pi imaging

Michel Antolovic

# Changing the way we count photons

EPIC Online Quantum Technology Meeting on Single Photon Sources and Detectors

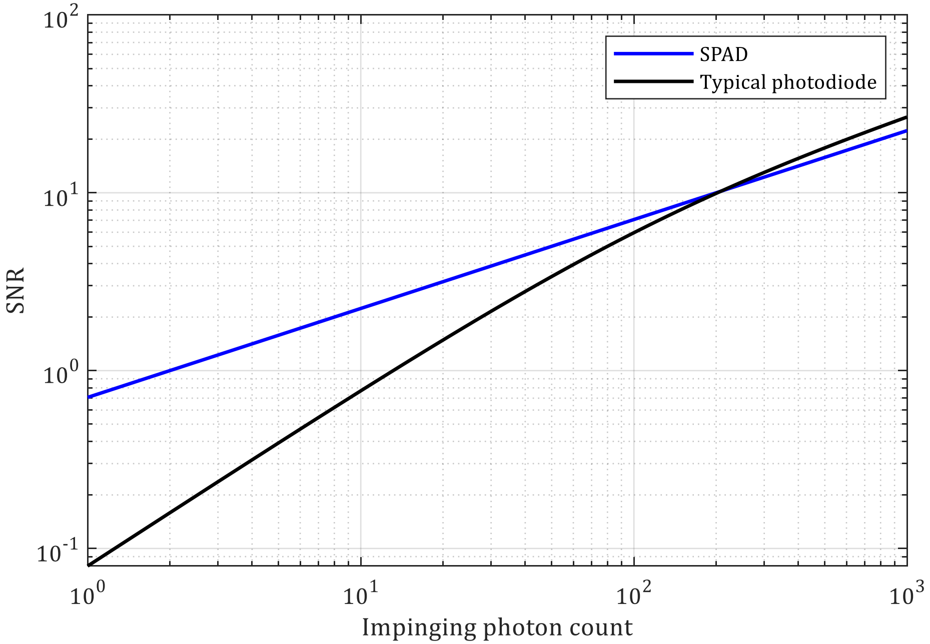
# Photon counting arrays

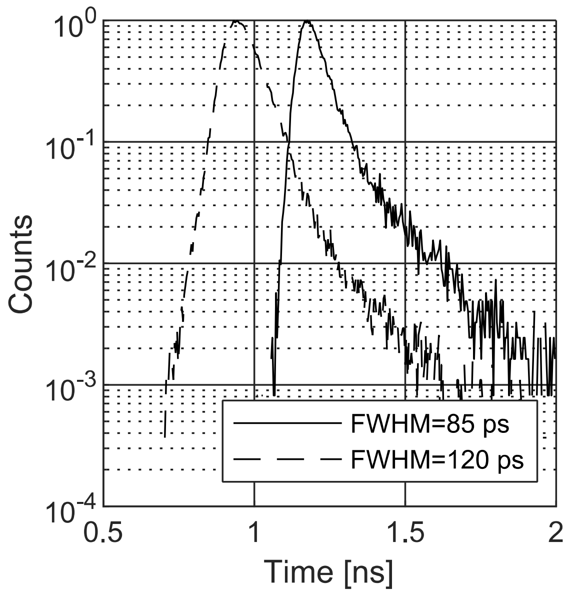
Based on **single photon avalanche diodes (SPADs)**

Tailor made SPAD **arrays and image sensors** with the highest sensitivity and lowest noise

# Why SPAD arrays?

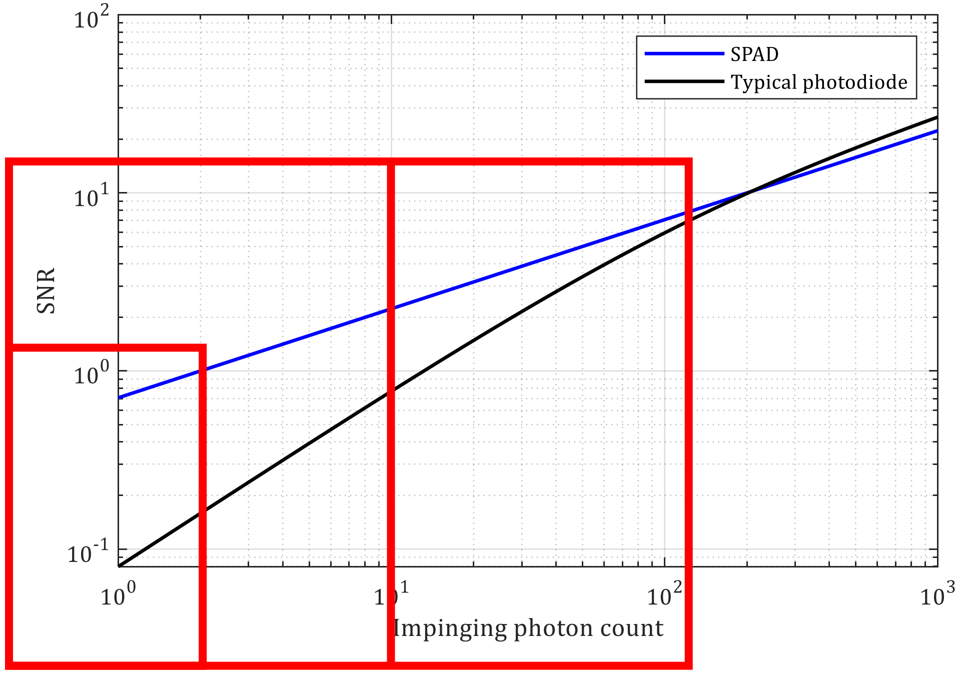
- SPADs have exceptionally **high readability of low light signals** (quantified in a high signal-to-noise ratio)
- SPAD have extremely **precise timing** (quantified in a low standard deviation)

