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FLAMES

High-Speed Flash-LiDAR CMOS Imager for Landing Missions

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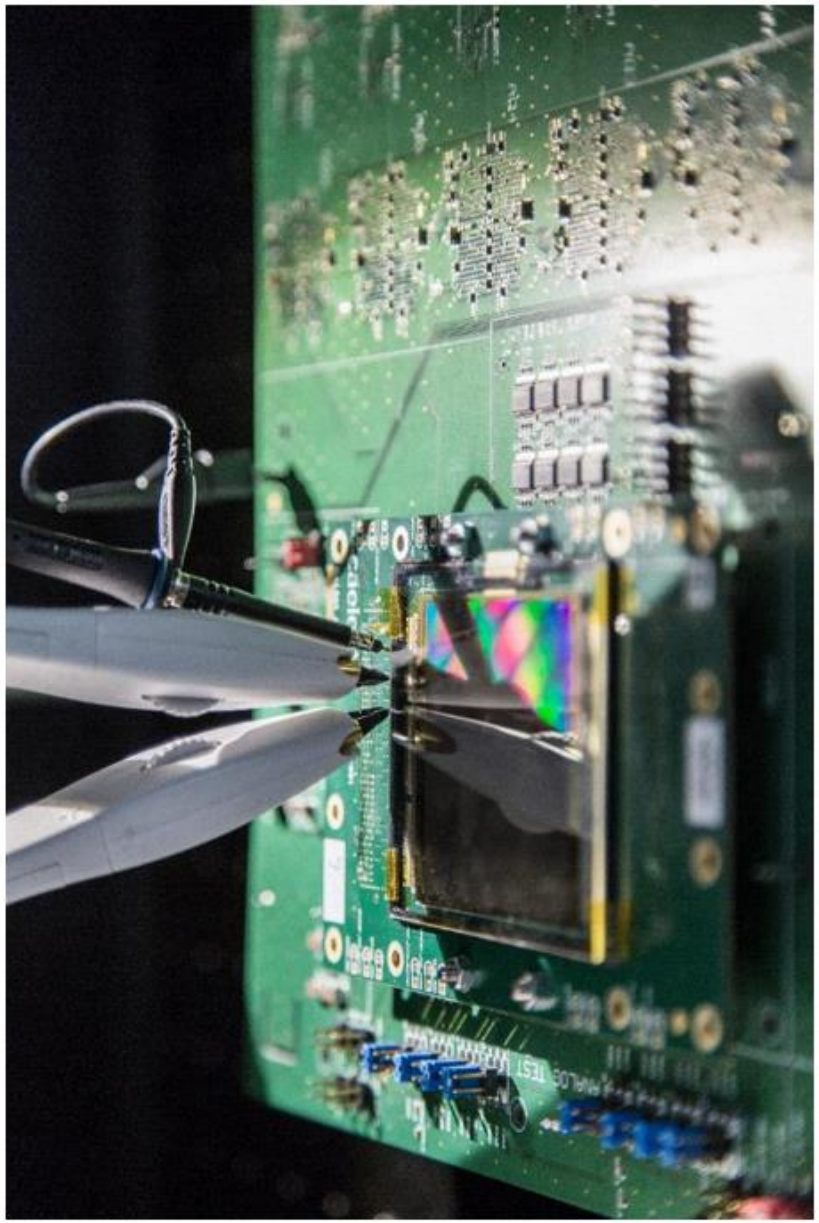
Outline

- Who we are
- Motivation
- Pixel concept
- Architecture of the sensor
- Simulation results
- Conclusions & Outlook

WHO WE ARE

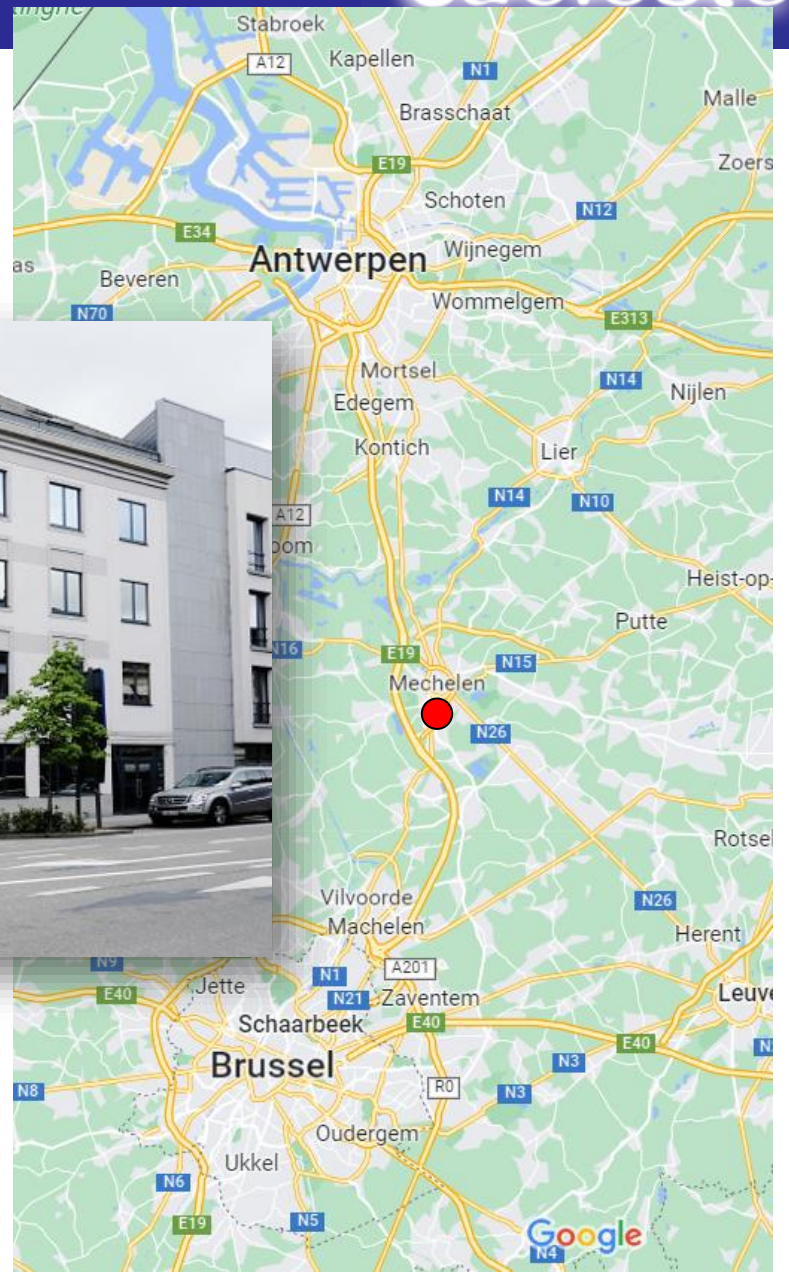
Caeleste's mission



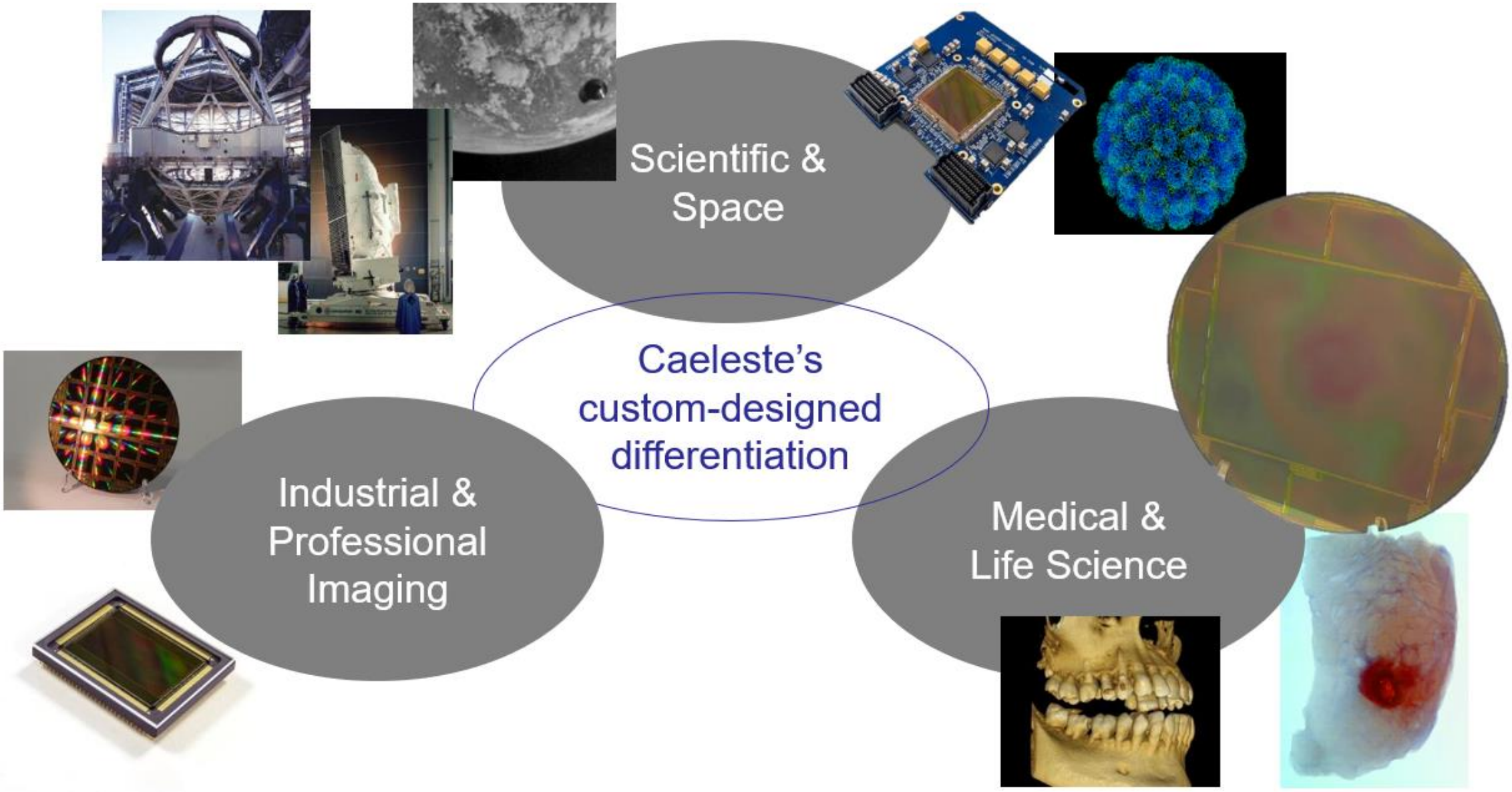
Be the supplier
of
beyond state-of-the-art
custom-designed
CMOS image sensors

