

# Characterization of Laser-Driven Photon Emission in Silicon Photomultipliers

Juliette M.J. Martin

TRIUMF, The University of Edinburgh

CAP Congress

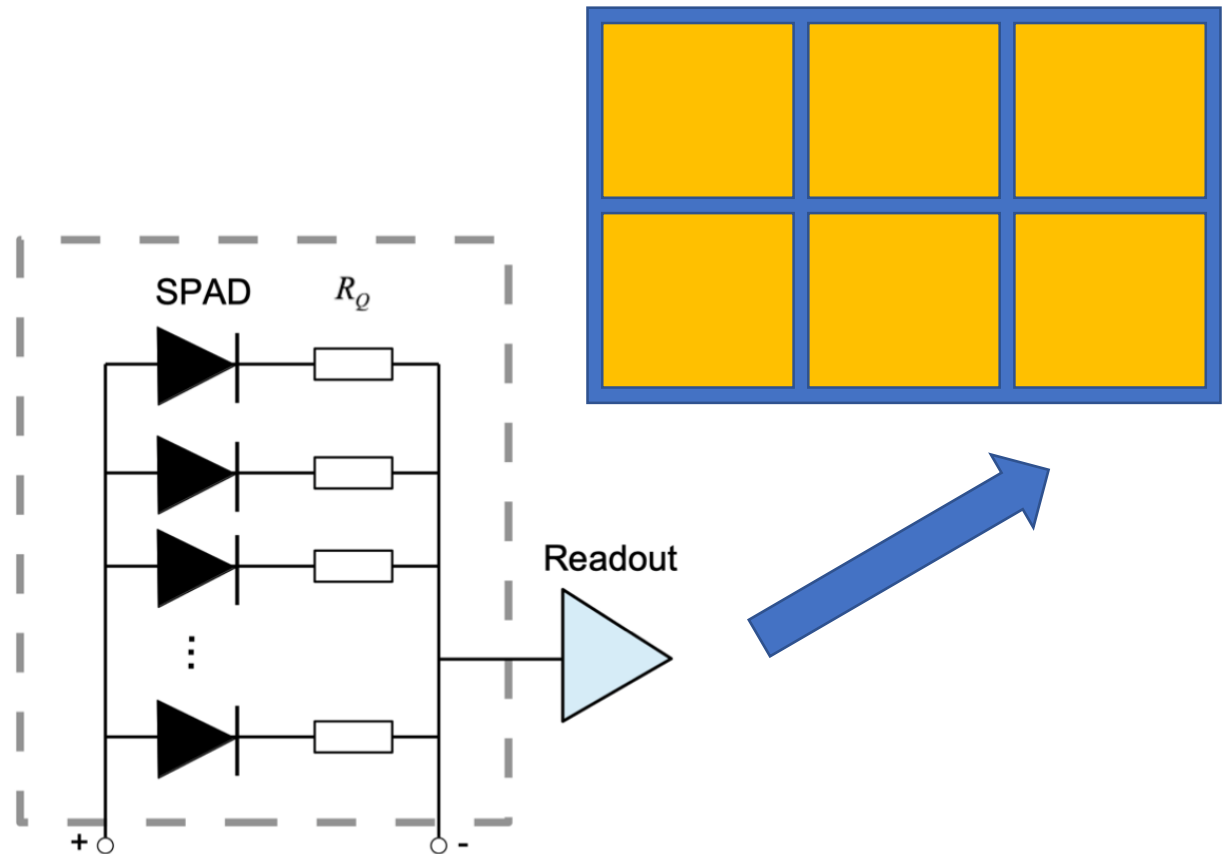
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# Outline

