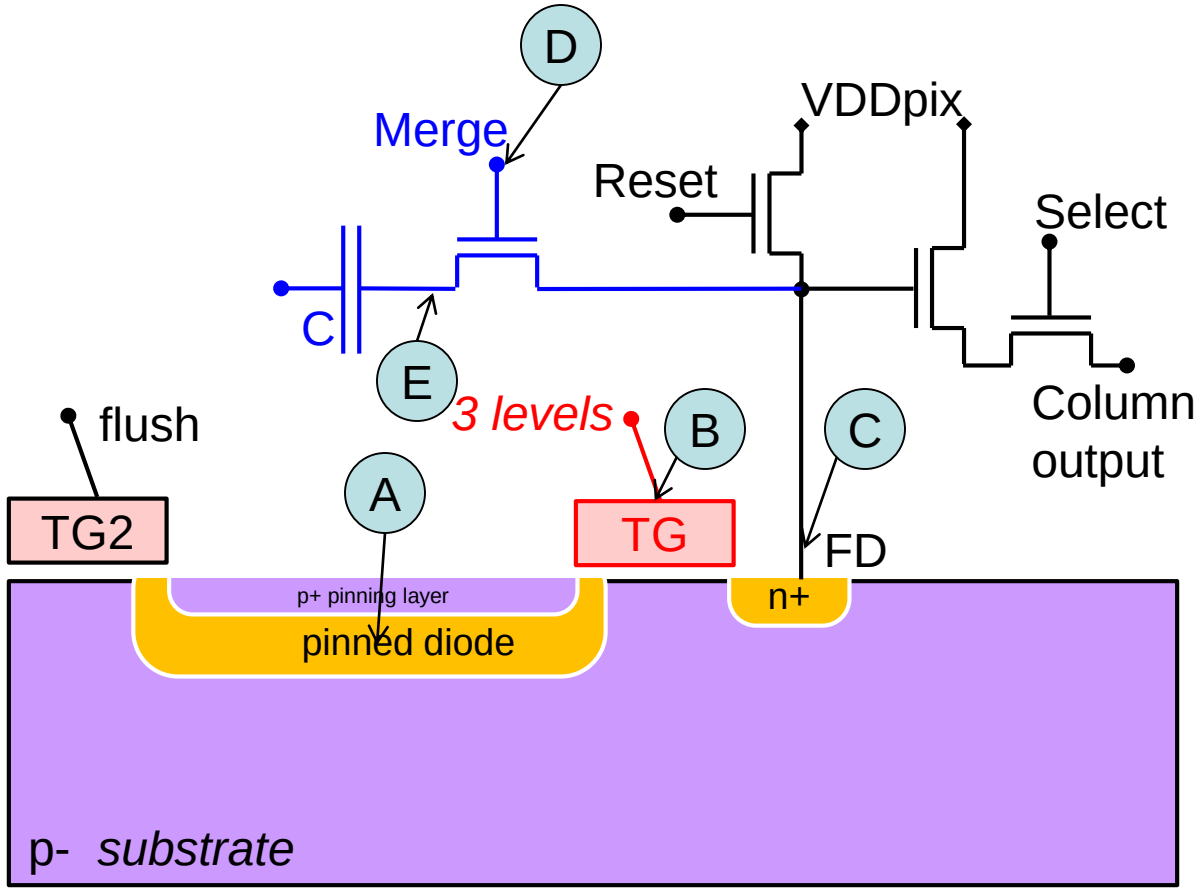
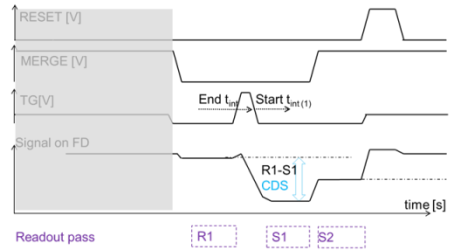
3 – Level TG Method