Who we are

- Address:
  - Hendrik Consciencestraat 1b, 2800 Mechelen, Belgium
- Staff:
  - ~ 40 people



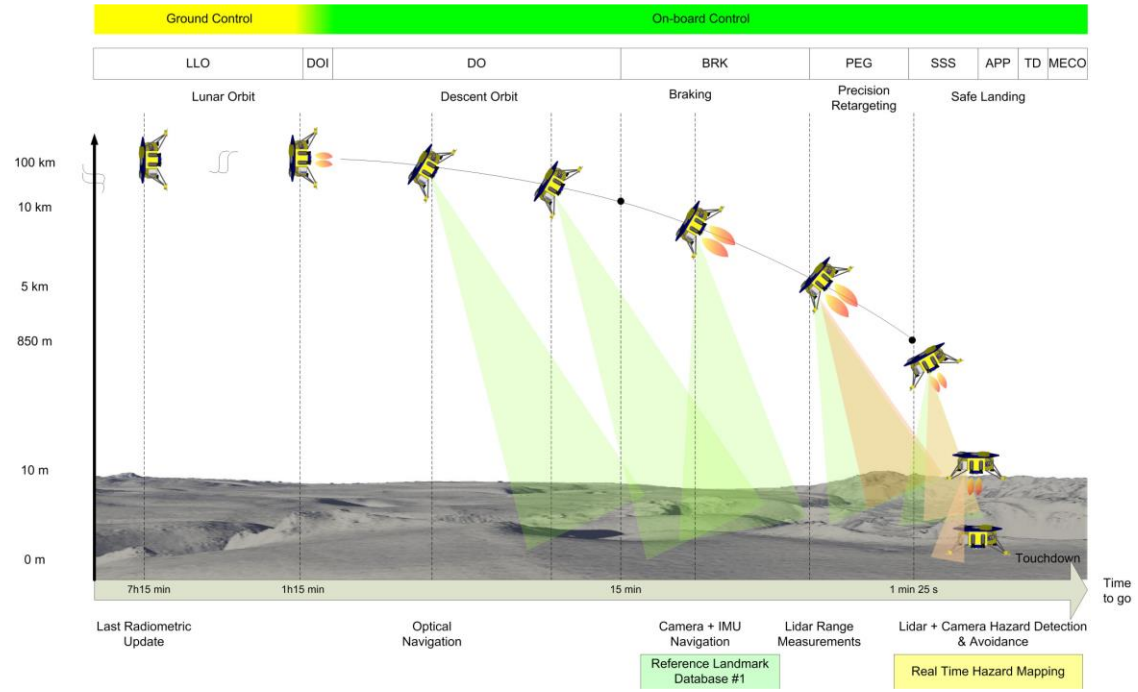
Business focus



MOTIVATION

Motivation

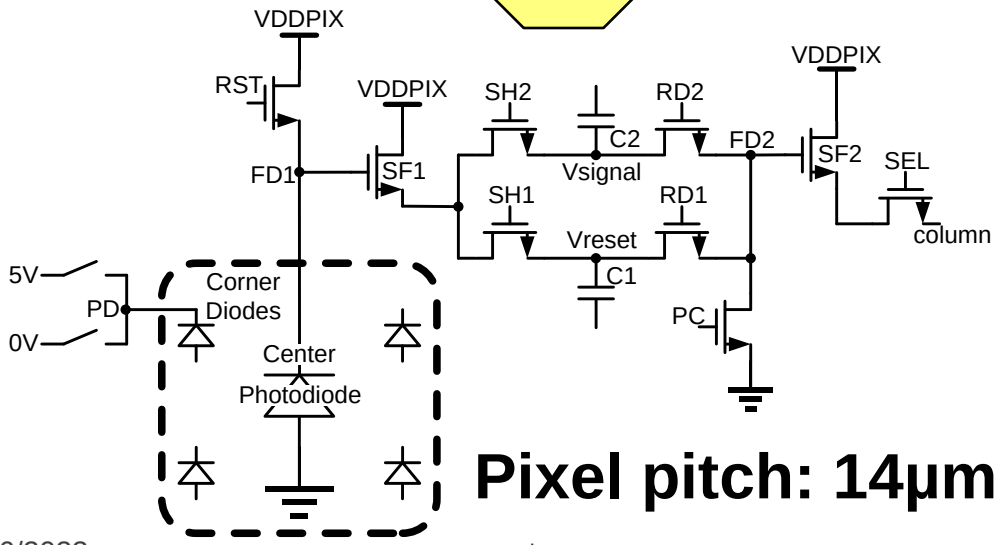
- LiDAR for space applications:
  - Controlled soft landing
  - Navigation of rovers
  - Rendezvous of spacecrafts
- Flash vs Scanning LiDAR:
  - Flash LiDAR Can be smaller and lighter
  - Significant higher measurement rate than scanning LiDAR
  - No moving parts for Flash LiDAR



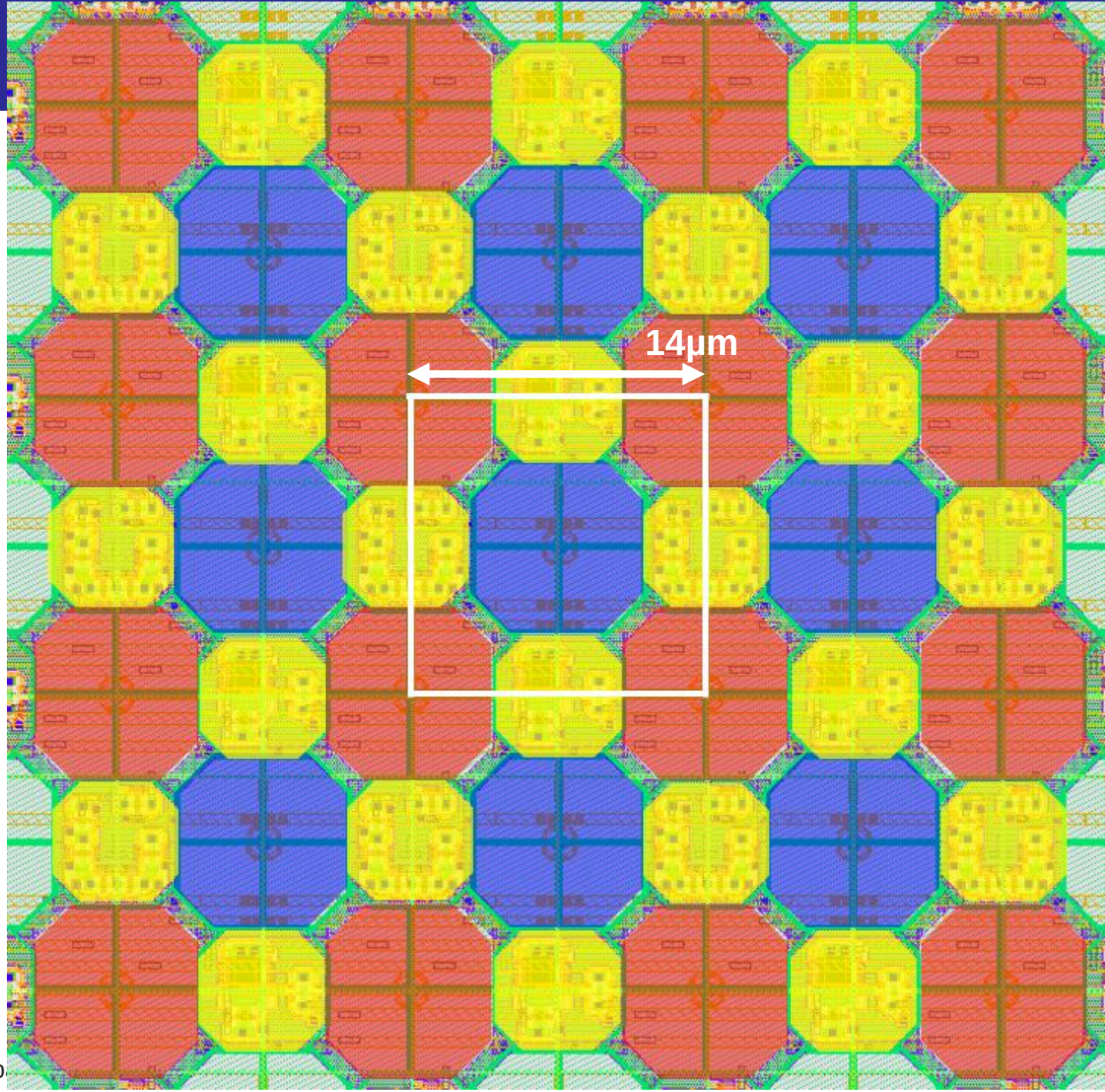
PIXEL CONCEPT

Pixel concept

- **Collecting photodiode:**
  - centered
  - collect photoelectrons
- **Non-collecting photodiodes:**
  - 4 corners
  - modulate the sensitivity of collecting photodiode
- **Transistors:**