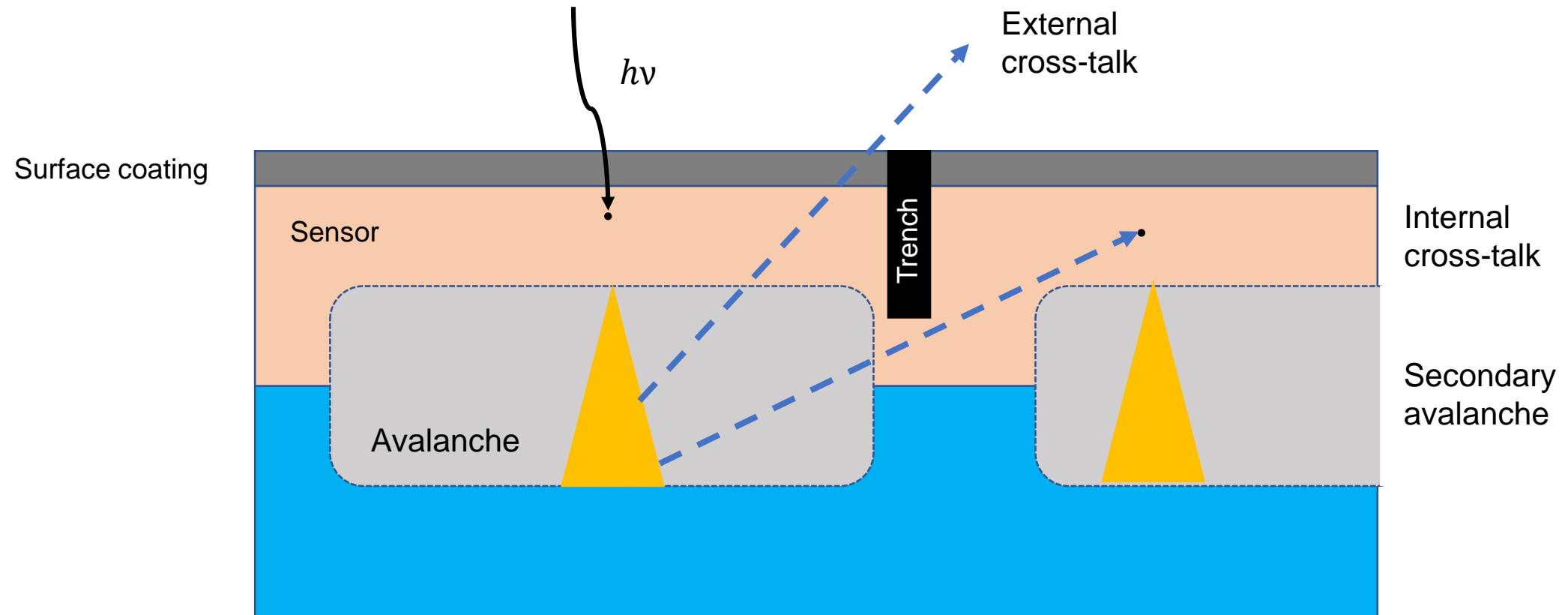
- The Silicon Photomultiplier
- Cross-Talk
- Optical cross-talk studies at TRIUMF
- Results

# What is a Silicon Photomultiplier (SiPM)?

- **Solid-state** detector
  - PMT alternative
  - **Single photon** resolution
  - Good photon detection efficiency
- Basic unit: single photon avalanche diode (**SPAD**)
- p-n junction biased **above breakdown**
  - **Overvoltage**:  $V_{ov} = V - V_{bd}$
  - **Avalanche process**: gain is  $10^5$ - $10^7$