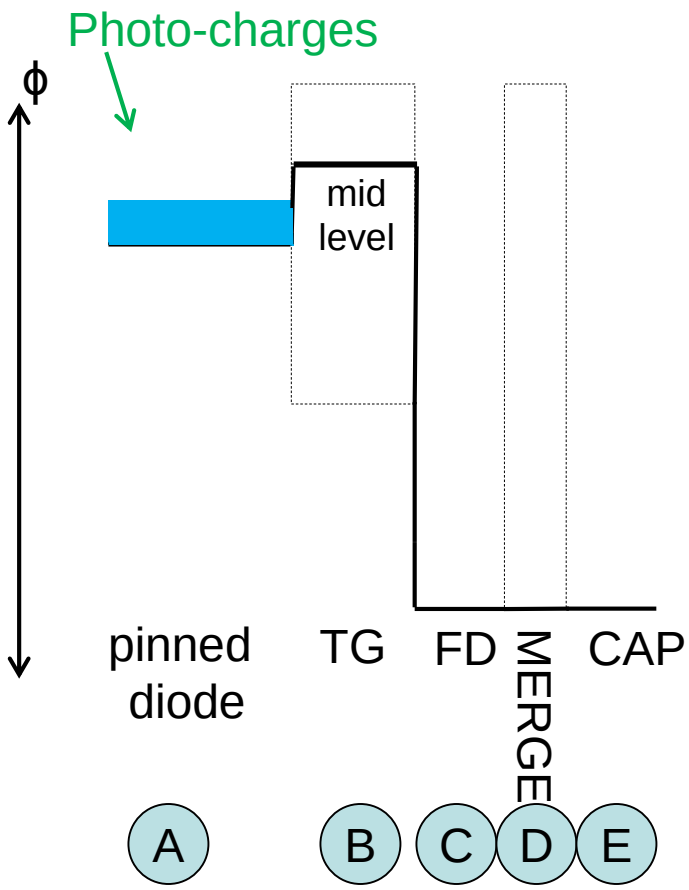
3 – Level TG Pixel - Topology



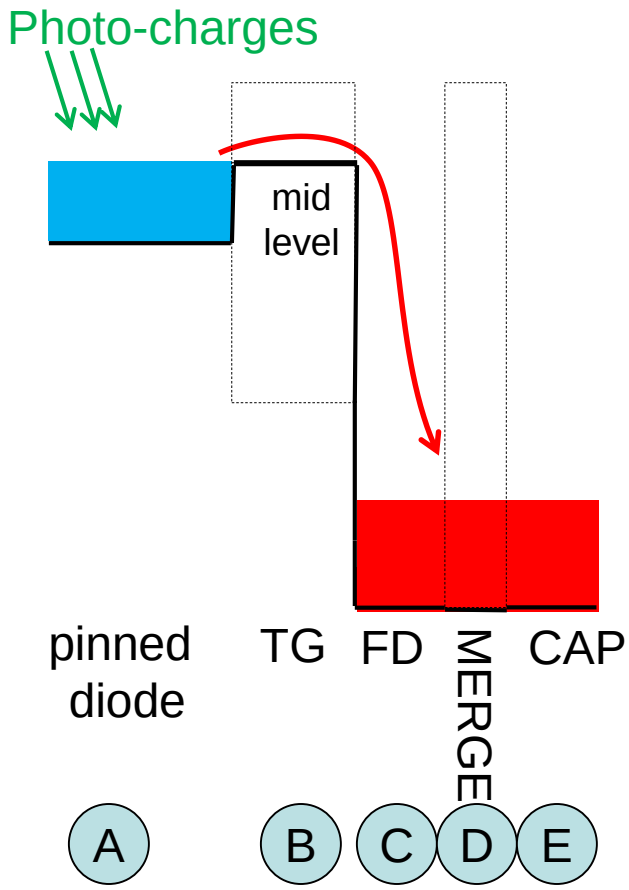
During Integration



Low Illumination

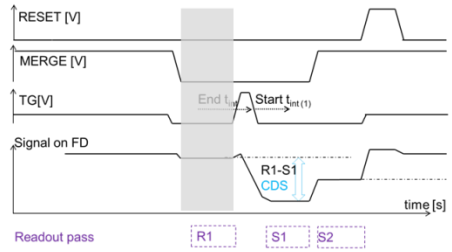


High Illumination



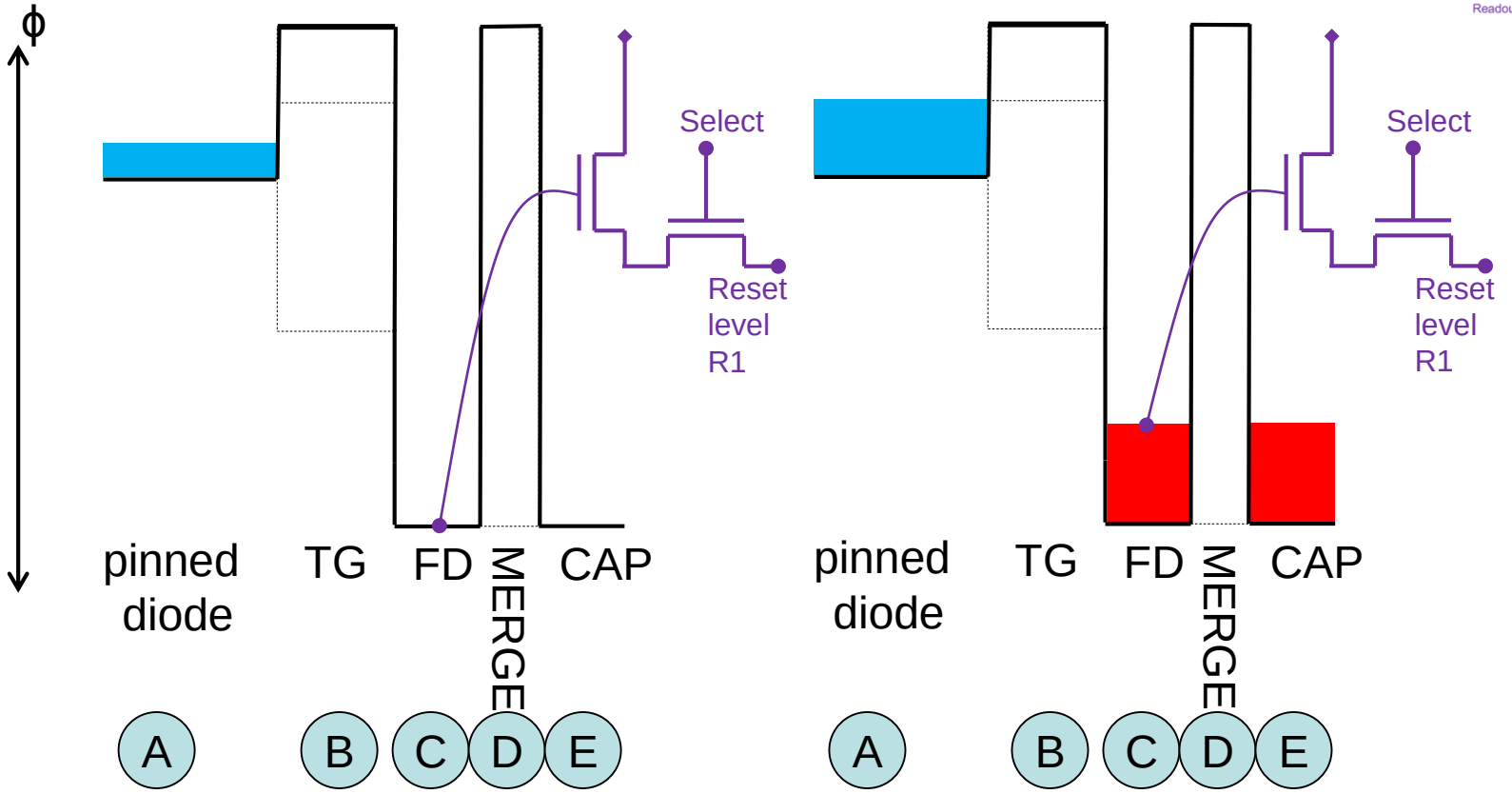
TG is set to “barrier” potential

Reset readout “R1”