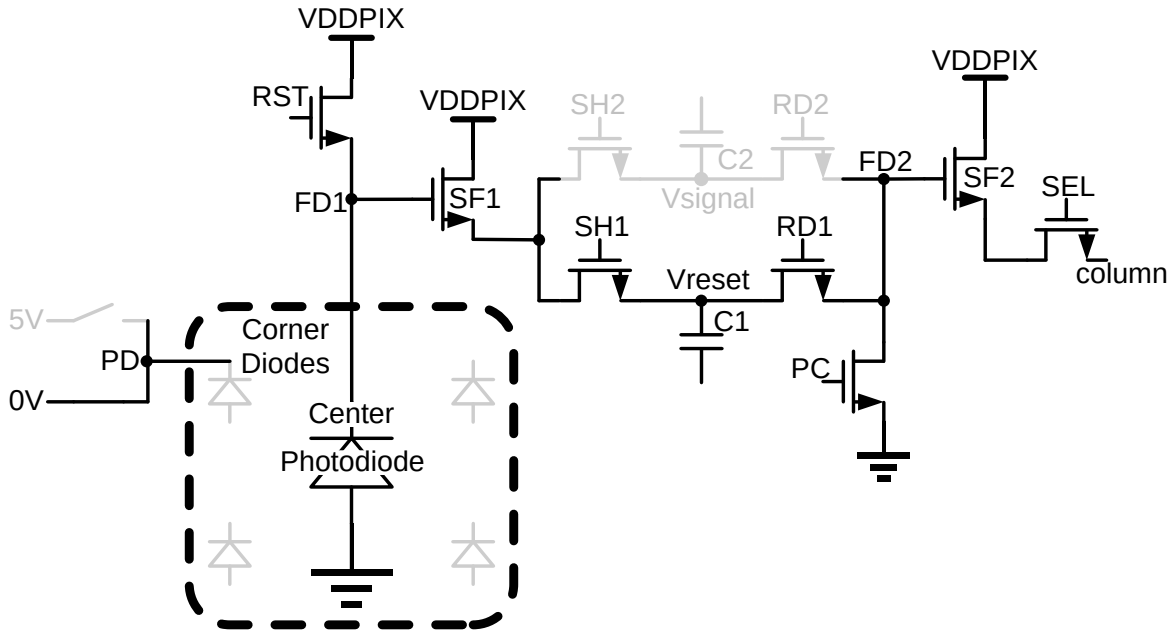


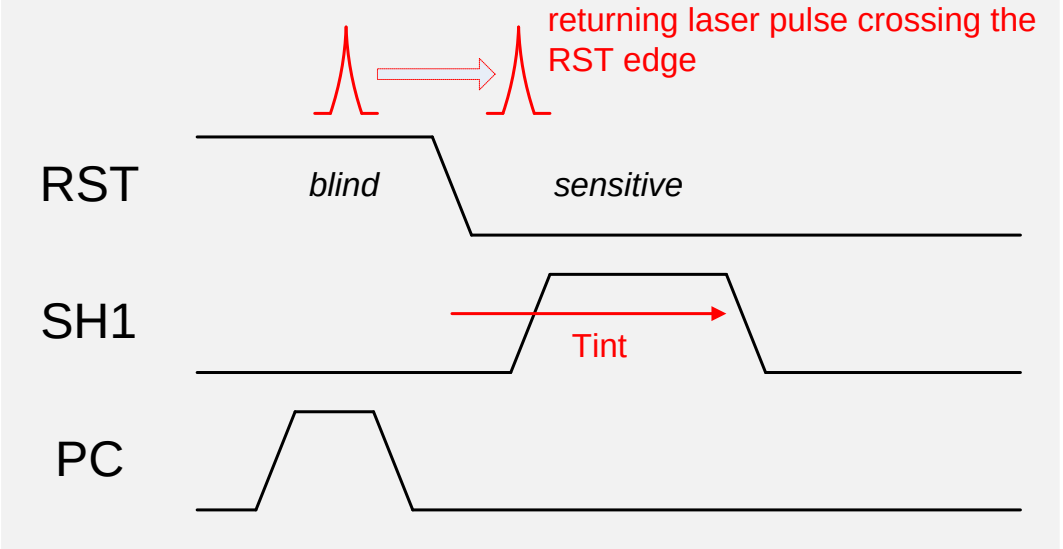
Pixel pitch: 14µm



RM1: time gating with RST, no CDS

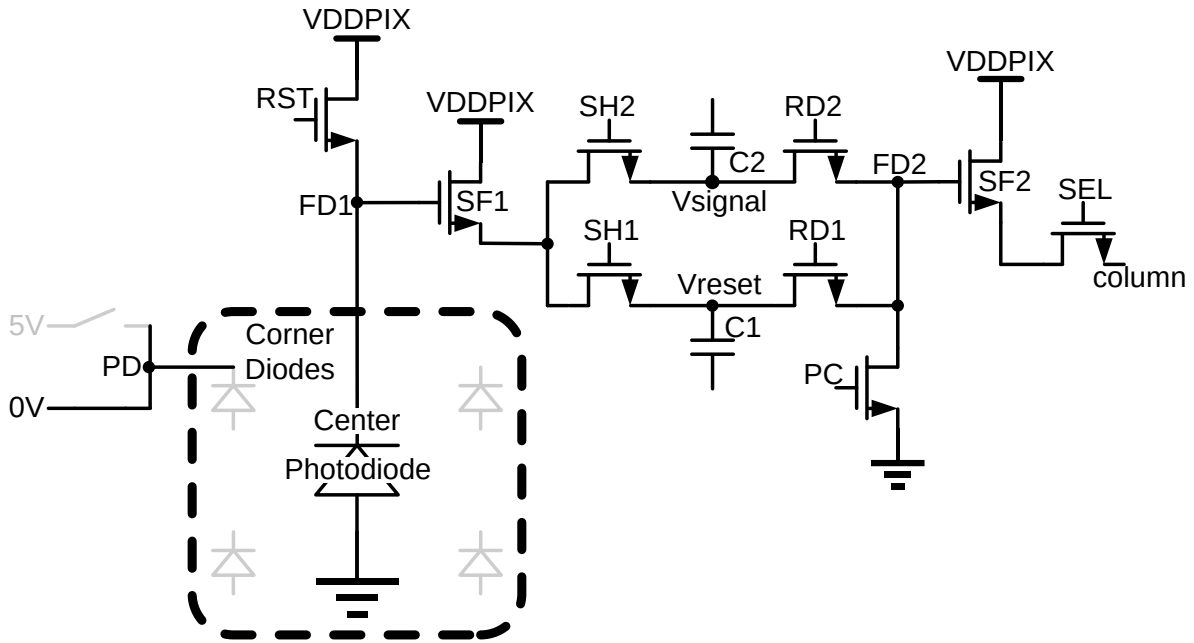
- Returning laser pulse crossing the falling edge of RST
- Signal can be sampled on C1 only or C1&C2
- No CDS (Correlated Doubling Sampling)

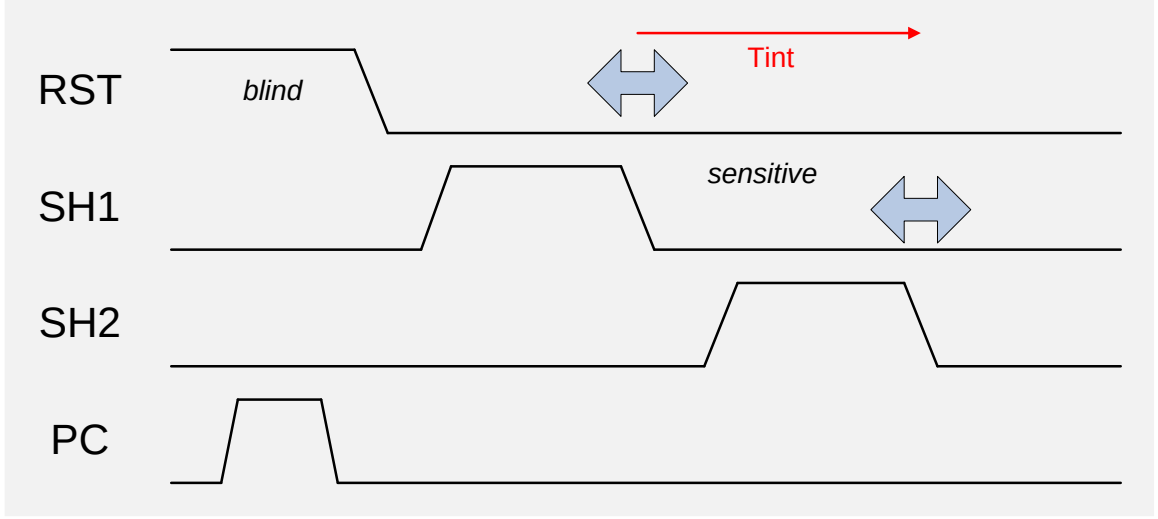




RM2: time gating with SH, CDS

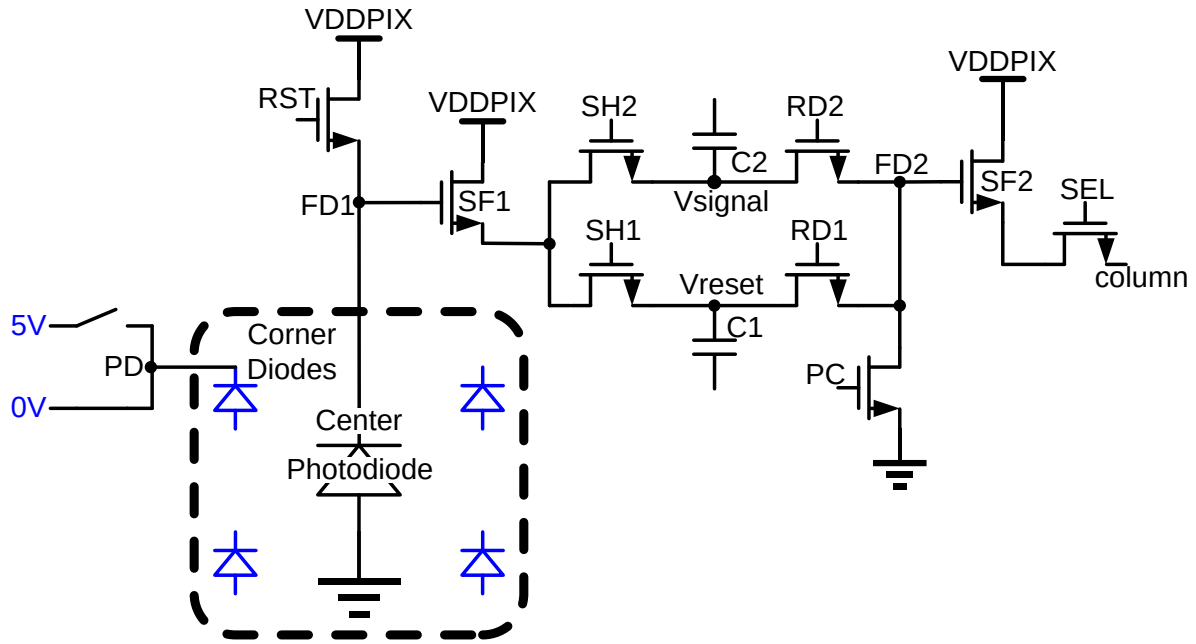
- Returning laser pulse crossing the edges of SH pulses
- Slower time gating due to limited S&H speed
- CDS used for low noise
  - RESET level on C1
  - SIGNAL level on C2

