Data processing of SPAD sensors for high quality imaging

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Outline

- ADAPS introduction
- ADAPS Gen1 SPADIS
- Data processing
  - Coincidence detection
  - Denoising
- Conclusion
- Challenges

We focus on

high-efficiency single-photon avalanche detector sensors & systems

We create eyes for the smart future

Company Introduction

Shenzhen Adaps Photonics Technology Ltd.,

Founded in Shenzhen, China in May 2018

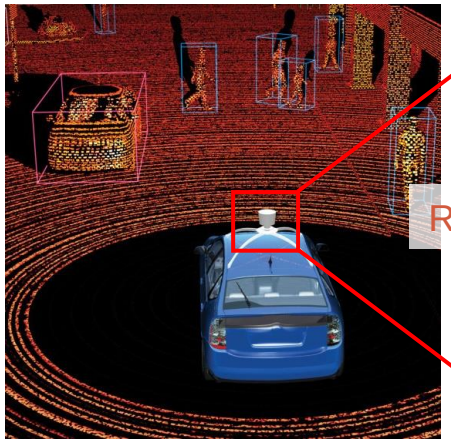
- HQ Nanshan, Shenzhen
- SV RDC: San Jose, CA
- SH RDC: Zhangjiang, Shanghai

Full time: 35

+ 9 PhD
+ Stanford , TU Delft, UCBerkeley, CMU, Peking University, Tsinghua University, NTU alumni
+ 5 Engineers with over 10 years industrial experience
+ >15 technical consultants, over 20 years