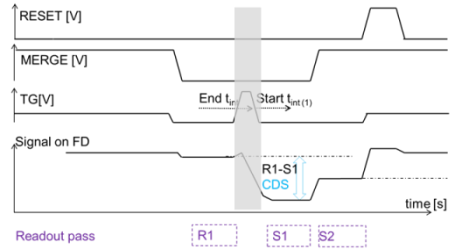
Low Illumination

High Illumination

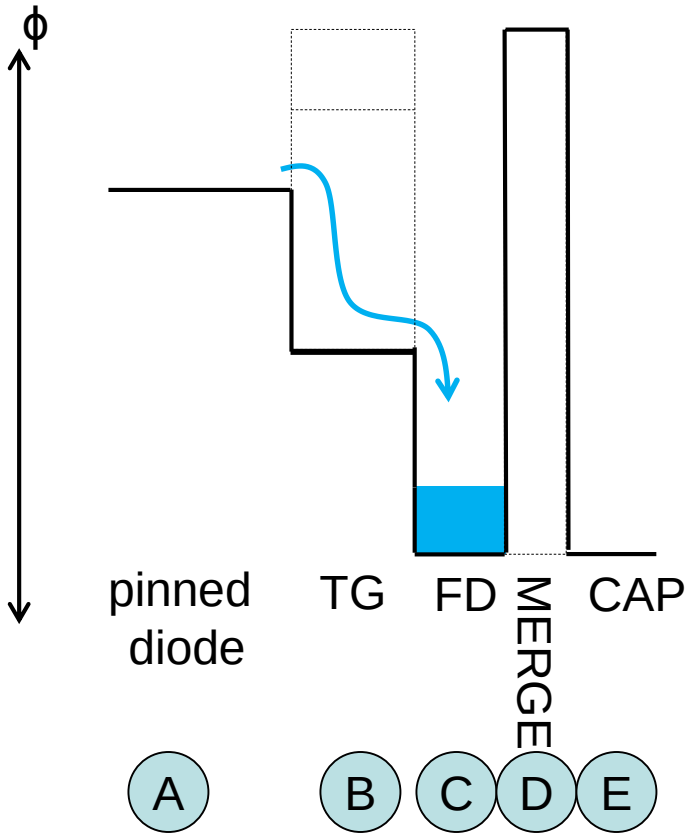


TG and MERGE is turned OFF

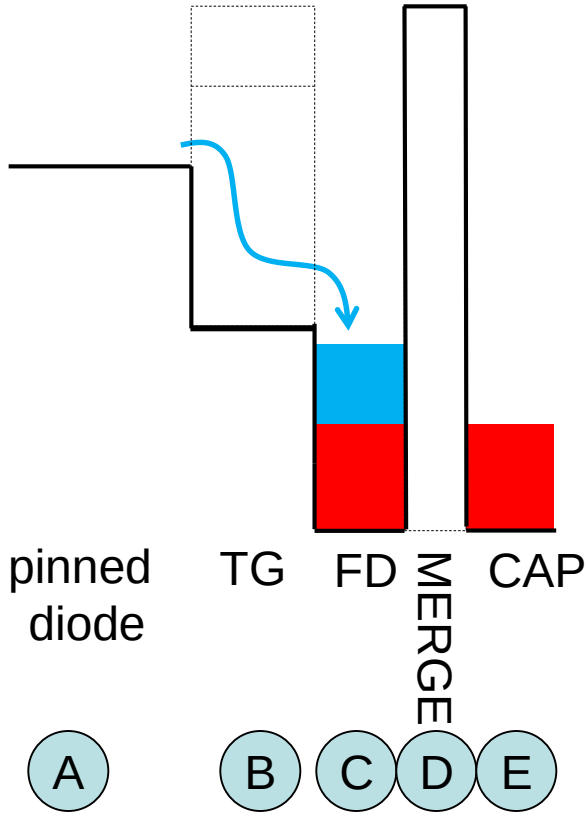
Charge transfer from PPD to FD



Low Illumination

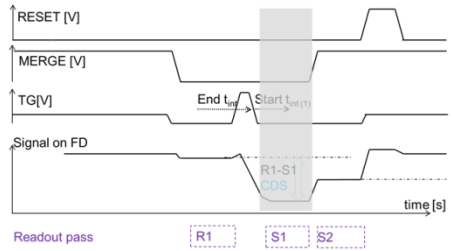


High Illumination

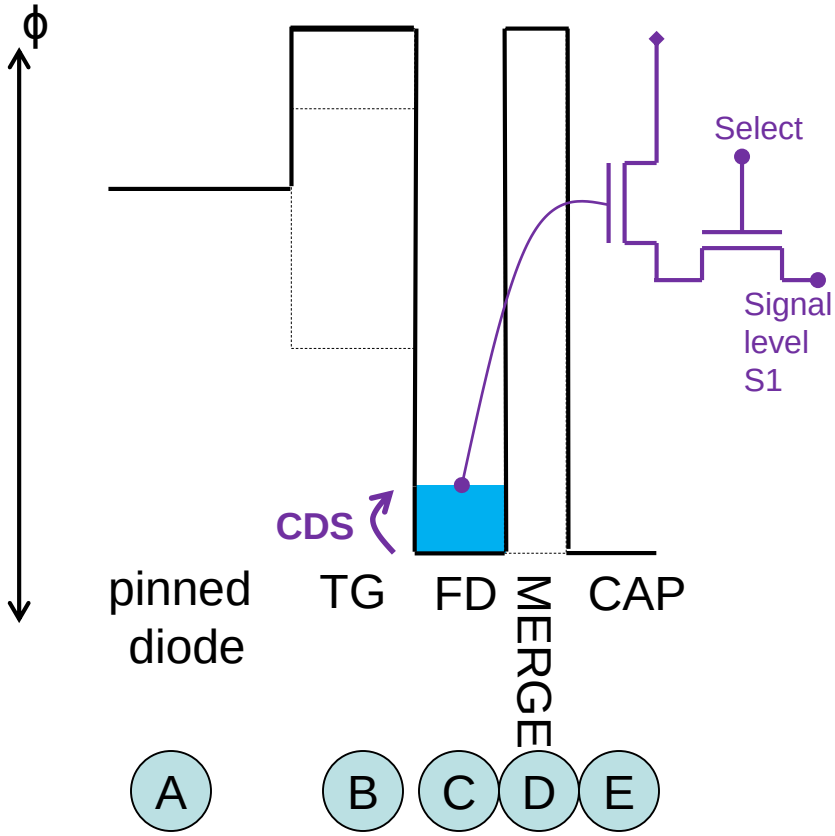


TG is turned ON: remaining photocharge flows into FD. TG is turned OFF

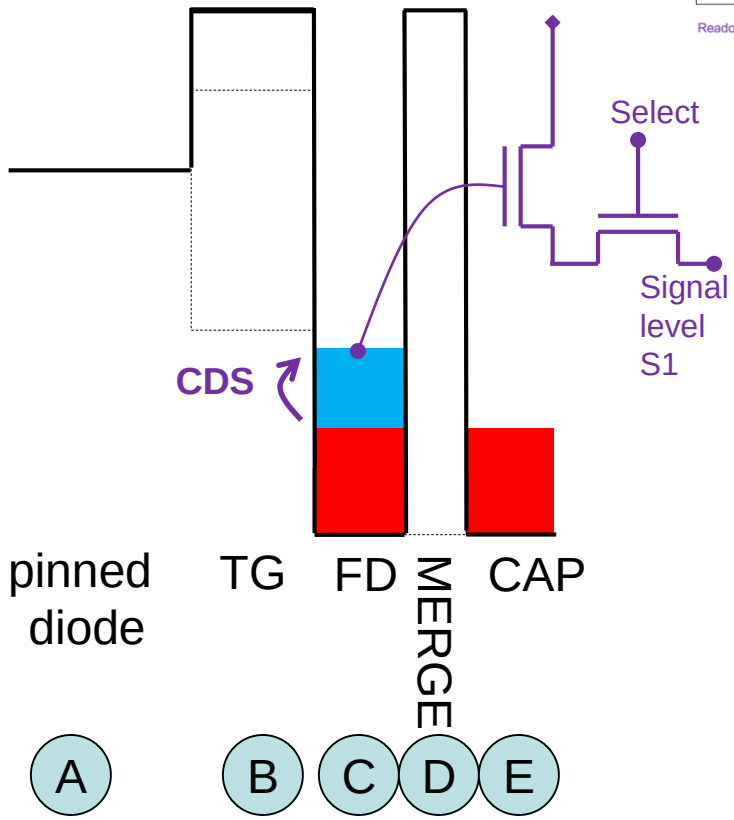
Signal readout “S1” and CDS



Low Illumination



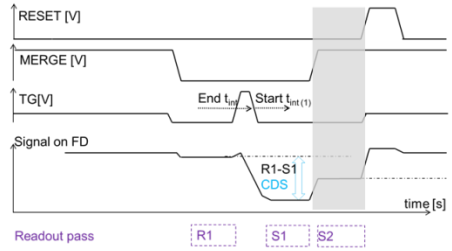
High Illumination



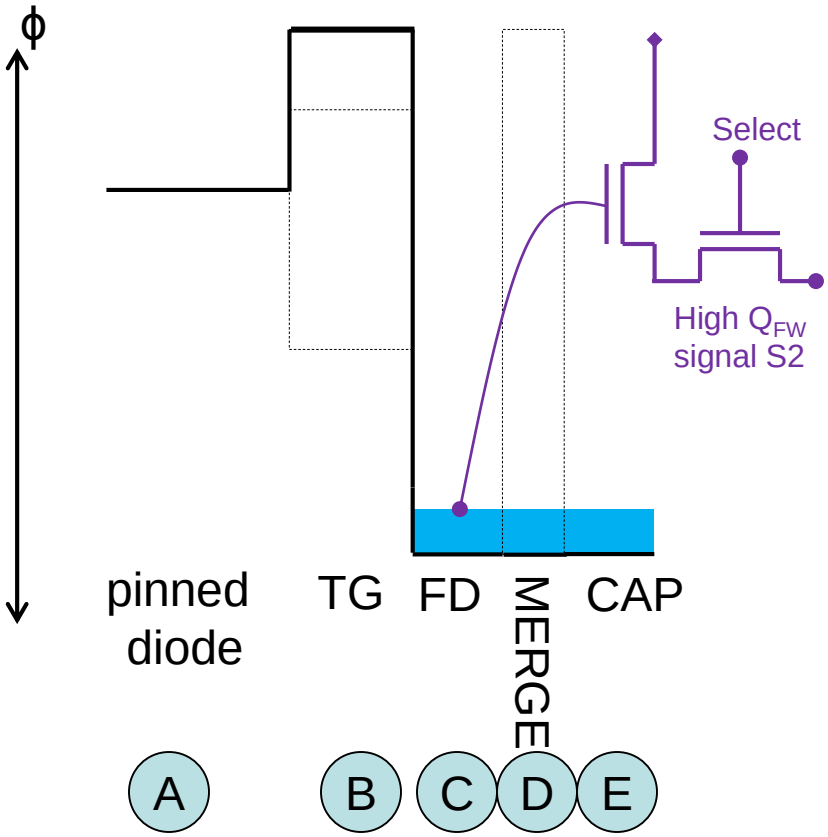
TG is turned ON: remaining photocharge flows into FD. TG is turned OFF

Downstream CDS must be done.