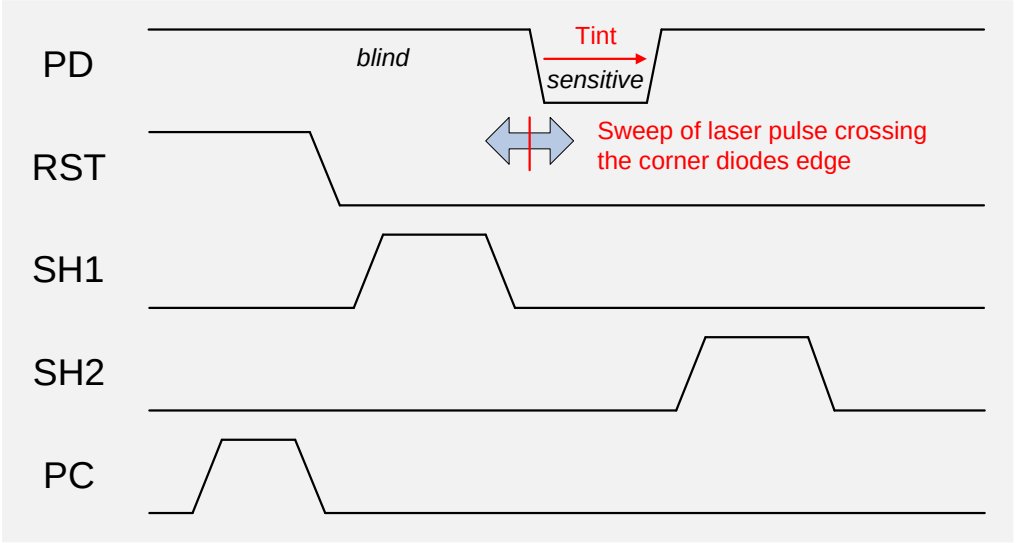




RM3: time gating with PD modulation, CDS

- Returning laser pulse crossing the edges of PD modulation pulse
- Faster time gating than RM2
- CDS used for low noise
  - RESET level on C1
  - SIGNAL level on C2

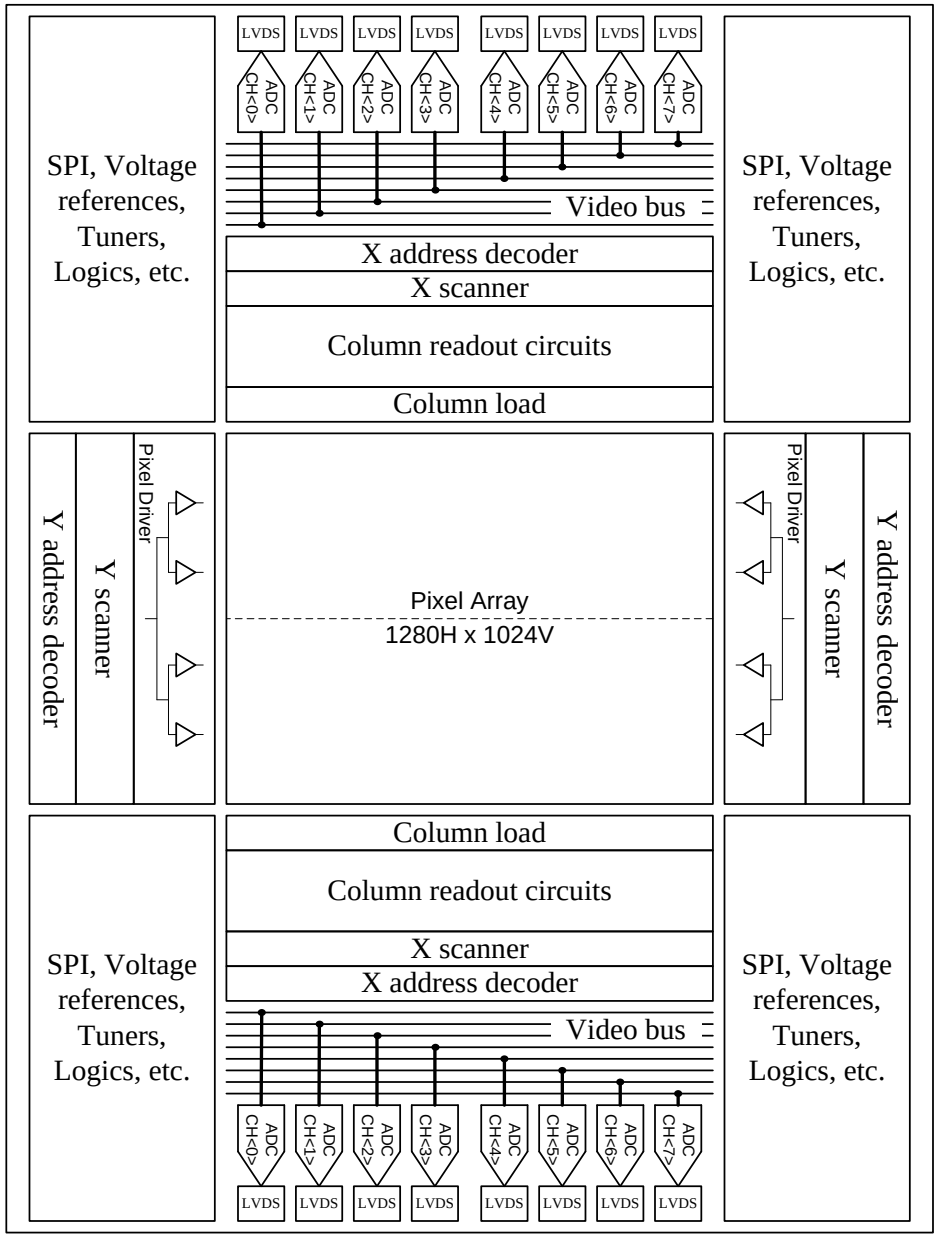




ARCHITECTURE OF THE SENSOR

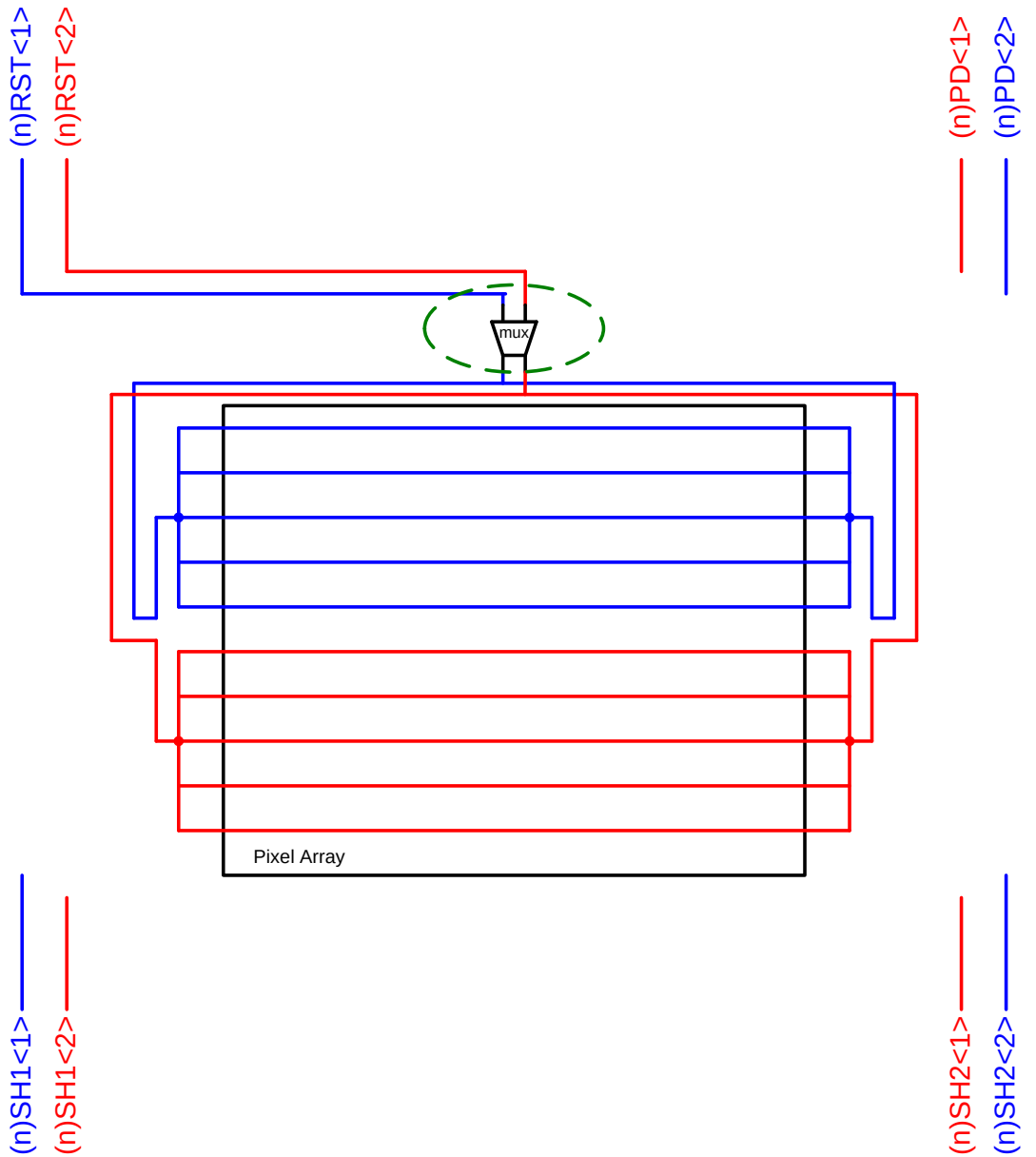
Architecture of FLAMES sensor

- BSI (Backside illumination) is used
- Pixel array are driven from West & East sides
- Top half and bottom half of the array can be driven separately
- Readout are from North & South sides
  - Each side has 8 LVDS channels
  - Each readout channel has 8 time-interleaved SAR ADCs
- SPI, Voltage references, etc. are at the four corners