# SiPM signal detection: SPAD level



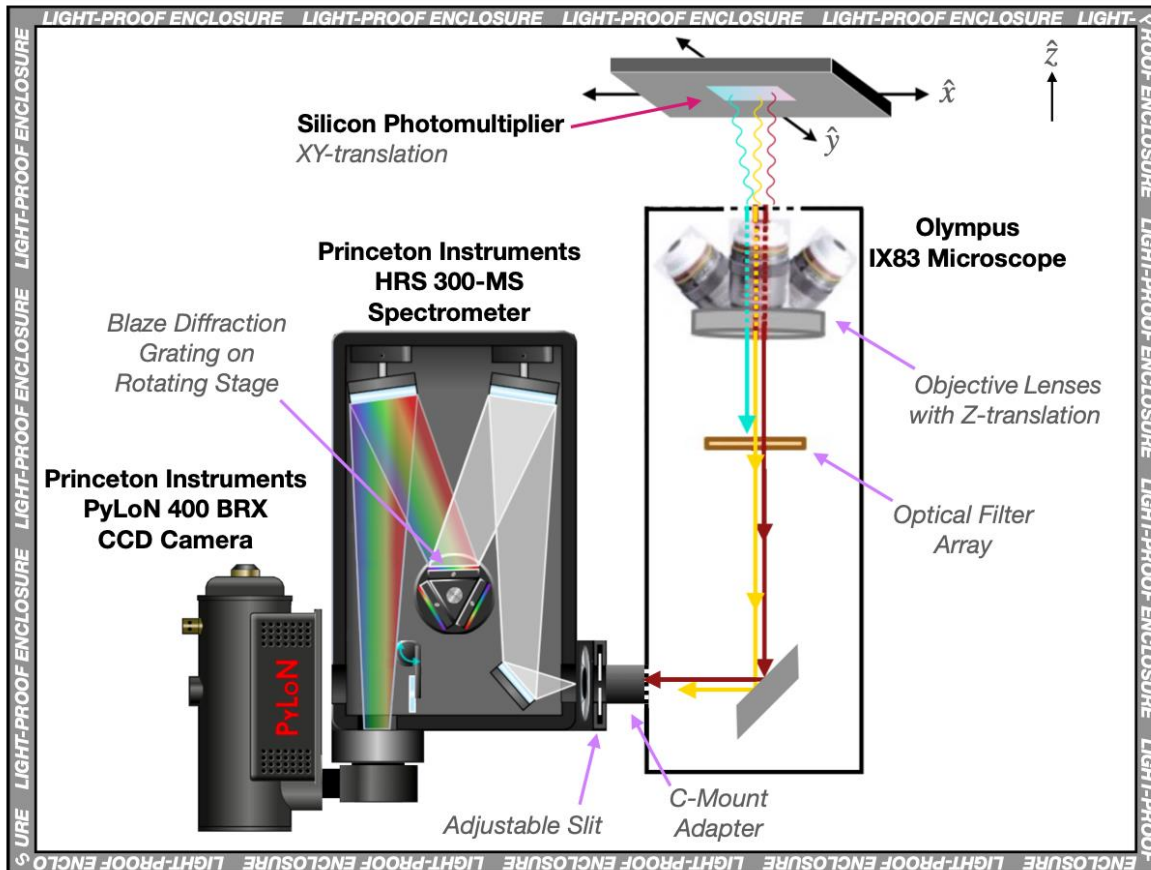
# Cross-Talk

- Secondary photon by-product of avalanche mechanism
- **Systematic effect** on detector background
- Must be quantified for use in rare-event searches (e.g. nEXO)
- Is photon emission significant?

# MIEL at TRIUMF

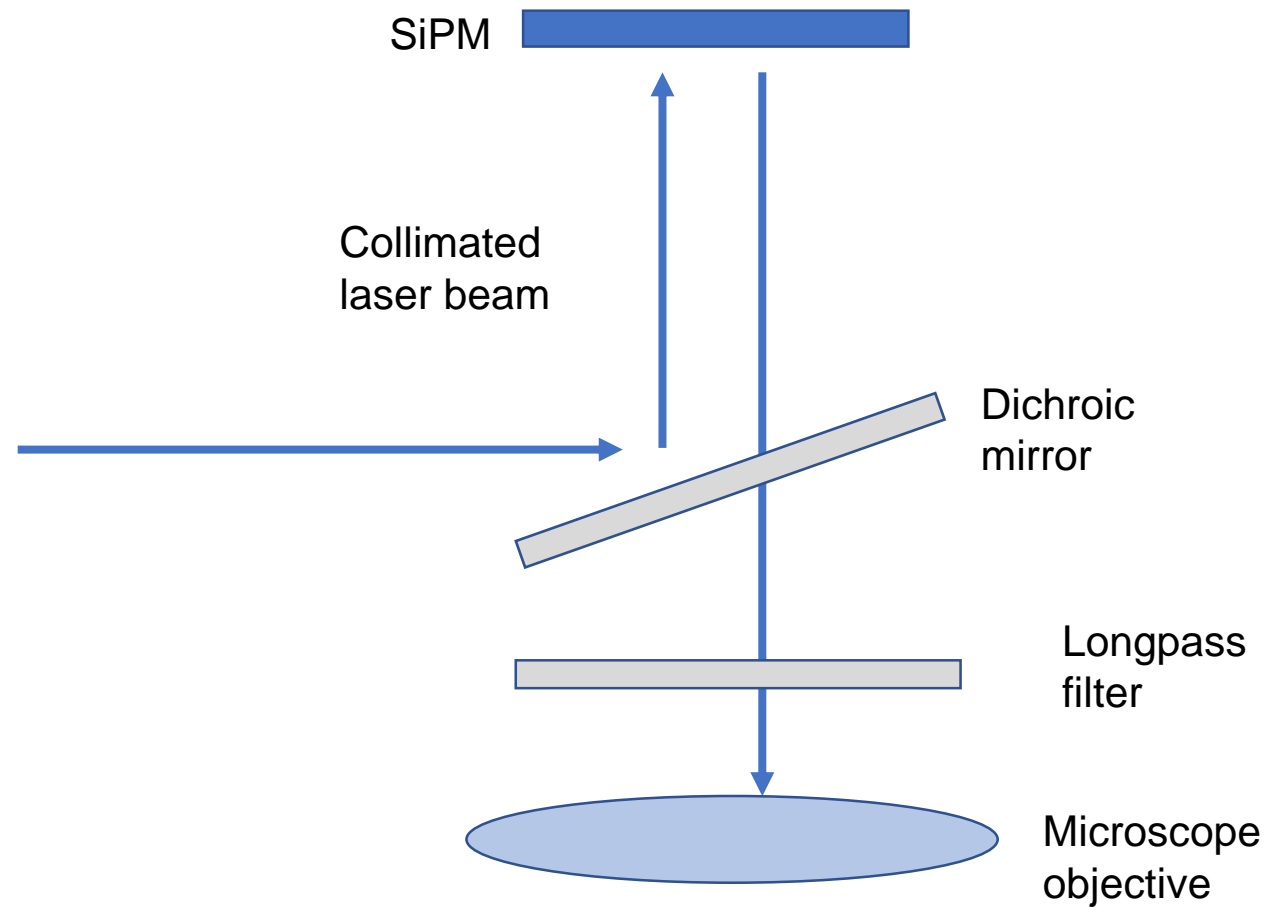
- SiPM **M**icroscope for **I**njection and **E**mission of **L**ight.
- Setup developed at TRIUMF
  - Study **spectral features** of SiPM emission
  - **Geographical location** of light emission
- **Two SiPMs**: FBK VUV-HD3.6, HPK VUV4
  - nEXO candidate photodetectors