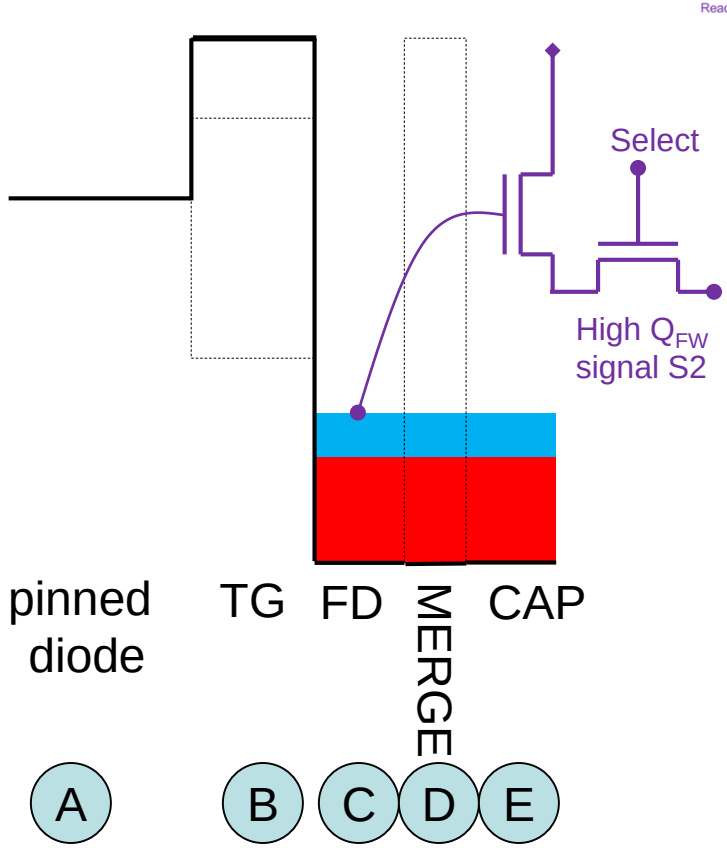
High Q_{FW} Readout "S2"