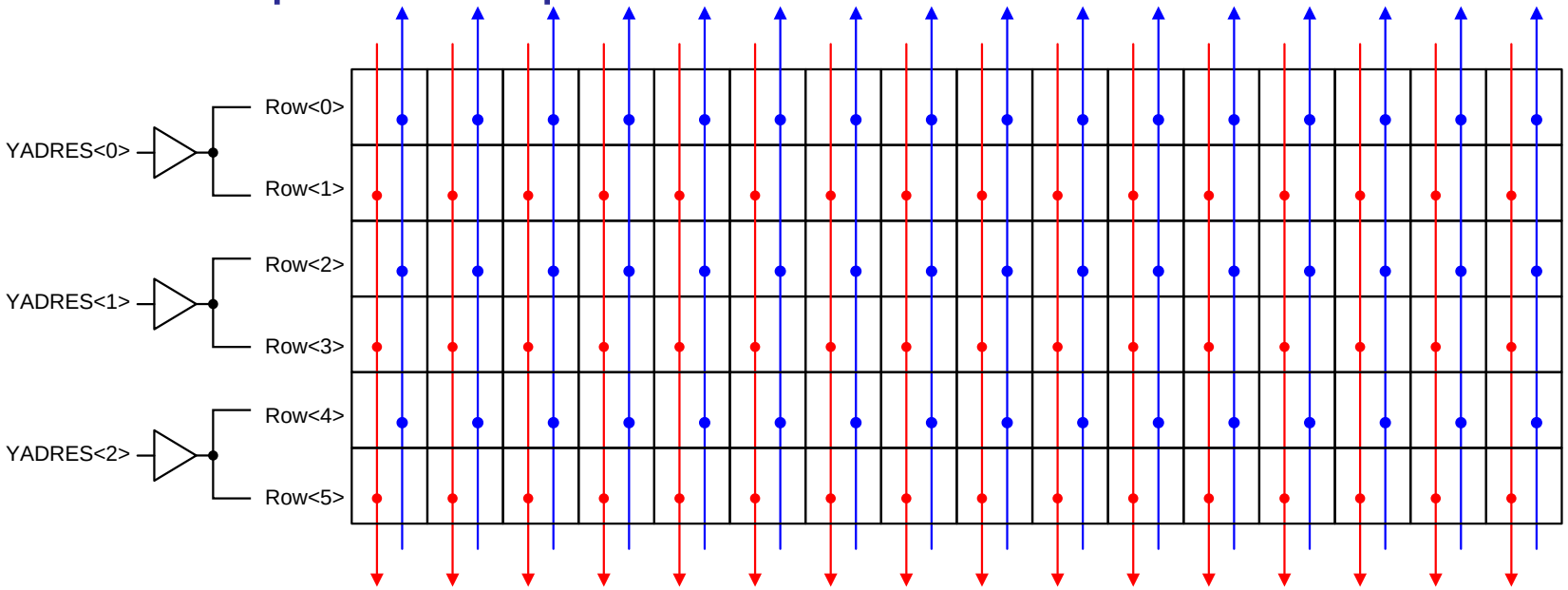
Independent control for top & bottom halves

- 4 signals determine the integration time of the pixel
  - RST, SH1, SH2 & PD
- 2 pairs of LVDS receivers for each signal
- Example: RST
  - LVDS pair: RST<1>, nRST<1>
  - LVDS pair: RST<2>, nRST<2>
- Each LVDS pair can control one half independently or the entire array simultaneously



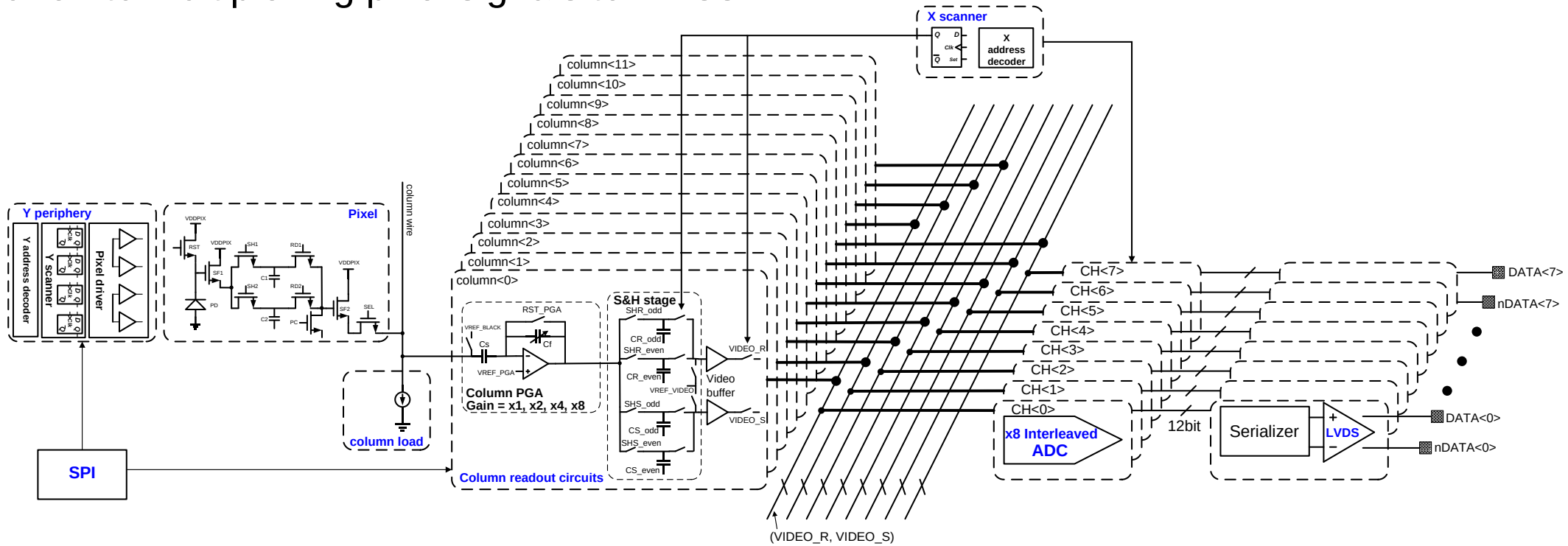
Scan the pixel array in Y direction

- Y address decoder determine the start position of Y scanning
- Y scanner can scan the array from top to bottom
- Always address 2 rows of pixels at the same time
  - One row is readout at the North
  - Another row is readout at the South
- 500fps @ full frame, up to 2000fps with smaller ROI



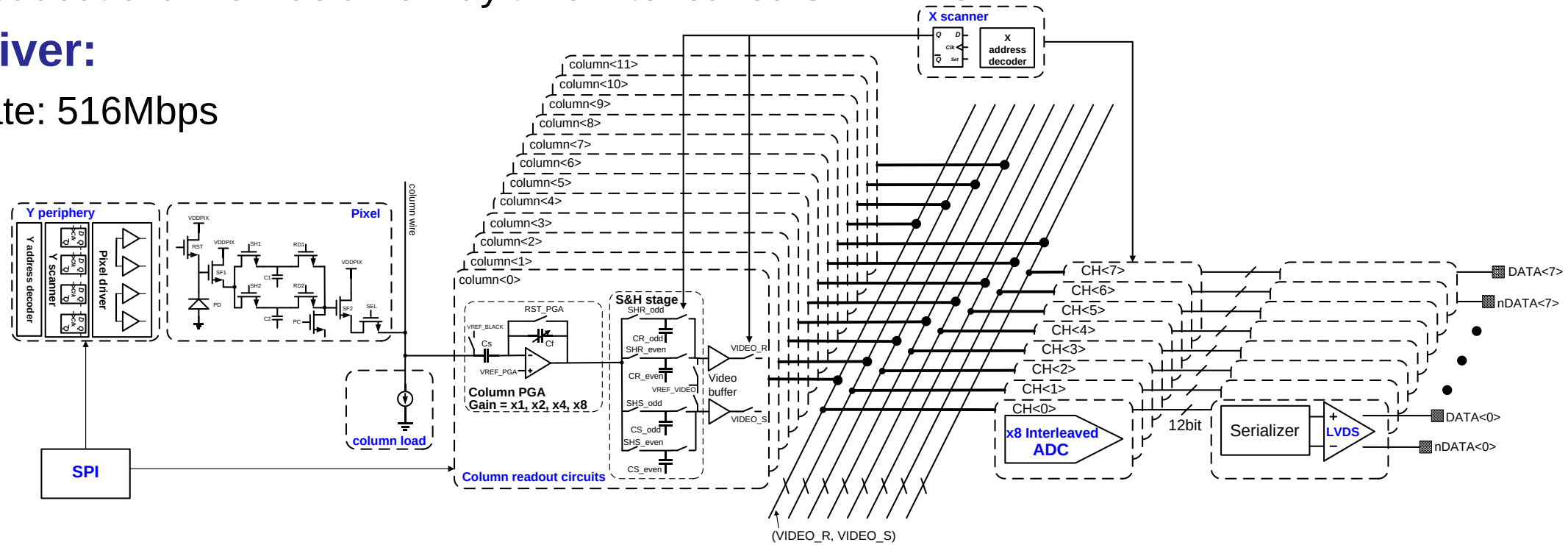
Pixel readout chain (1)

- **Column load:**
  - provide current bias for SF2
- **Column readout circuits:**
  - PGA: provide column gain which can be x1, x2, x4 or x8
  - S&H stage: Odd & Even capacitor banks for pipelining readout
  - Video buffer: to multiplexing pixel signals to ADCs



Pixel readout chain (2)