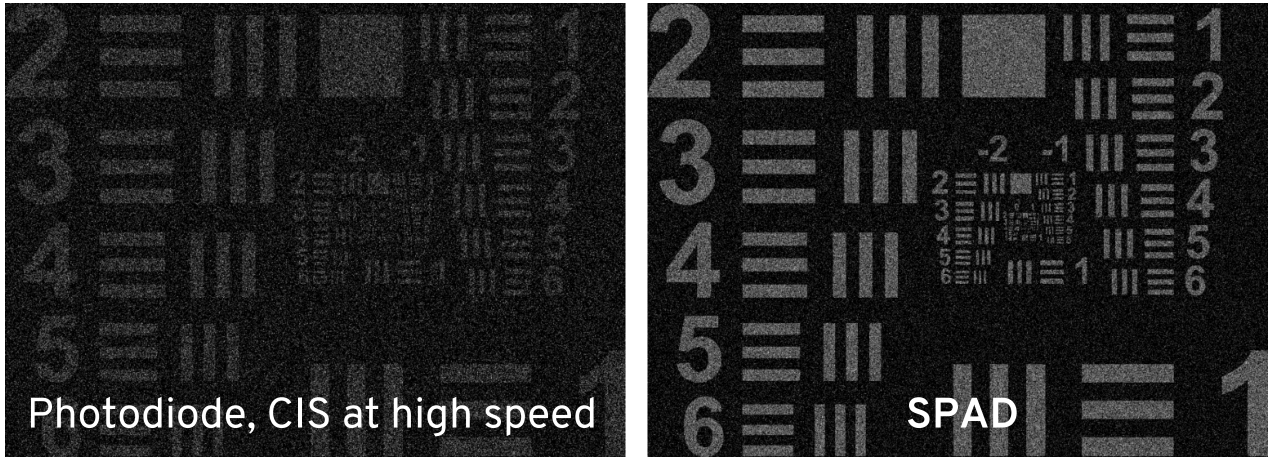


# Why SPAD arrays?

| Low light | High speed | Timing precision |
|---|---|---|
| Quantum, single particle | Scanning over space, oversampling in time | Estimating a time distribution, typically with a pulsed light source |
| **Examples** | | |
| Single molecule analysis, photon antibunching | Scanning microscopy, high-speed imaging | FLIM, LiDAR |