# MIEL at TRIUMF



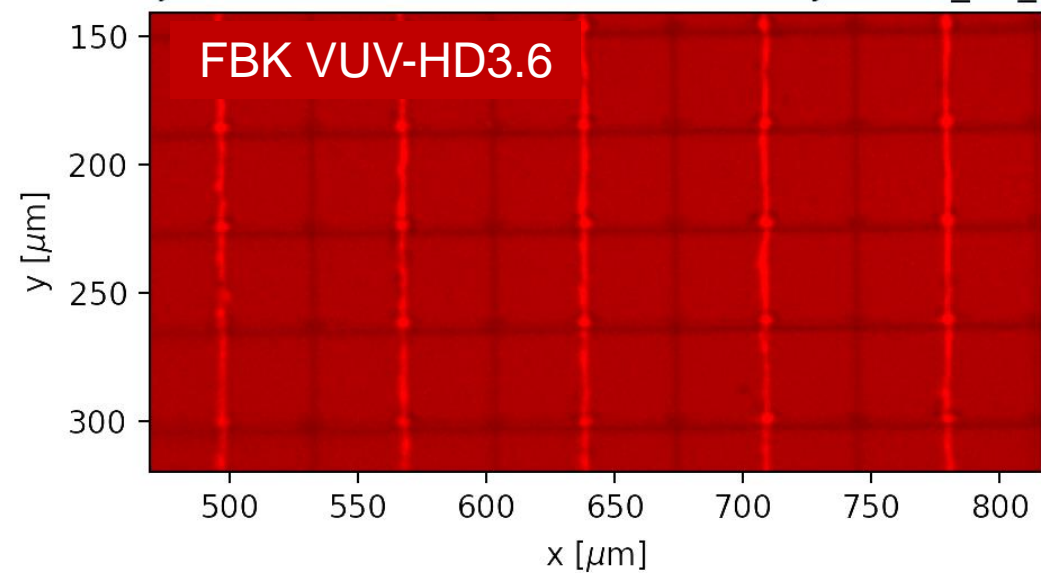
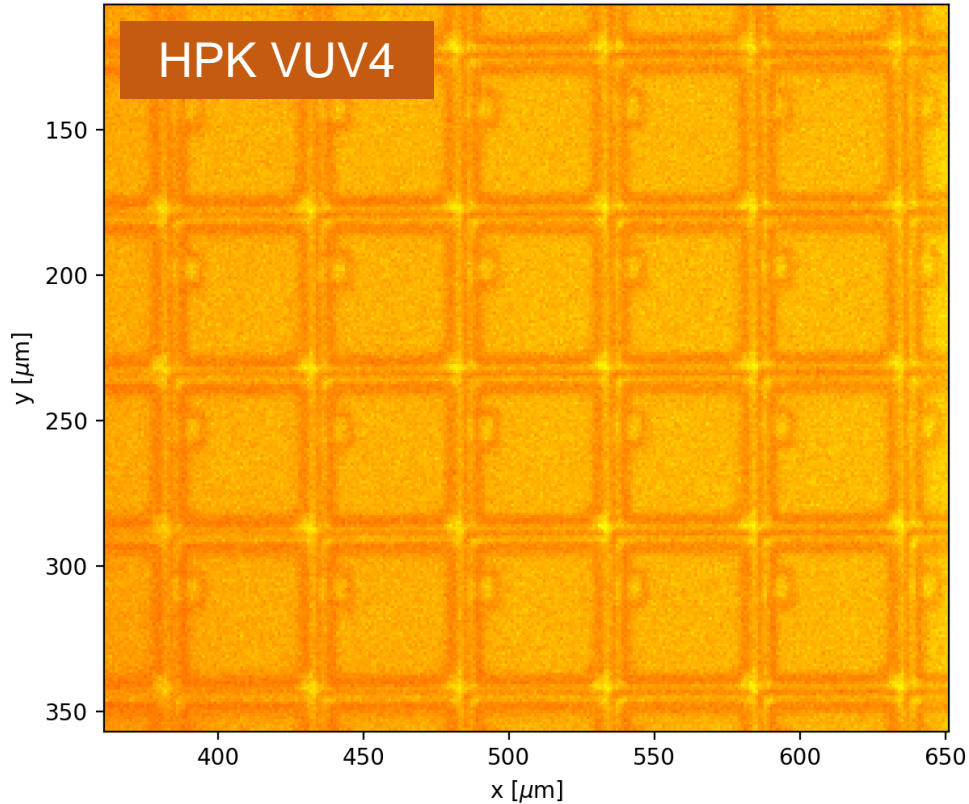
- Previous studies explore emission of SiPM in **dark conditions**
- Additions:
  - **Cryogenic cooling:** reduce dark noise, replicate conditions in cryo experiments (nEXO etc)
  - **Laser injection system:** stimulate emission of secondary photons at variety of wavelengths