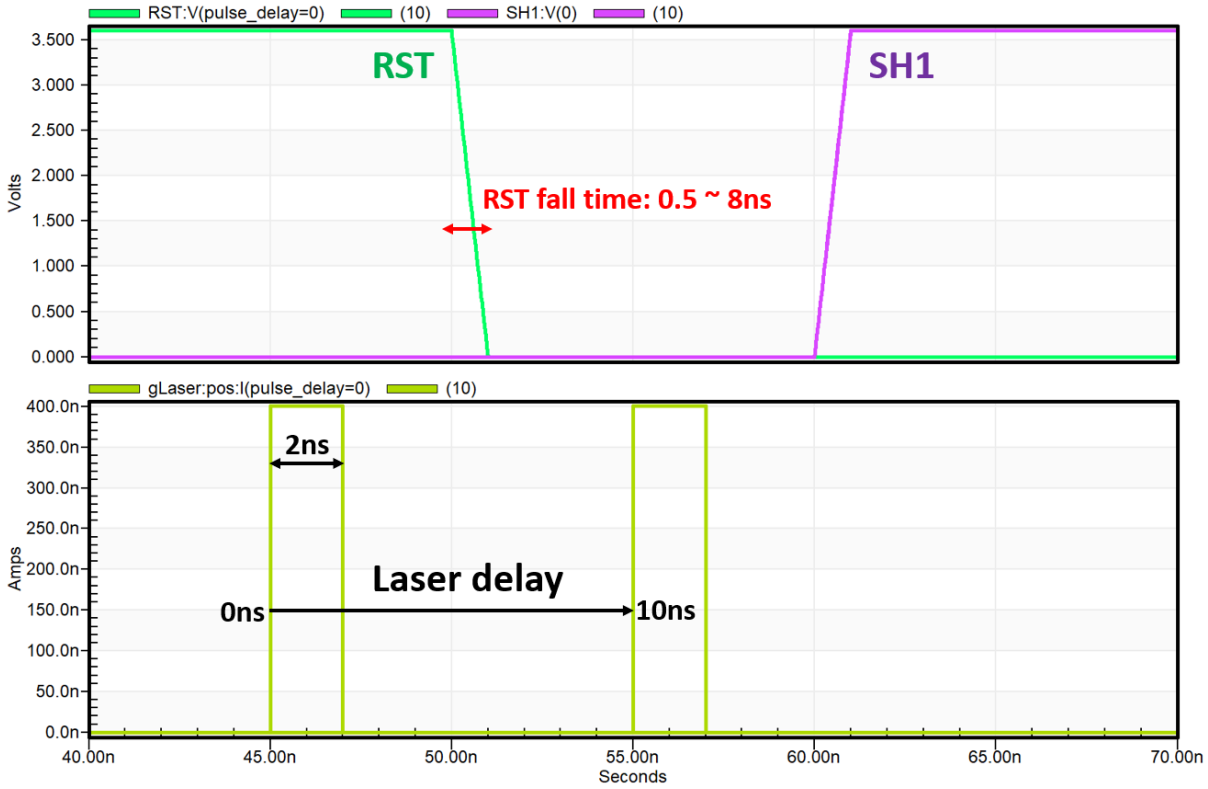
- **X scanner:**
  - control video buffers
  - Clock rate: 43MHz
- **12-bit SAR ADC:**
  - 8 readout channels at both North and South sides of the array
  - Each readout channel has an 8-way time-interleaved SAR ADC
- **LVDS driver:**
  - Data rate: 516Mbps

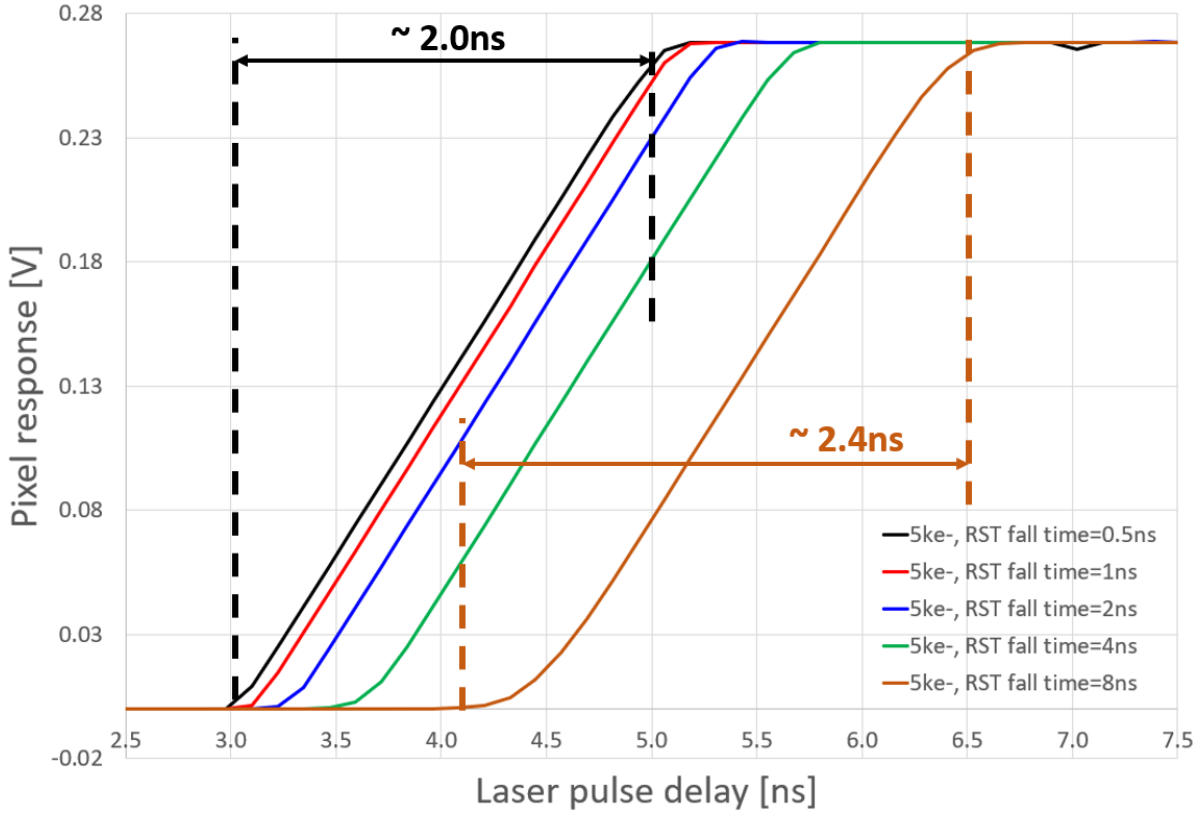


SIMULATION RESULTS

RM1 time gating sharpness

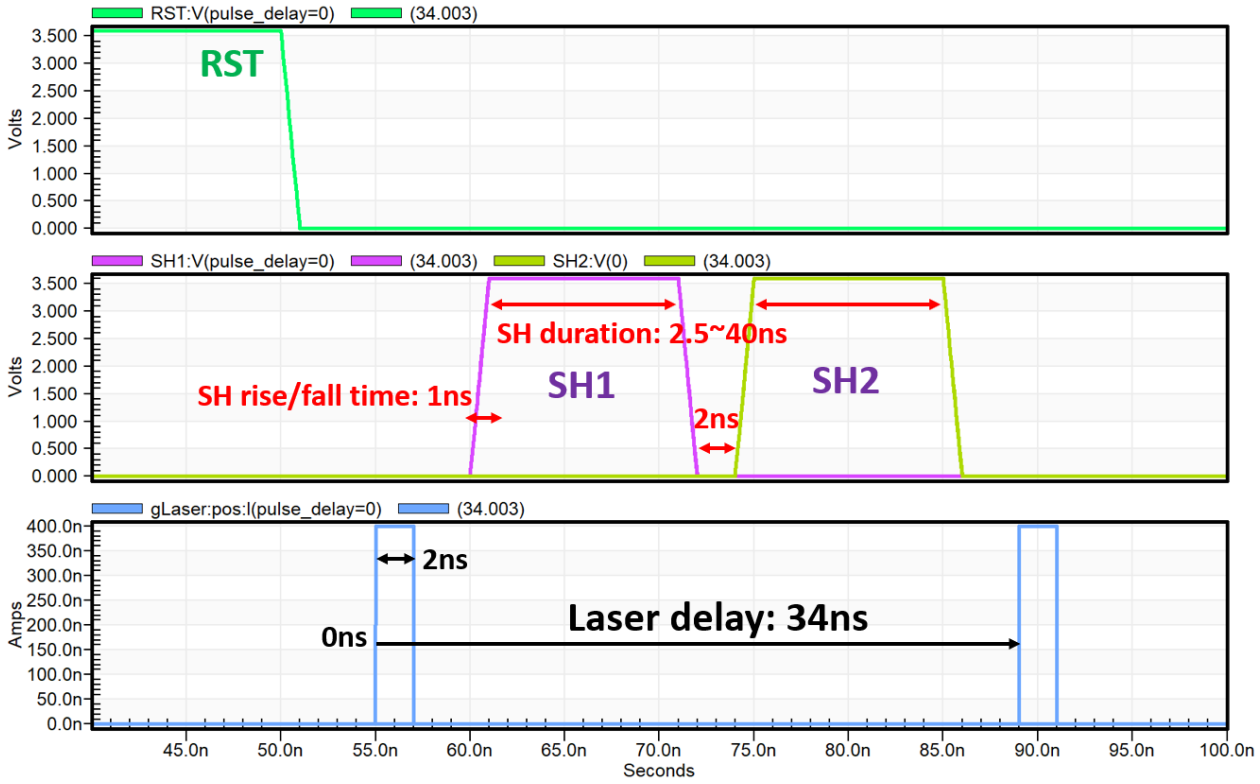
- Laser pulse length is 2ns
- Sweep laser pulse delay:
  - from -5ns to +5ns around the falling edge of RST
- Time gating sharpness is ~2ns when fall time of RST < 4ns