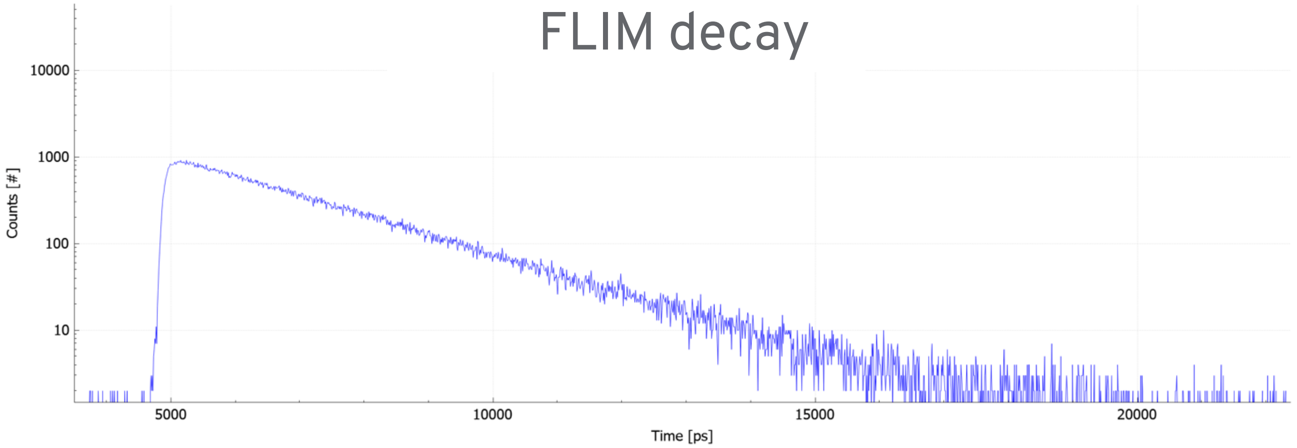

80% sensitivity

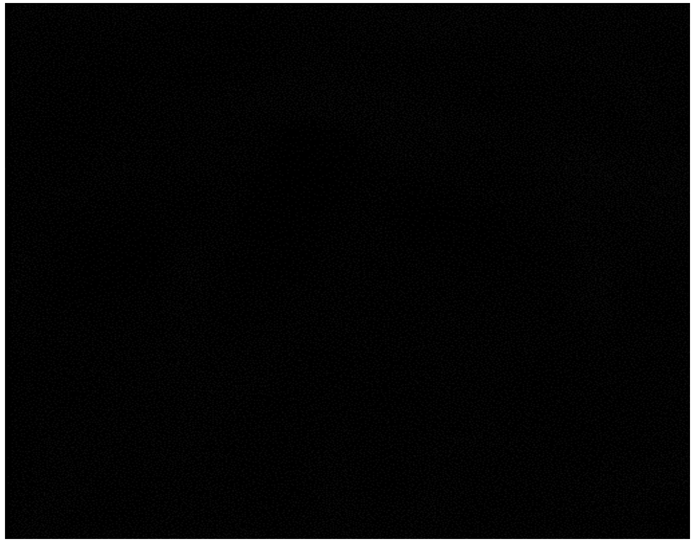
50% sensitivity

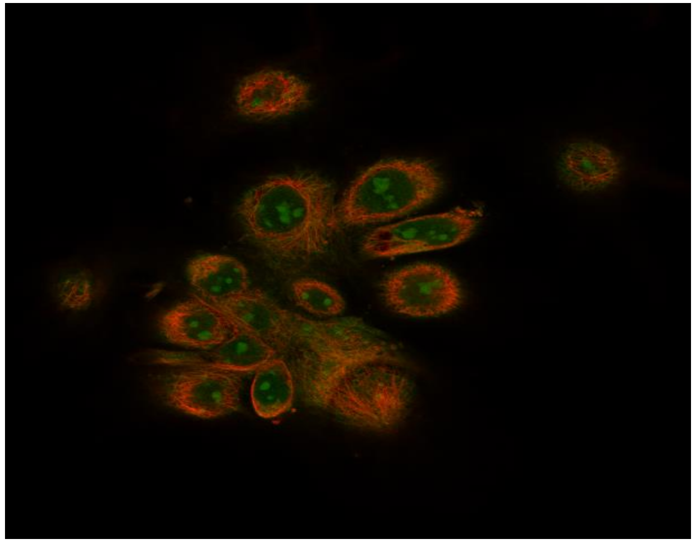
10 impinging photons

# SPAD arrays in scanning microscopy

- Image scanning microscopy (ISM)
  - Increase resolution by a factor of 1.7 to 4
  - Increase light collection
- Fluorescence lifetime imaging (FLIM)
  - Increase imaging speed / reduce pile-up effect by a factor of 23