1st place in China Innovation & Entrepreneurship Competition 2019

Time-of-flight (ToF) sensor and SPAD



ADAS system

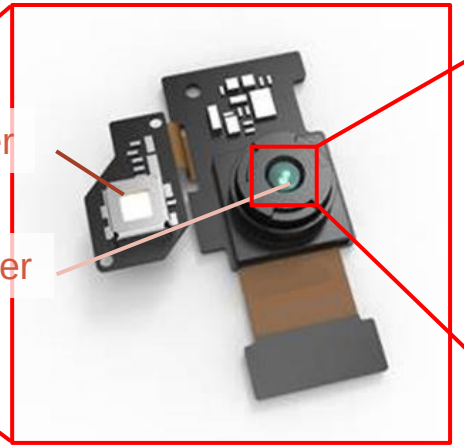
AI system

Smart Phone

LiDar

Sensor

3D Module



APD SiPM

LiDar receiving unit

Sensor chip

ToF chip

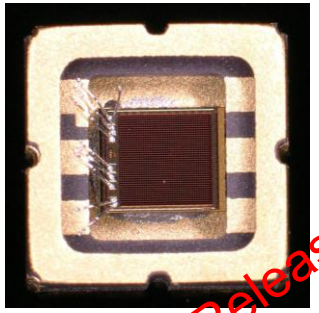
iToF sensor (dToF) SPADIS

SPAD

- Extreme sensitive
- Fast photon response

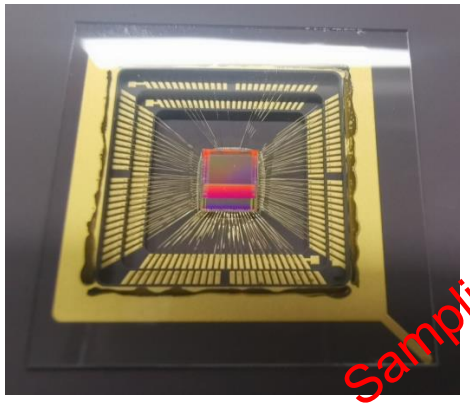
Adaps Products for dToF applications

Products



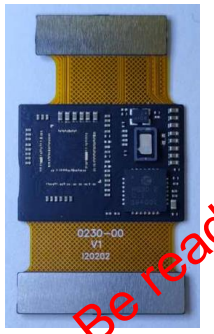
Released

High Performance SiPM



Sampling

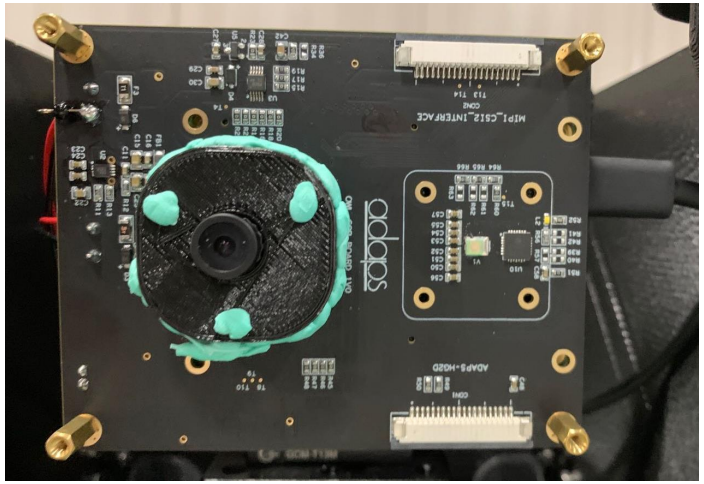
3D ToF SPADIS



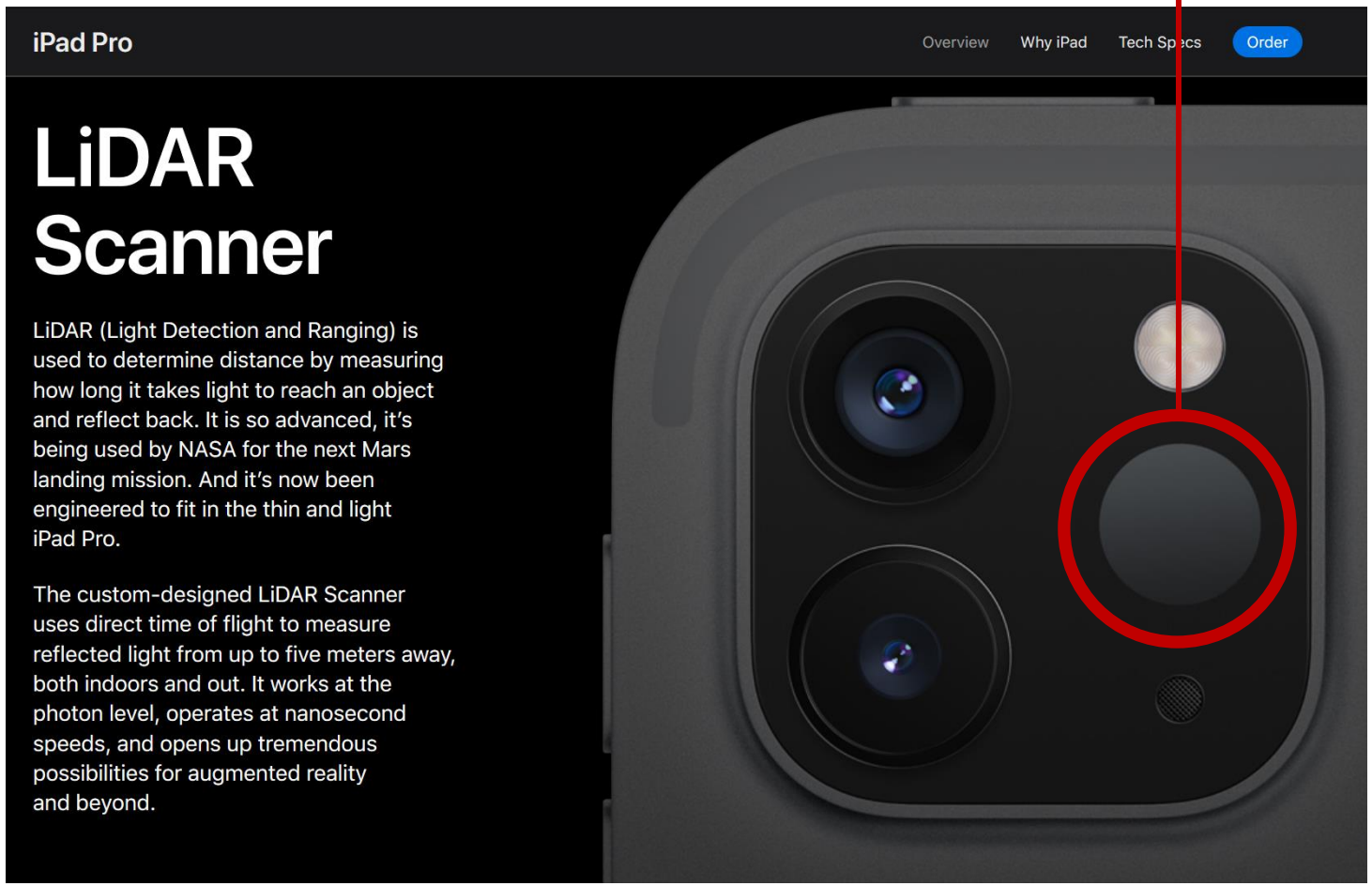
Be ready in July

SPADIS module

Demonstration platform



dToF Camera



2020 iPad Pro has adopted dToF 3D sensor targeting AR applications, starting a new Era of AR/MR on phone and tablets