# MIEL laser injection system





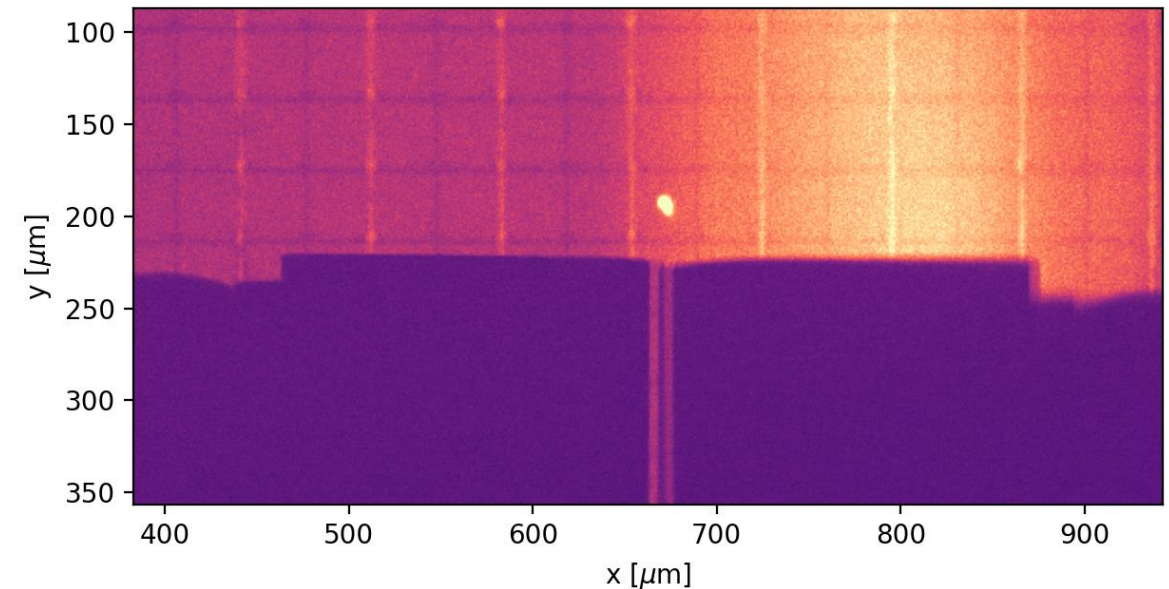
# HPK and FBK photosensors



Parameter	FBK VUV-HD3	HPK VUV4
Total Area	$6 \times 6 \text{ mm}^2$	$3 \times 3 \text{ mm}^2$
SiPM Fill Factor	80%	60%
SPAD pitch	$35 \times 35 \mu\text{m}^2$	$50 \times 50 \mu\text{m}^2$
Breakdown Voltage [298 K]	$31 \pm 1 \text{ V}$	$52 \pm 1 \text{ V}$