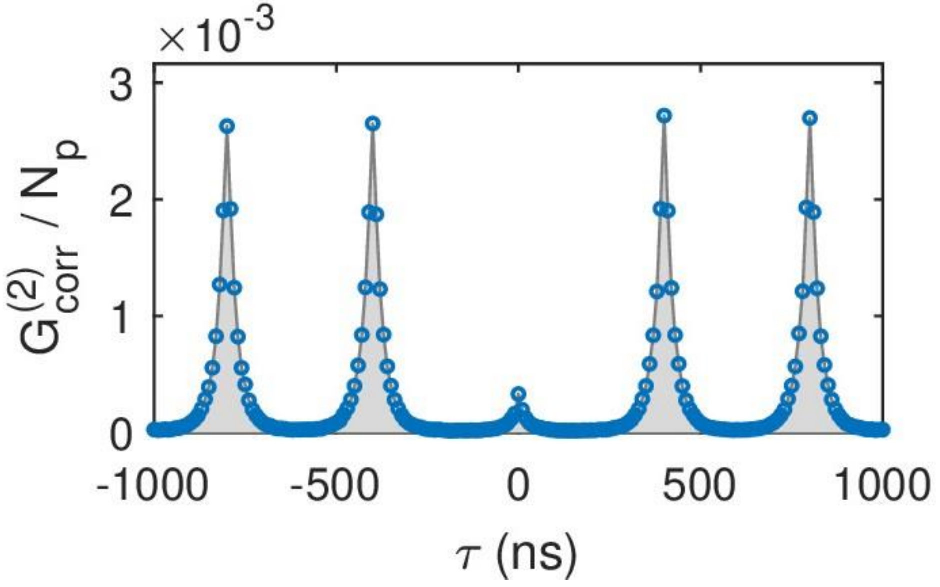




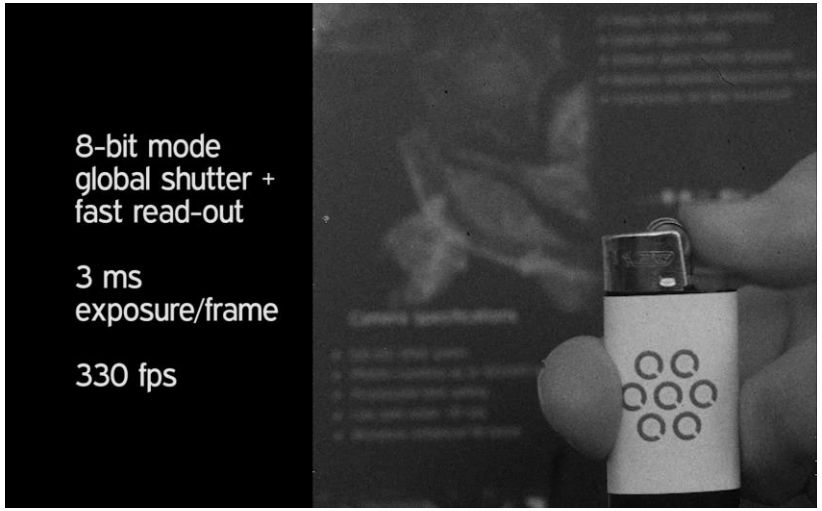
# SPAD arrays in quantum applications

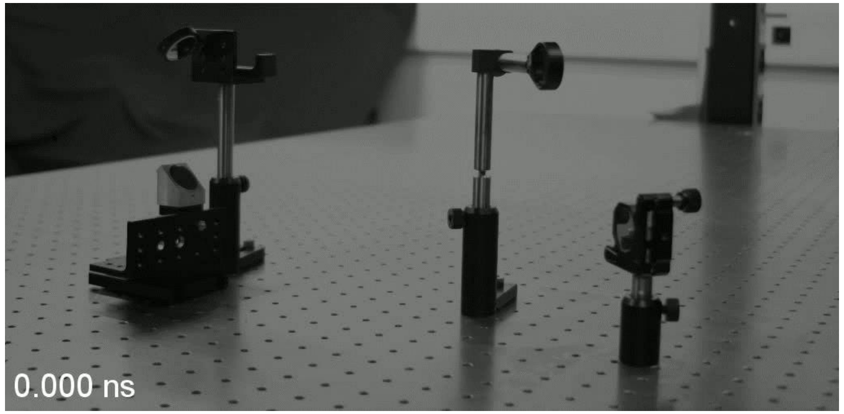
- Simplify setup for
  - Photon number resolving detection
  - Photon antibunching
- Due to
  - Integrated TCSPC/time-tagging
  - No need for beam splitting