Low Illumination

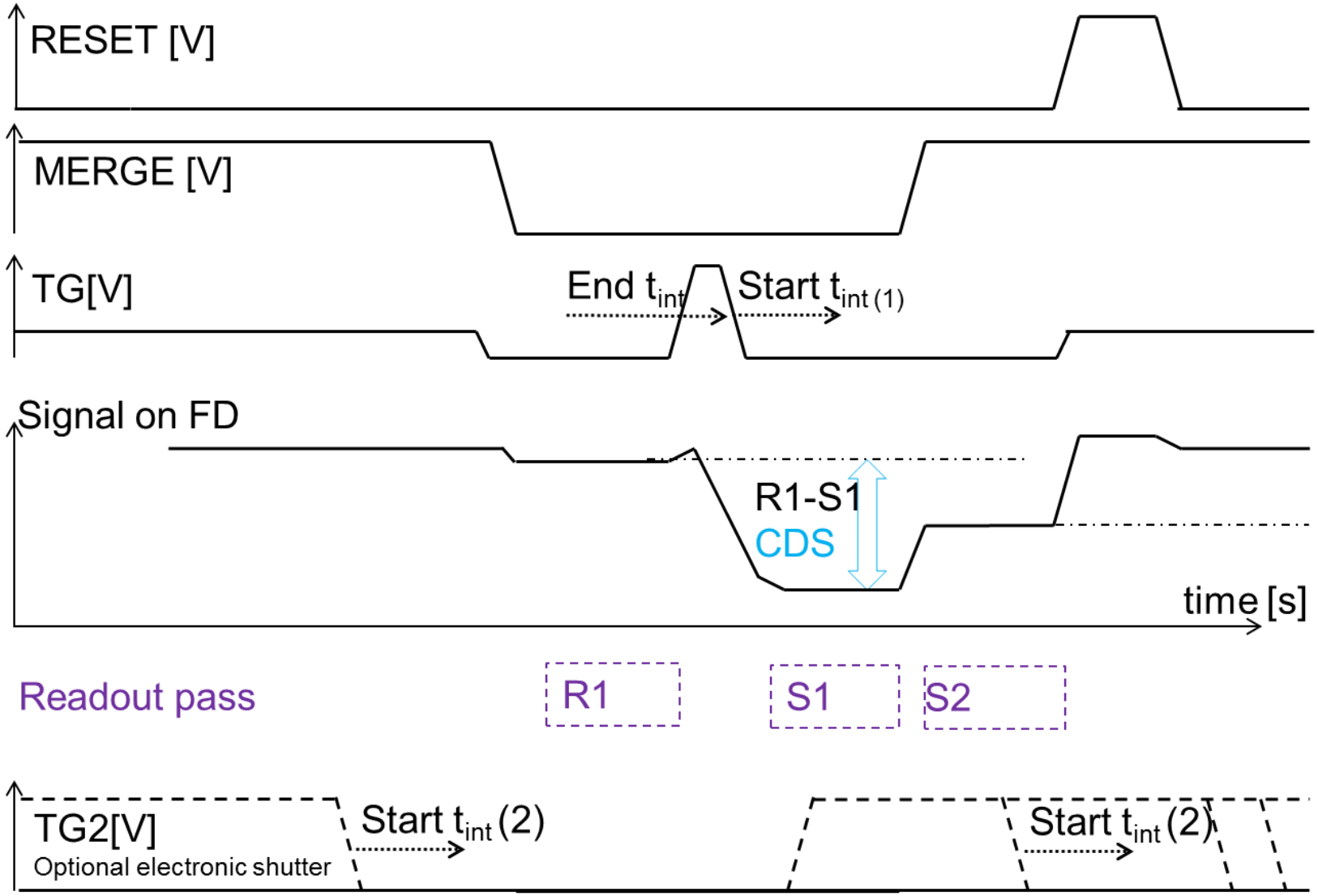


High Illumination



MERGE is turned ON: Read all the "high Q_{FW}" signal from FD

Pixel – Timing Diagram



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Measurement Setup