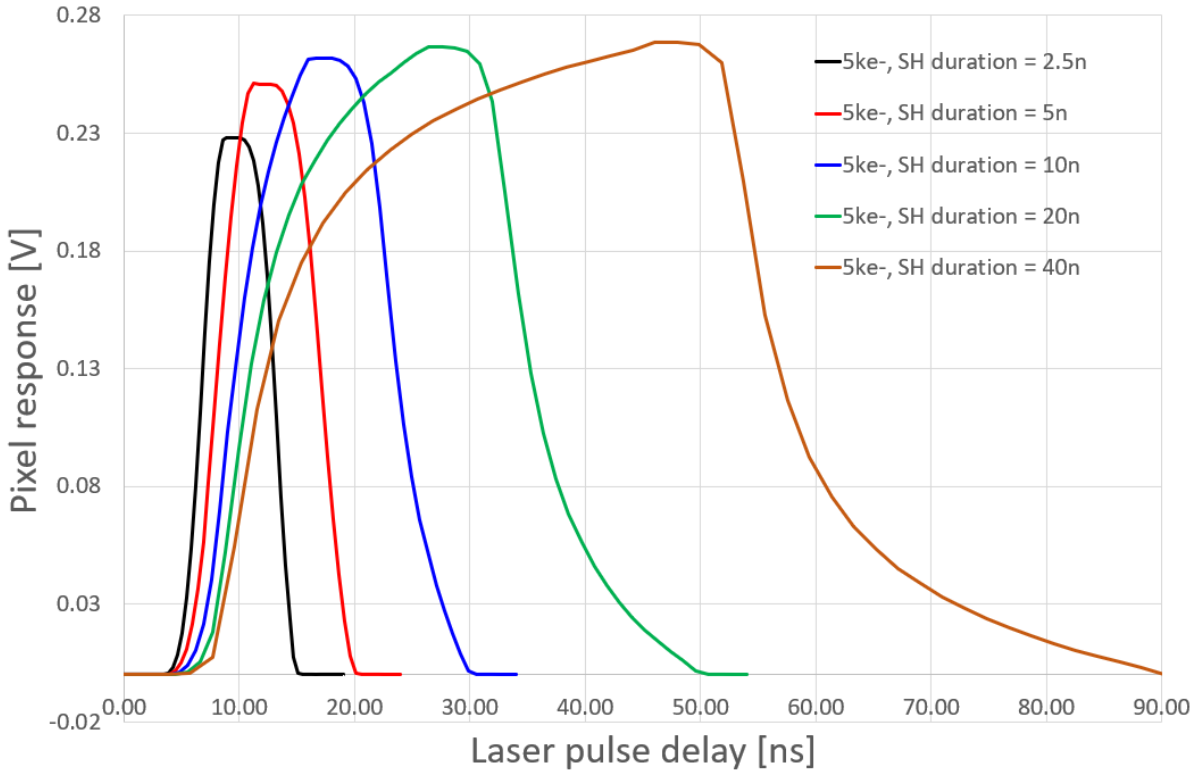




RM2 time gating sharpness (1)

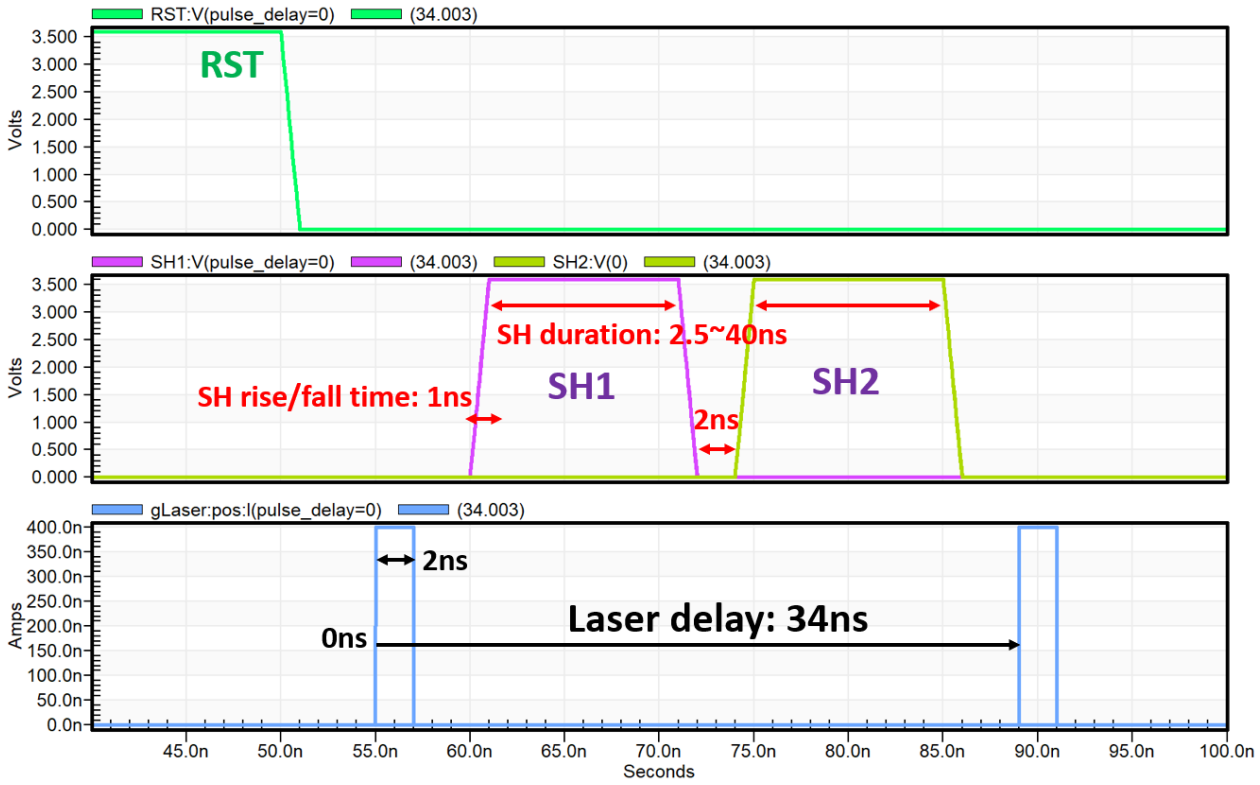
- Laser pulse length is 2ns
- Sweep laser pulse delay:
  - from -5ns before SH1 pulse to +5ns after SH2 pulse
- Minor signal degradation when SH pulse length > 10ns

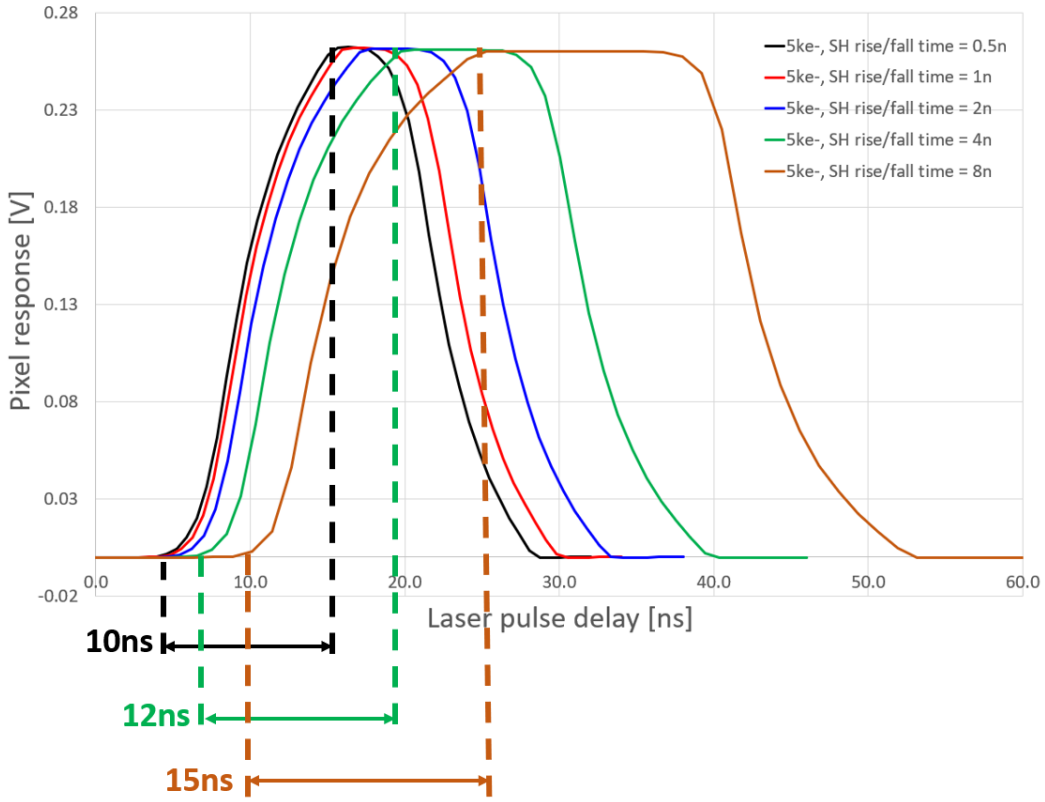




RM2 time gating sharpness (2)