*Lubin et al. 2019*

# SPAD image sensors for high speed imaging

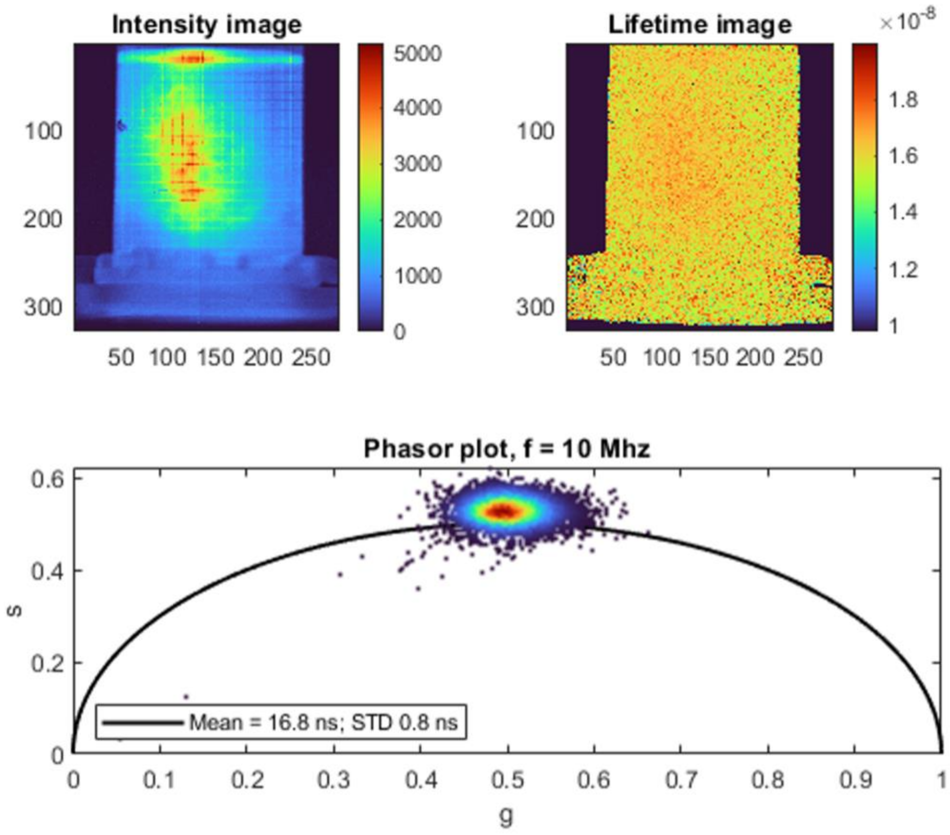

*Morimoto, Antolovic, Bruschini, Charbon et al., Optica, 2020*

- Count photons
- Up to 100’000 frames per second
- Zero readout noise

# SPAD image sensors for widefield FLIM

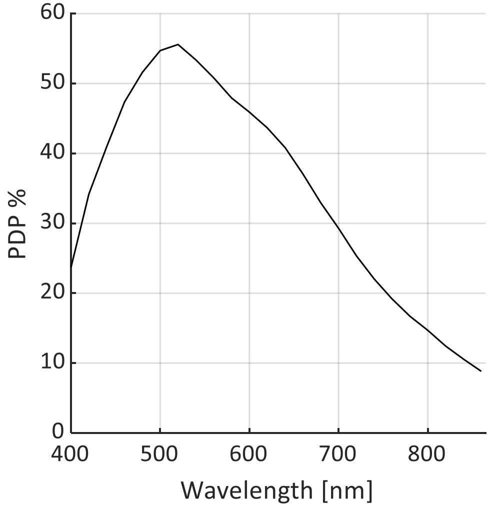
- Increase frame rate to 1-30 Hz
- Pixel resolution 512×512
- Complementary solution to scanning FLIM

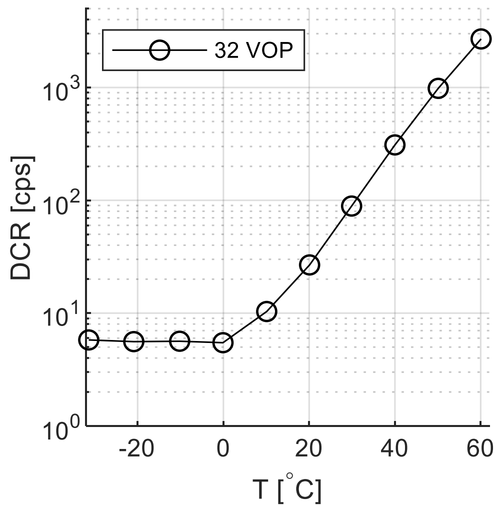
PpIX dissolved in DMSO 1.5 [µg/mL]

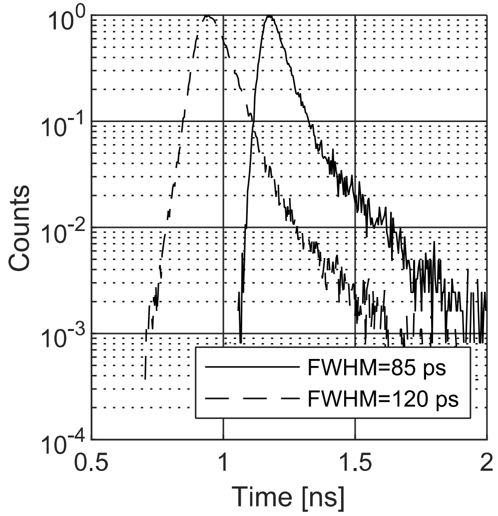


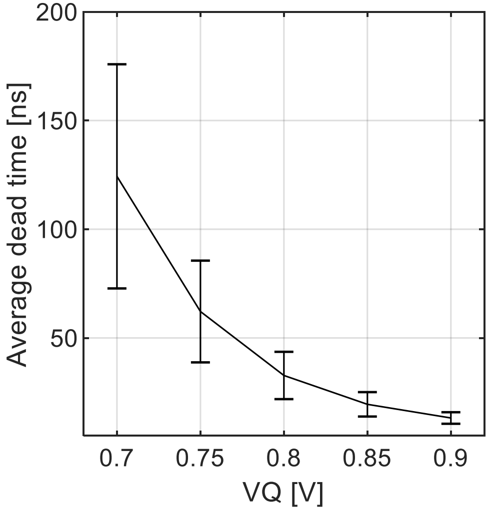
# SPAD technology

- 23 to 512×512 pixels
- **Peak detection probability >50%**
- Microlens enhanced fill factor
- Typical dark count rate <100 cps
- Integrated **time tagging** with 20 ps resolution
- Integrated **time gating** with 18 ps phase shift resolution