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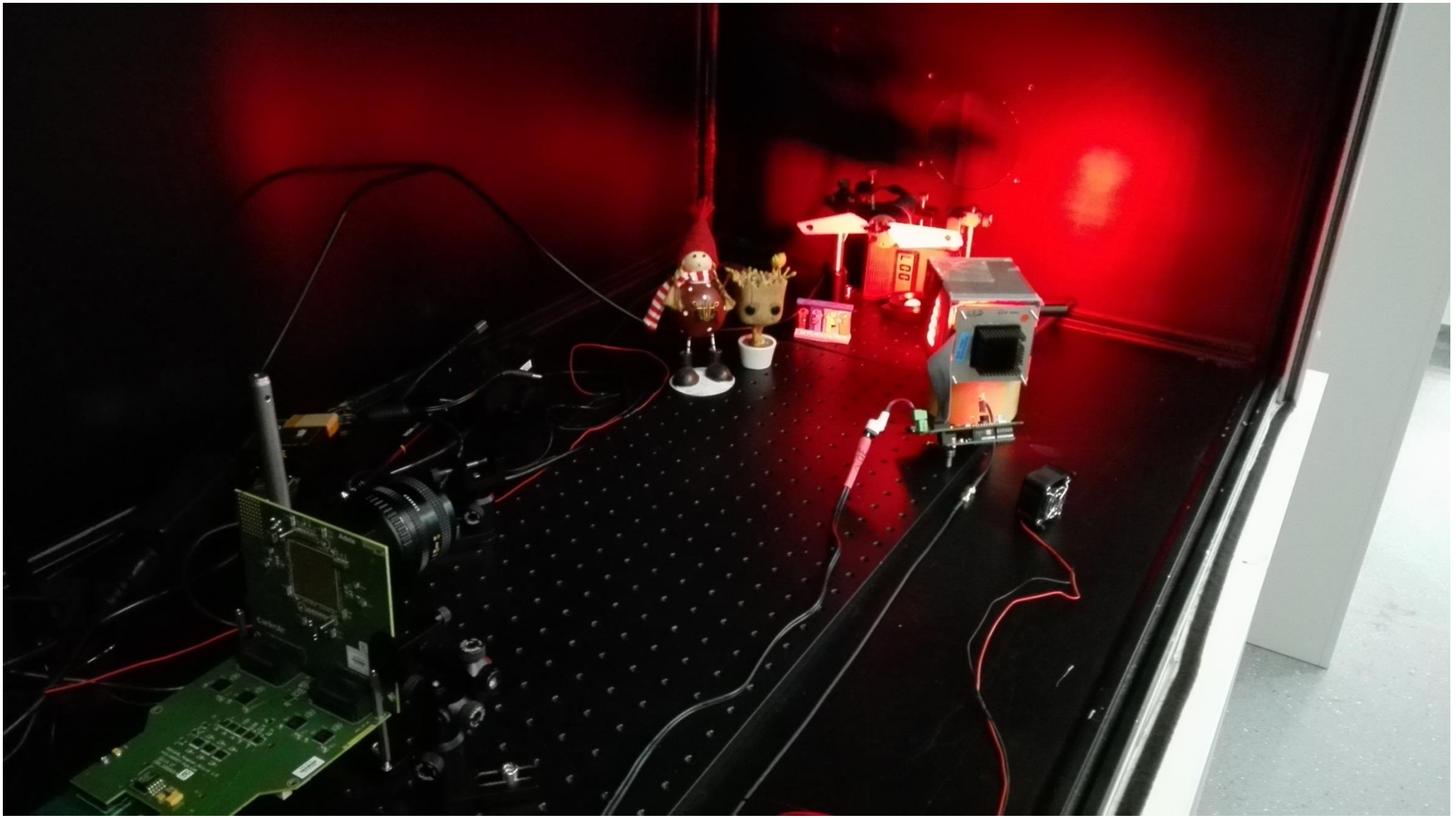

Merging of "Low Q_{FW}" and "High Q_{FW}" Images

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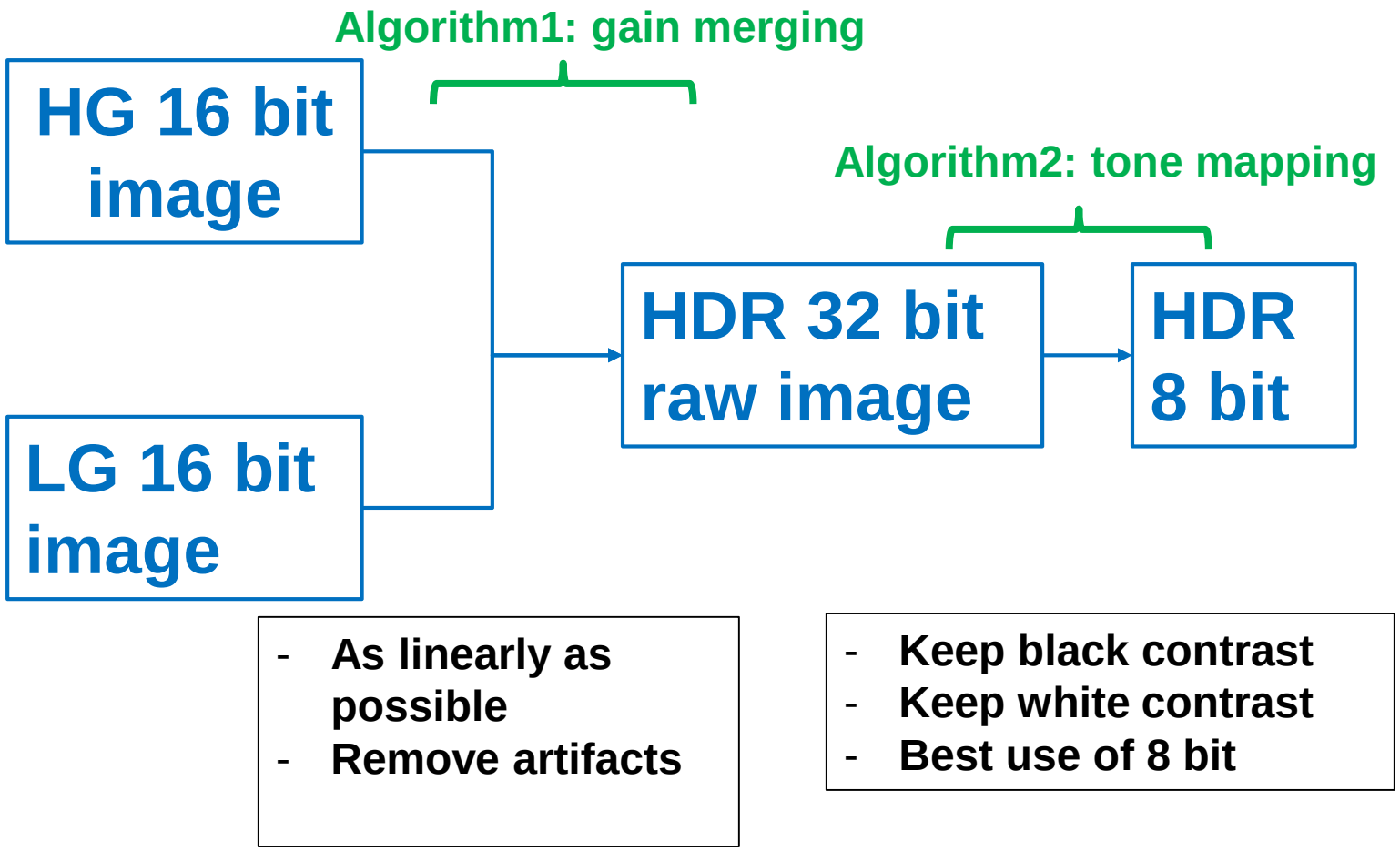