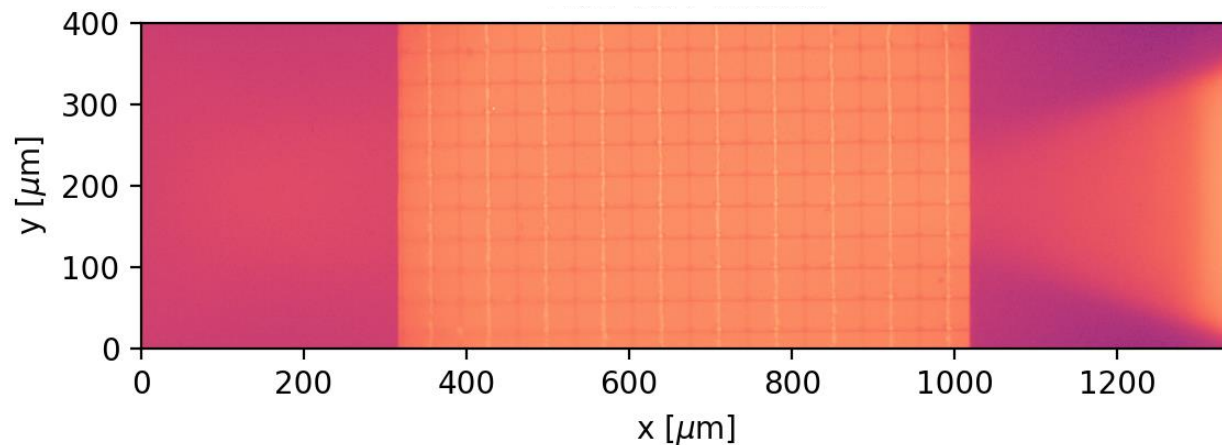
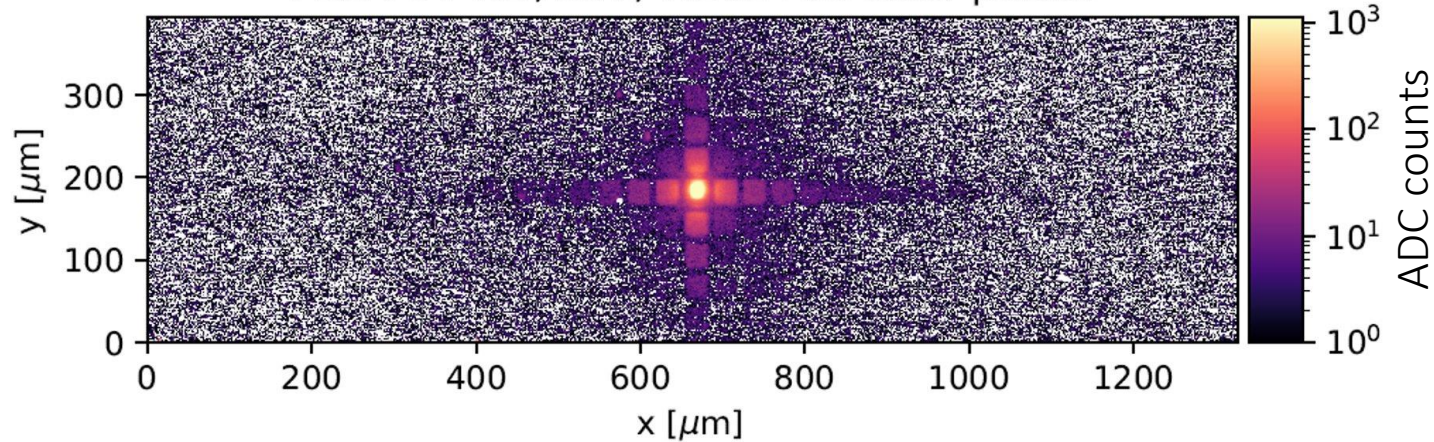
# Laser beam positioning: FBK

- Laser: 444nm wavelength
- Centre beam on SPAD
- Close slit over SiPM for spectra
- Open for emission maps.