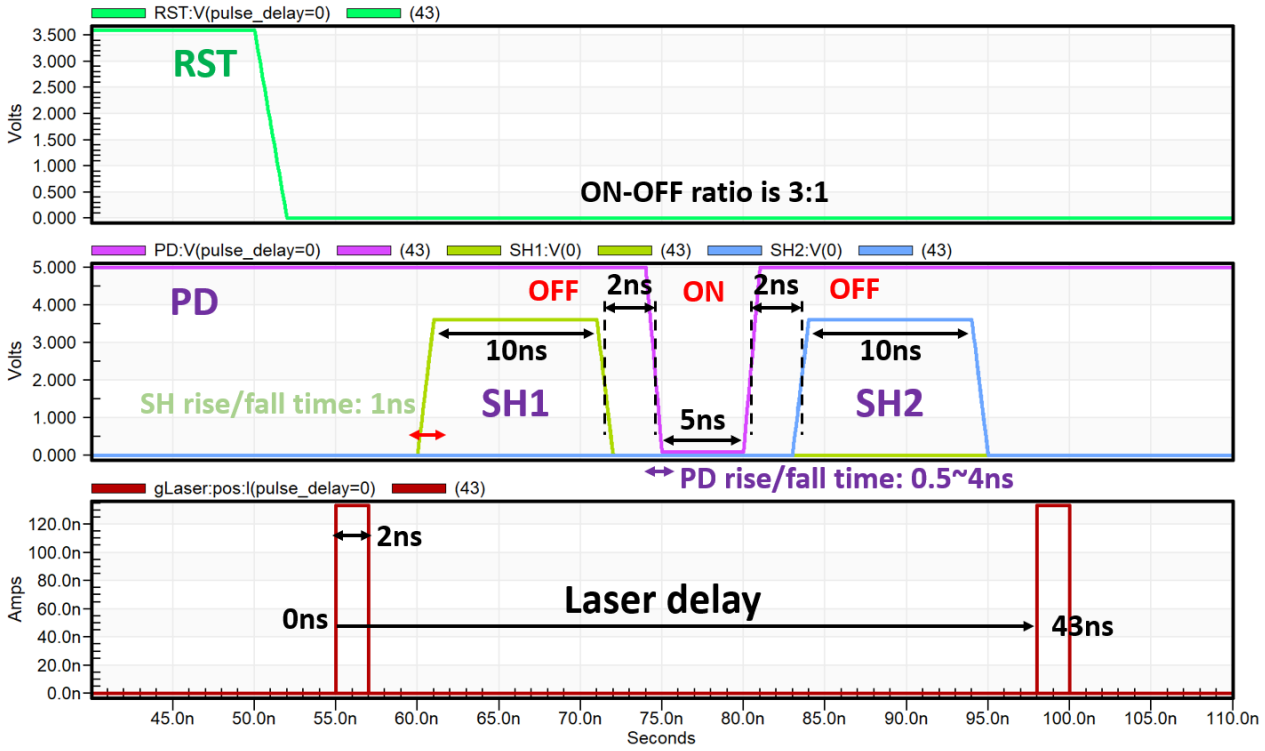
- Laser pulse length is 2ns
- Sweep laser pulse delay:
  - from -5ns before SH1 pulse to +5ns after SH2 pulse
- Minor time gating sharpness improvement when rise/fall time of SH <4ns

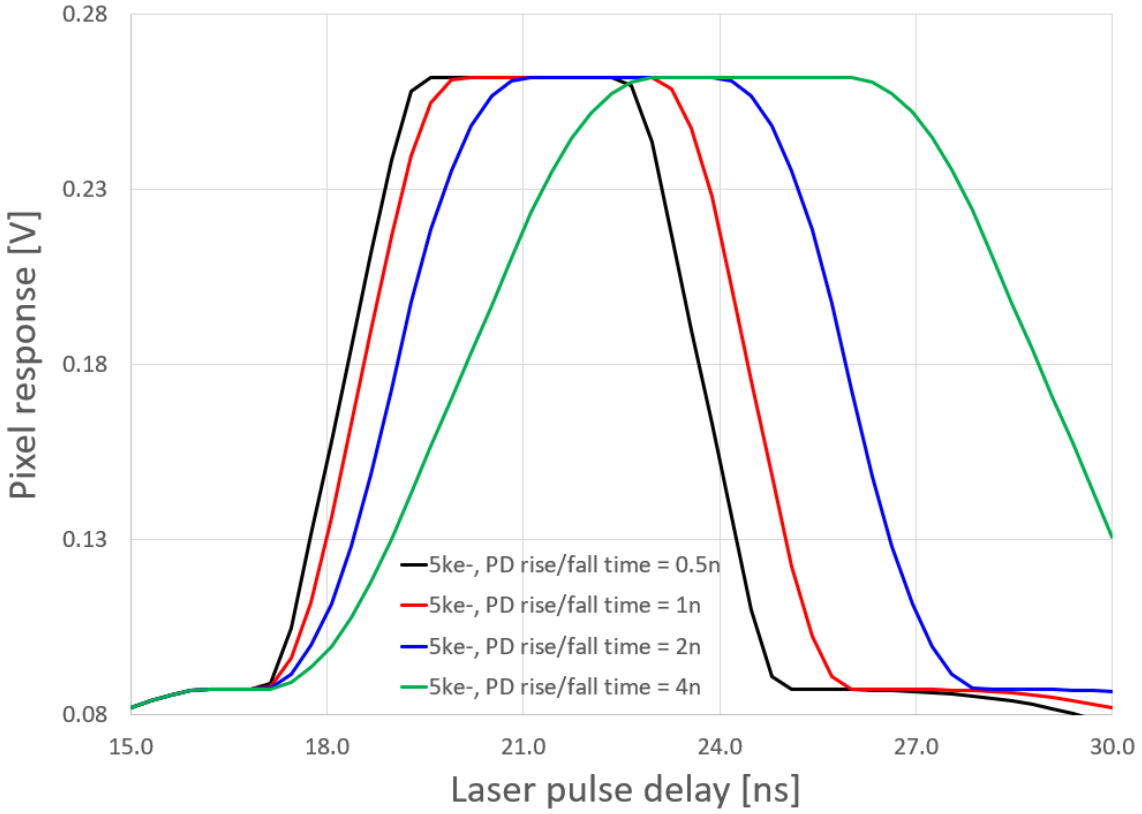




RM3 time gating sharpness

- Laser pulse length is 2ns
- Sweep laser pulse delay:
  - from -5ns before SH1 pulse to +5ns after SH2 pulse
- Time gating sharpness is ~2ns when fall time of PD < 2ns





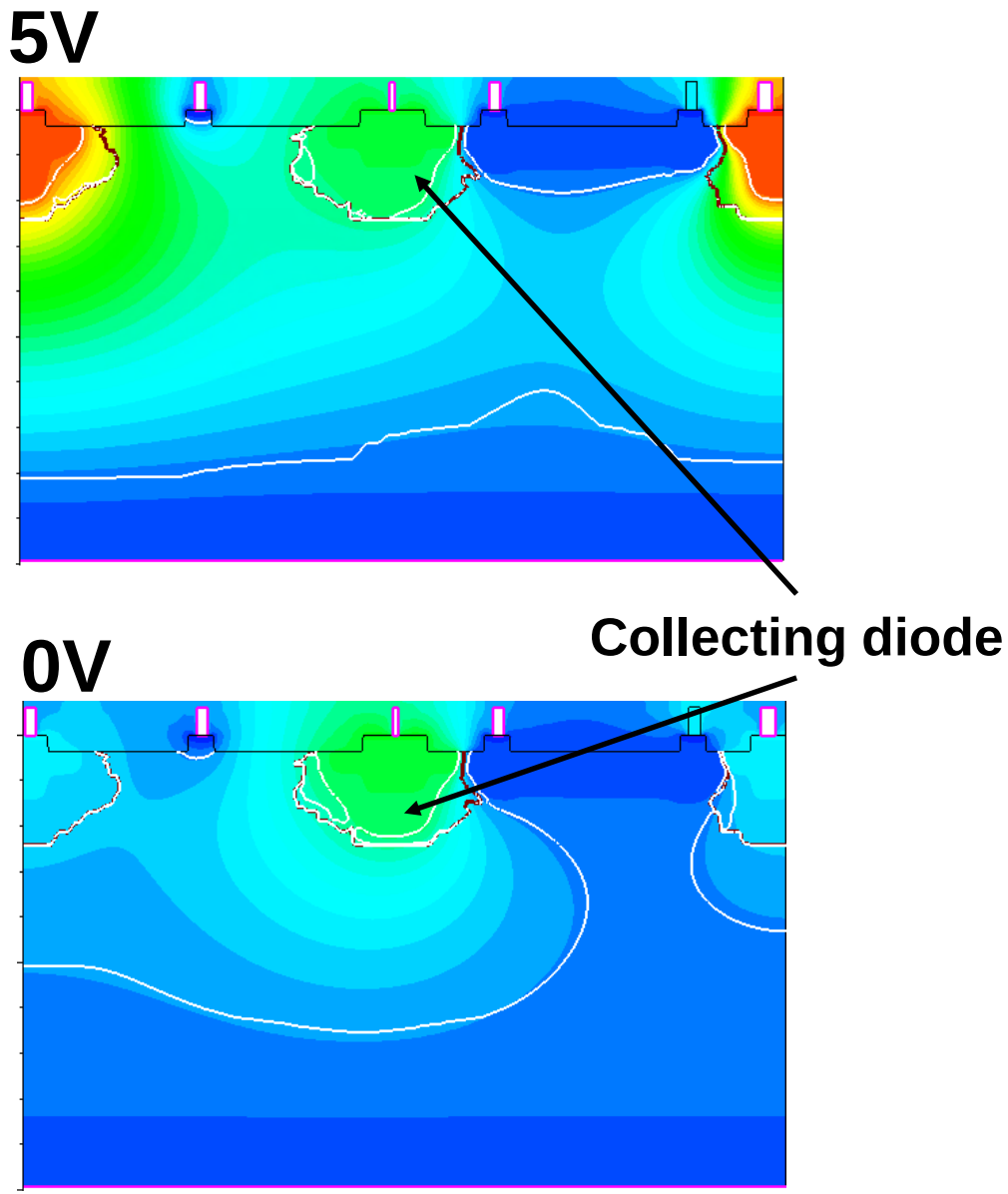
TCAD: photodiode sensitivity modulation

Simulation conditions:

- Fully depleted 10µm epi thickness
- OFF state: Non-collecting diodes biased at 5V
- ON state: Non-collecting diodes biased at 0V

Learned from TCAD results:

- Fully-depleted high-res epi is required
- No P-Well between collecting diode & non-collecting diodes
- PSUB connection is required between collecting diode & non-collecting diodes to block large surface leakage
- ON-OFF photocurrent ratio is between 2 and 5 depending on the sizes of the diodes



CONCLUSIONS & OUTLOOK

Conclusions & Outlook

Conclusions:

- 1.3Mpix, 500fps Flash-LiDAR CMOS image sensor is designed
- Pixel can operate in 3 different modes with their own pros and cons
- Time gating sharpness can be better than 5ns in RM1 & RM3, and better than 10ns in RM2
- Readout noise is expected to be below 10e- with CDS

Outlook:

- Tape out will be around the beginning of next month

For more information or questions, please contact:

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Scan the QR-code to visit our website:
www.caeleste.be

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