Measurement Results

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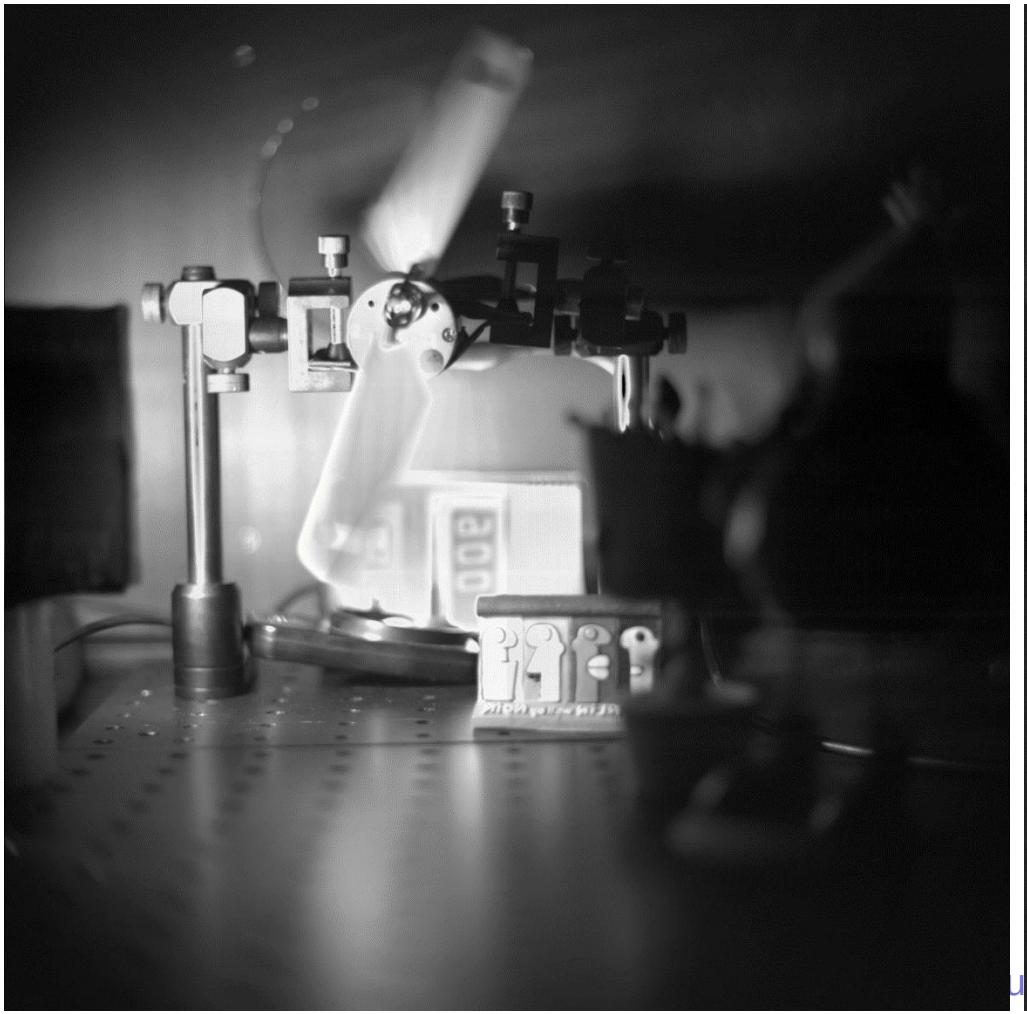
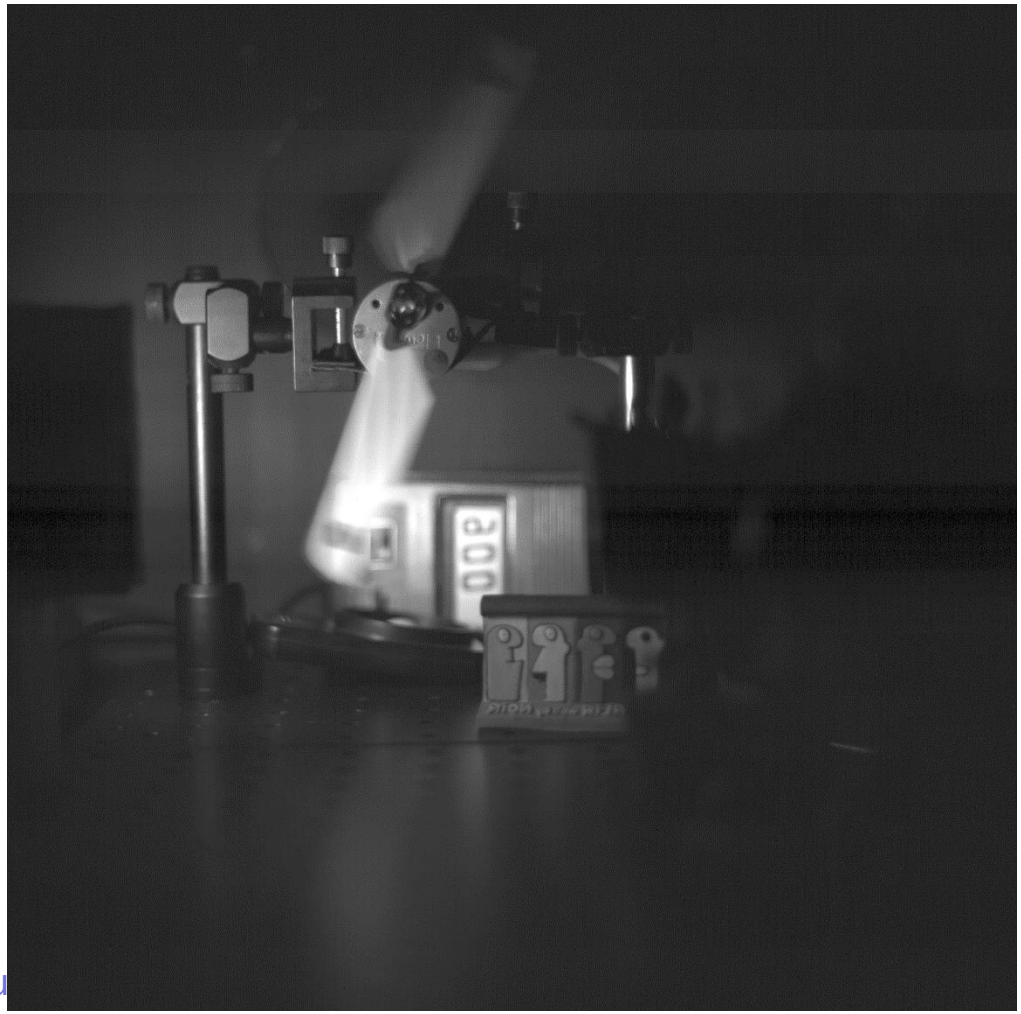
Low Q_{FW}