# Emission Microscopy Images: FBK

FBK VUV-HD, 35V, 7.20E+09 laser pulses

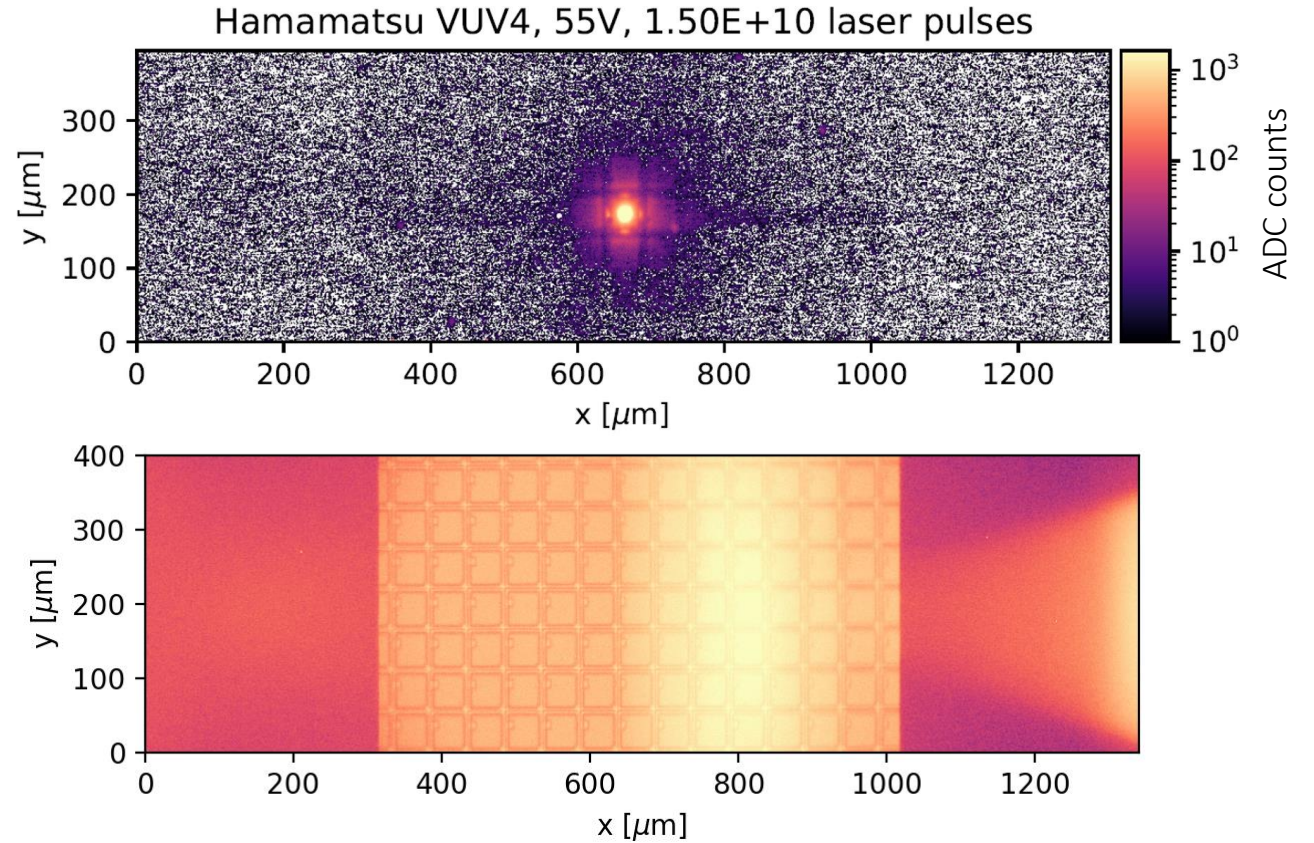


- Polysilicon trenches in FBK – less photon absorbance
- Reflection
- “Light guiding” effect observed