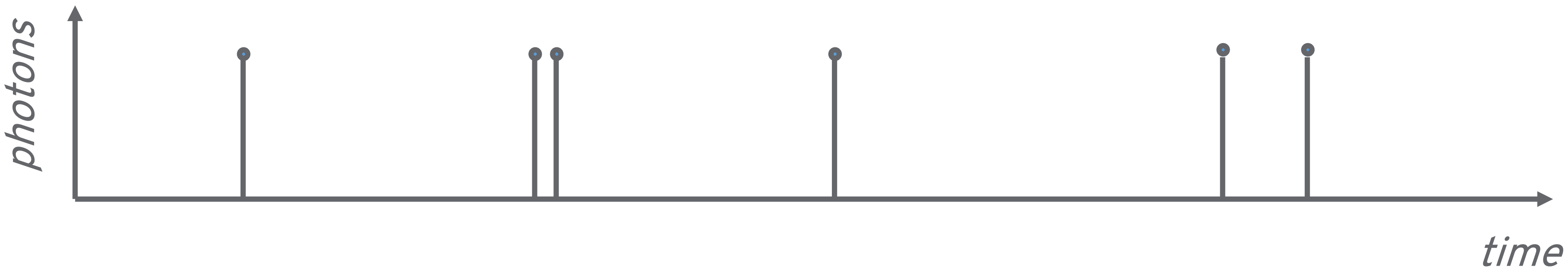



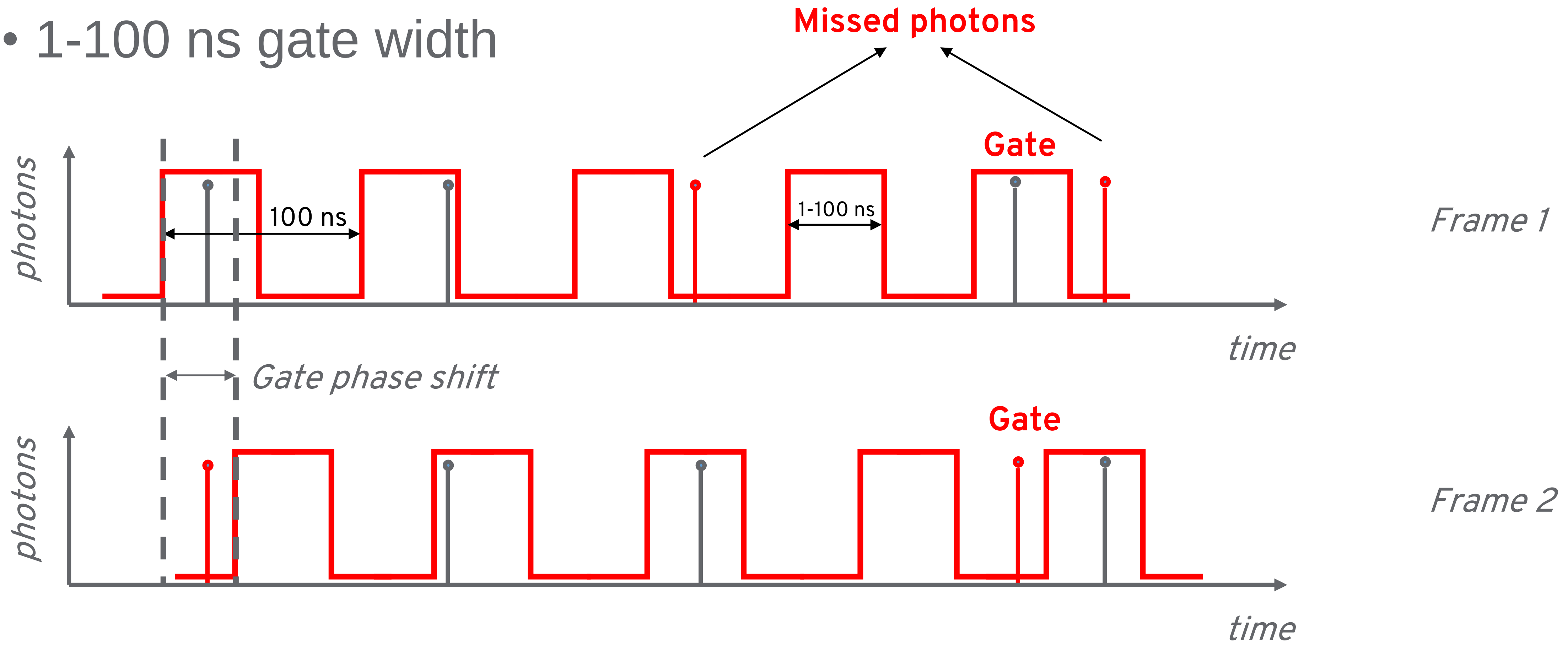
# Time tagging

- 20 ps resolution
- Get time of arrival and pixel address of each photon



# Time gating

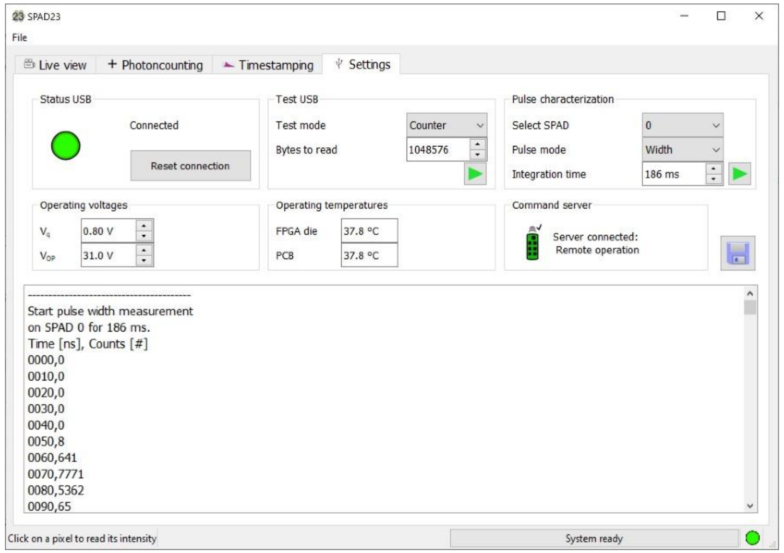
- 18 ps phase shift resolution
- 1-100 ns gate width