High Q_{FW}



Merged Images

Merged Images

Merged Images

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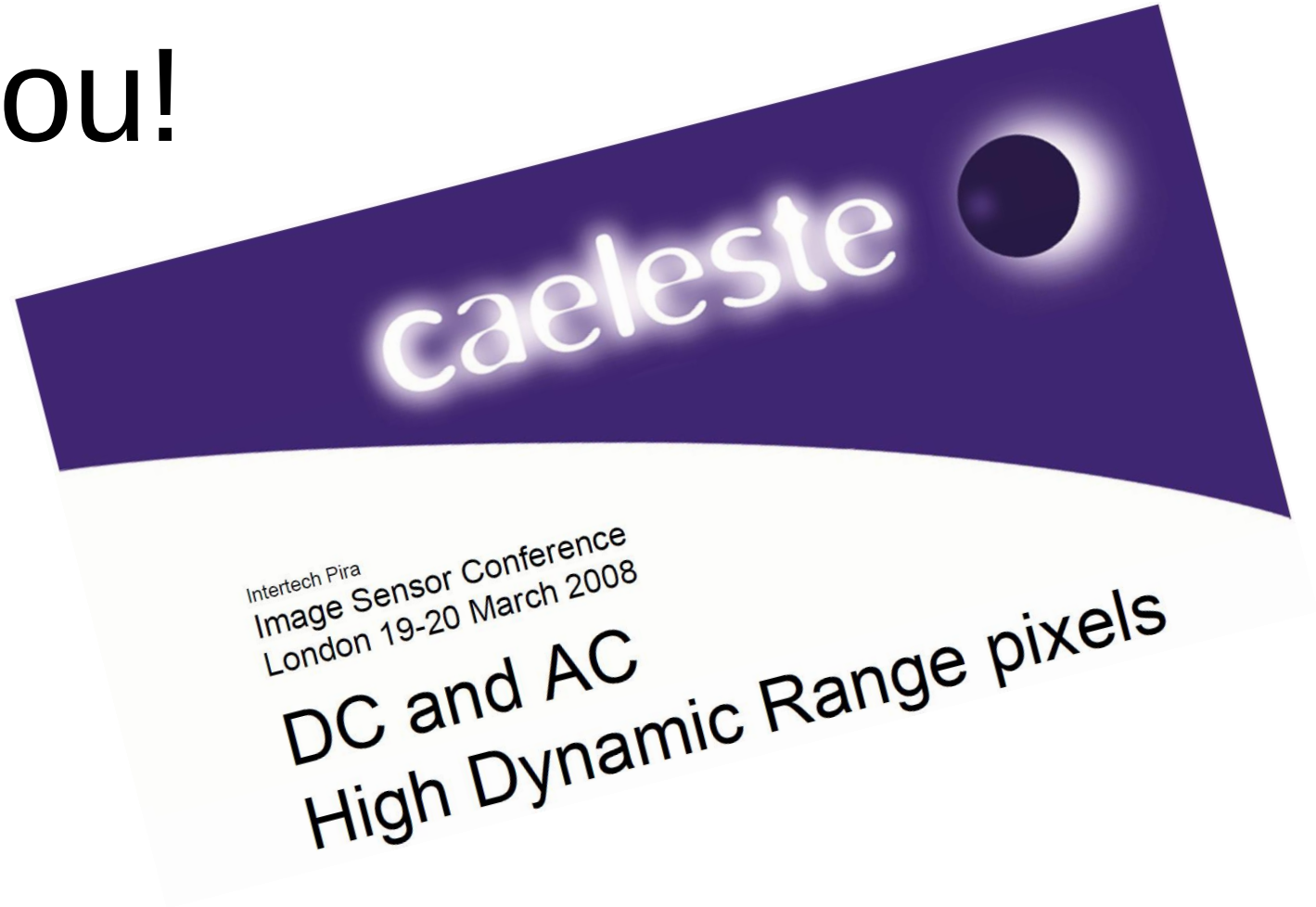
Demonstrated:

- ⇒ HDR using two linear ranges during same integration time
- ⇒ Synchronous (global, IWR) shutter operation
- ⇒ Both linear ranges are synchronous
- ⇒ The highest sensitivity range operates in digital CDS.

Room for improvement?

- ⇒ Color (coming)
- ⇒ BSI (coming)
- ⇒ Global shutter CIS technology (coming)

Thank you!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Intertech Pira
Image Sensor Conference
London 19-20 March 2008
DC and AC
High Dynamic Range pixels