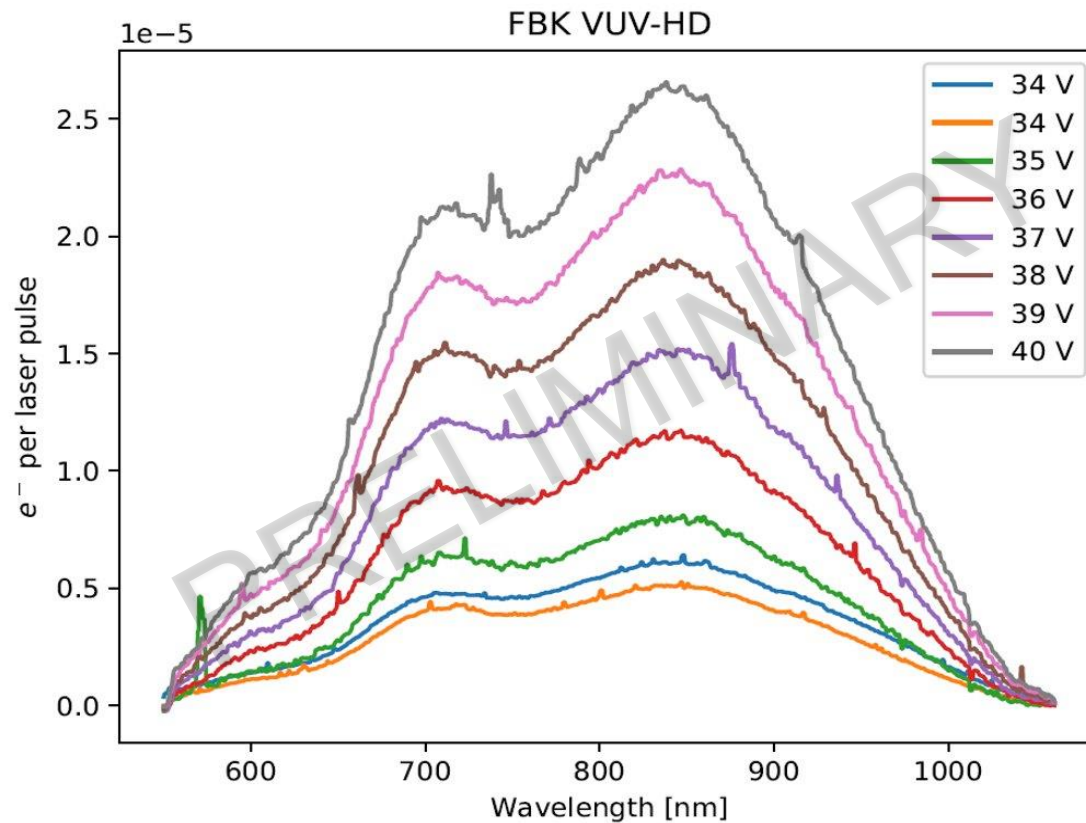


# Emission Microscopy Images: HPK

- HPK has tungsten trench
- Photon absorption
- No distinct 'cross' pattern



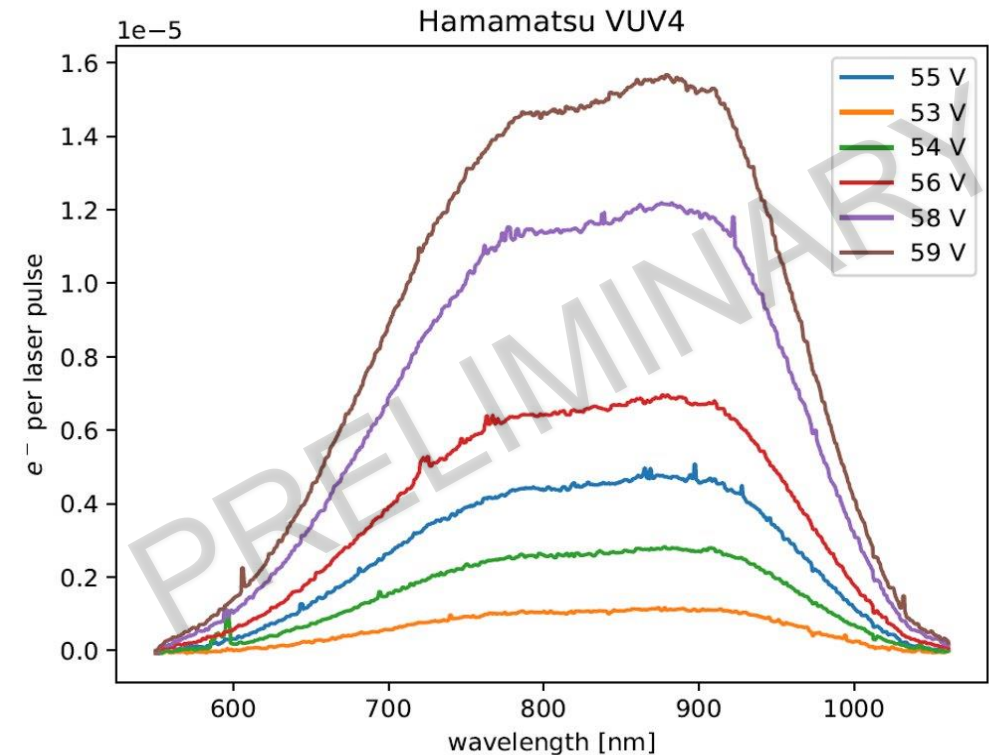
# Spectra: FBK



- Raw spectrum
- Uncorrected for system efficiency
- Rudimentary cosmic removal
- 550nm longpass filter
- Evidence of thin-film interference due to SiO<sub>2</sub> coating.

# Spectra: HPK

- Raw spectrum
- Uncorrected for system efficiency
- Rudimentary cosmic removal
- 550nm longpass filter
- Fewer oscillation than FBK – thinner coating.

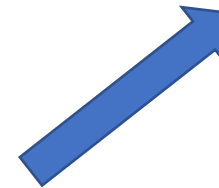


# Summary

- Stimulated two SiPM with 444nm laser
- Obtained raw spectral distributions
- Emission maps reflect differences in structure between SiPMs

# Ongoing and future work

D. Minchenko, 8<sup>th</sup> June,  
16:15 in MDCL 1110



- More effective cosmic removal
- Error analysis
- **Active simulation efforts to model photon transport in SiPM**
- Correct spectra for system efficiency – intensity calibration
- Correct for finite numerical aperture – simulation
- Is the level of photon emission a problem for future experiments?
- **Stay tuned!**



# Acknowledgements

- Supervisor: F. Retière
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- PHAAR group at TRIUMF

Thank you!  
Merci!

## Contact

[juliettem@triumf.ca](mailto:juliettem@triumf.ca)

**Backup**

# Efficiency curve

- Calibrate spectrometer using PI IntelliCal<sup>®</sup> source.
- Wavelength and intensity calibrations computed.
- Spectra produced treated with efficiency curve
- Rudimentary error analysis, potential wavelength miscalibration