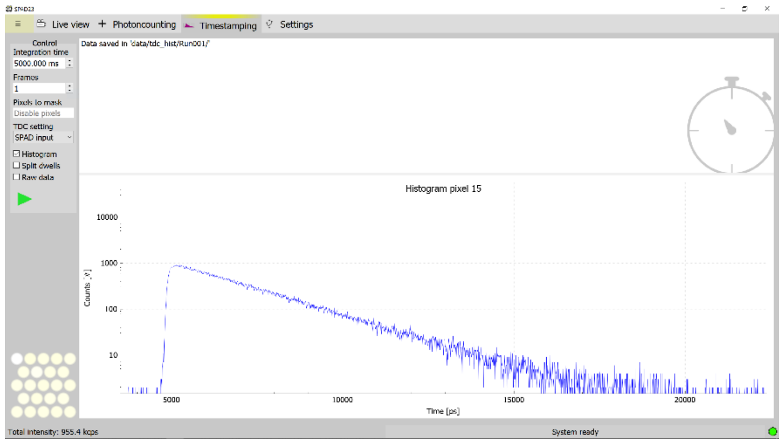


# SPAD23

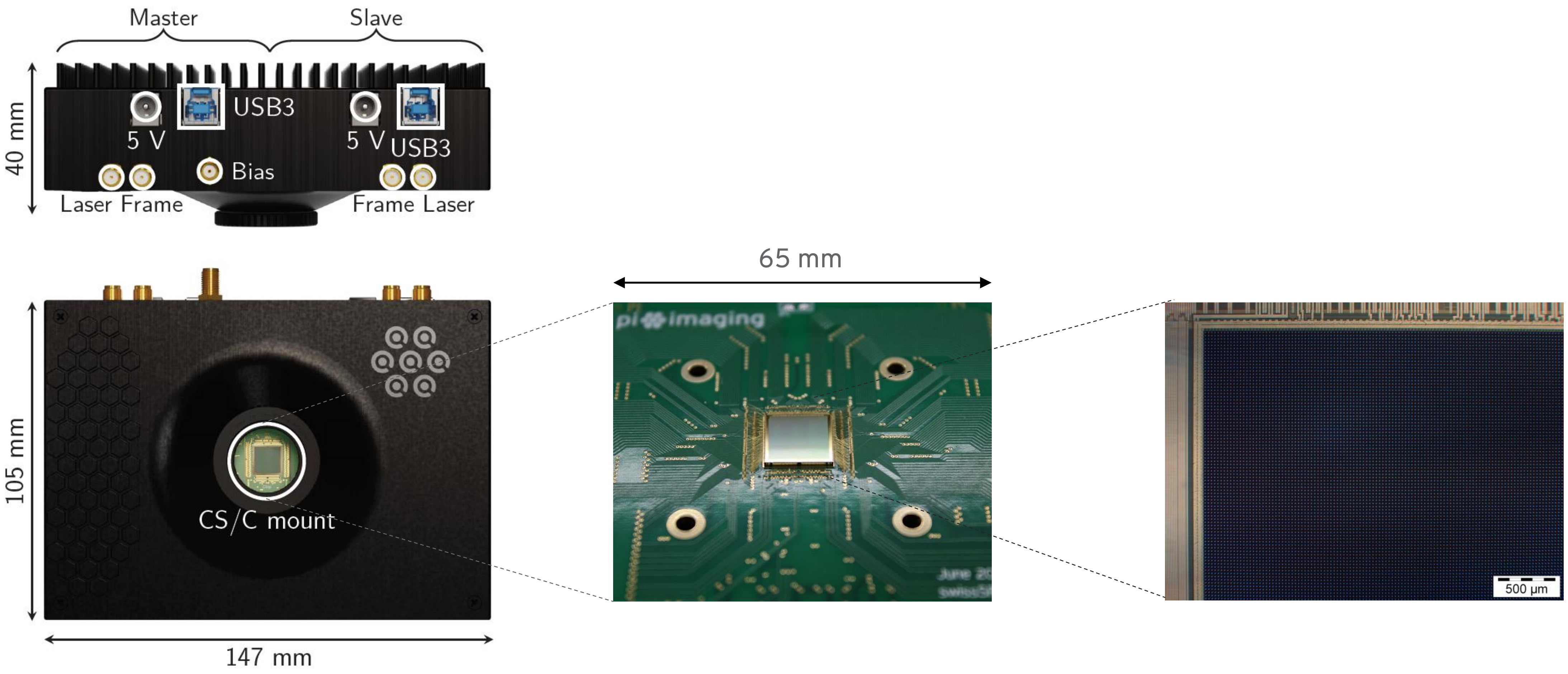
# SPAD23 software

- Photon counting **up to 180 Mcps**
- Time tagging **up to 90 Mcps**
- TCP/IP control of the software
- Simple integration in MATLAB, Python or Octave



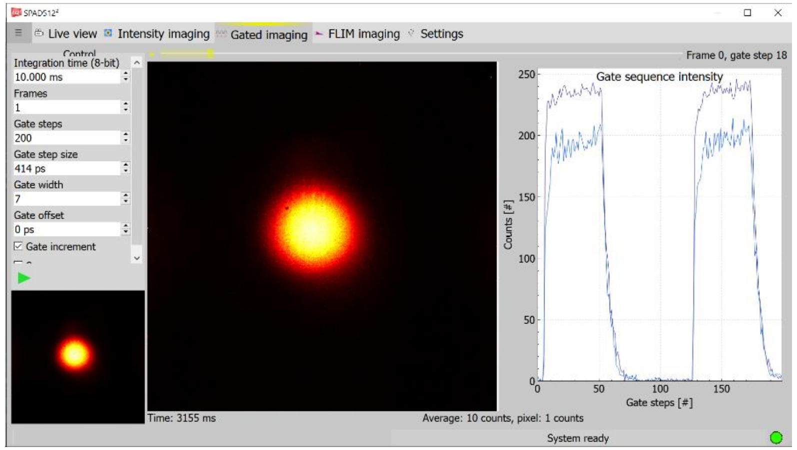



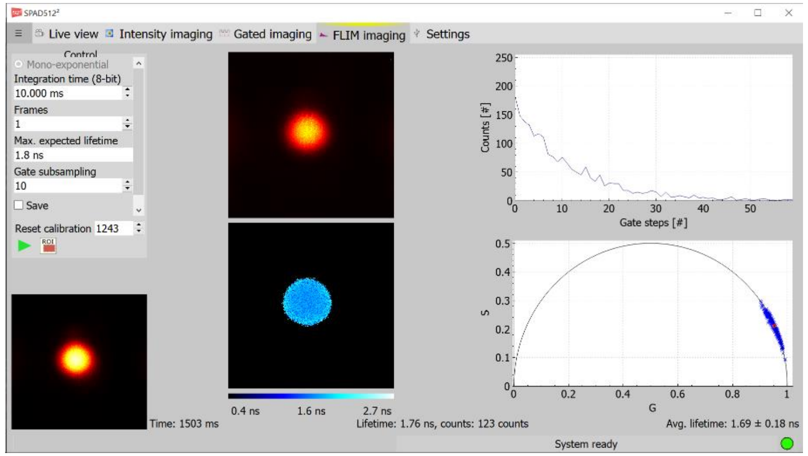
# SPAD512²


Master
Slave
40 mm
USB3
5 V
5 V
USB3
Bias
Laser
Frame
Frame
Laser
105 mm
CS/C mount
147 mm
65 mm
pi imaging
500 µm

# SPAD512$^2$ software

- Photon counting
  - 100,000 fps @ 1-bit for 1.3 s
  - 2,500 fps @ 4-bit continuous
  - 400 fps @ 8-bit continuous
- Time gating with 18 ps gate shifts
- Integrated phasor FLIM functionality
- TCP/IP control of the software
- Simple integration in MATLAB, Python or Octave



# Get in touch with us

What we offer: SPAD arrays

Looking for: system integrators of SPAD arrays

#hiring, check out our LinkedIn page

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