SPAD dToF 3D Camera

Lower power

Higher 3D data quality
Longer distance

iToF 3D Camera


OPPO R17 Pro

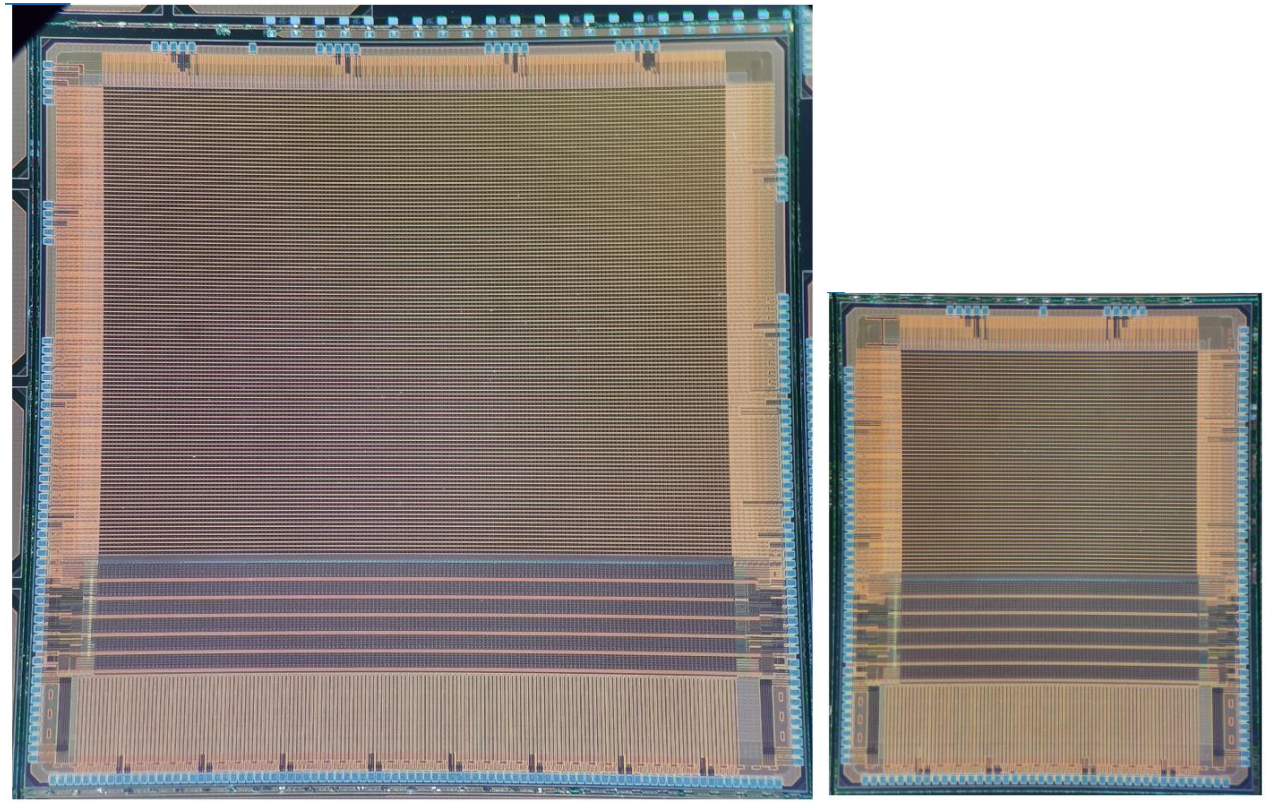

Huawei Mate30 Pro


Huawei P30 Pro

ADAPS Gen1 SPADIS

Spec:

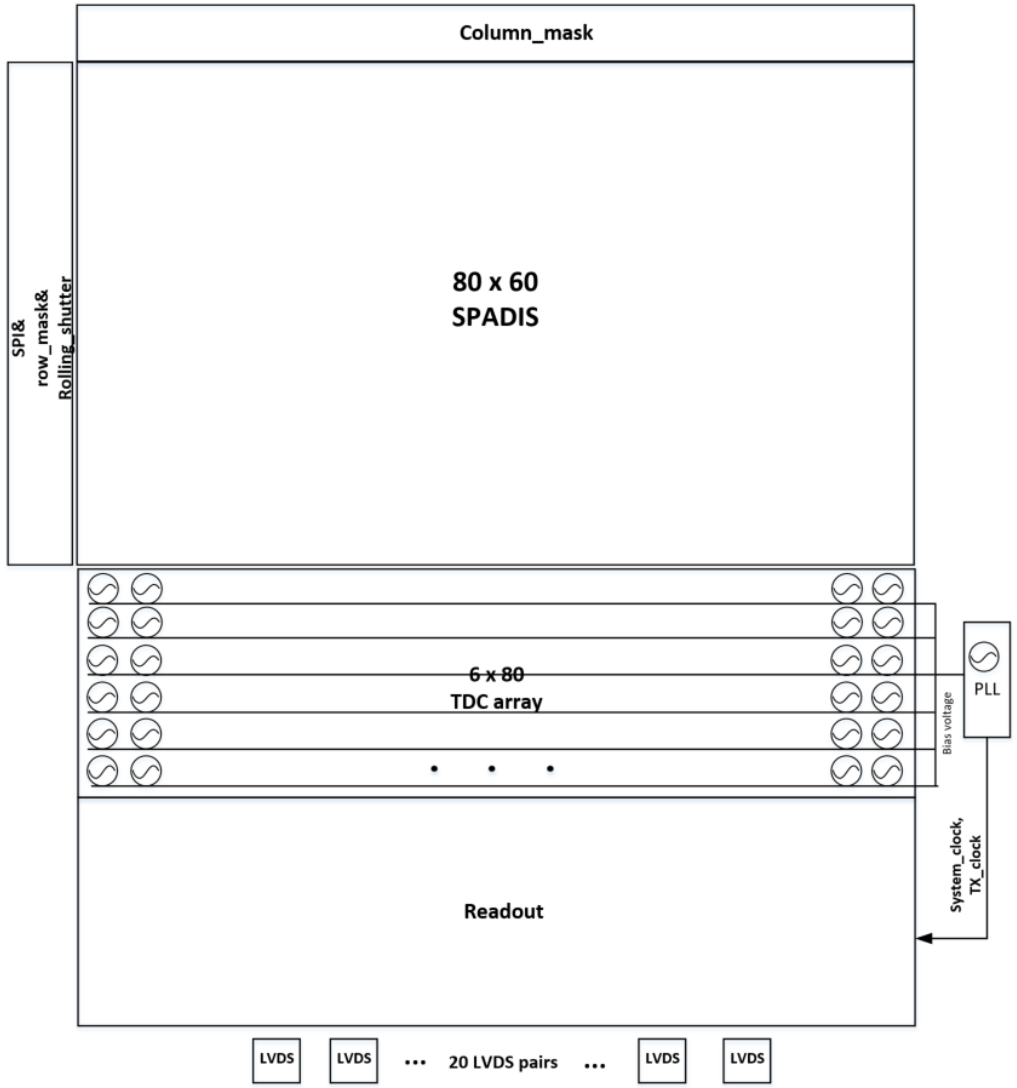
- 130nm CMOS
- Resolution： 160 x 120 (EAGLE)
  80 x 60 (OWL)
- Pixel size： 30um
- Dead time： 20ns
- FF： 35%
- PDP @940nm: 3% @3V
- Median DCR : 2000 Hz,
- Crosstalk: 5%



EAGLE

OWL

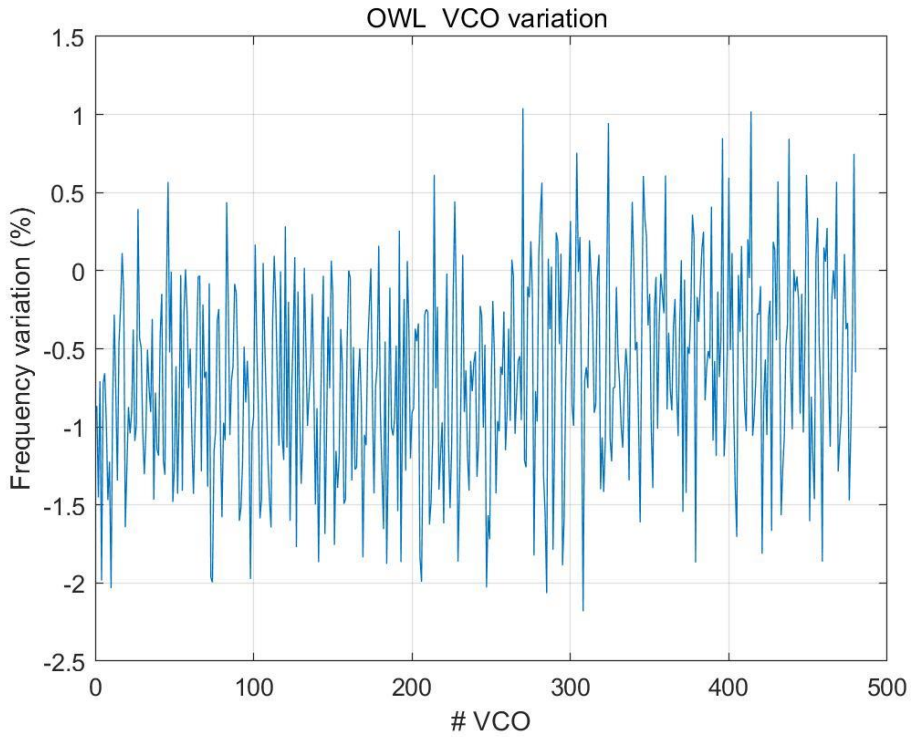
OWL Architecture

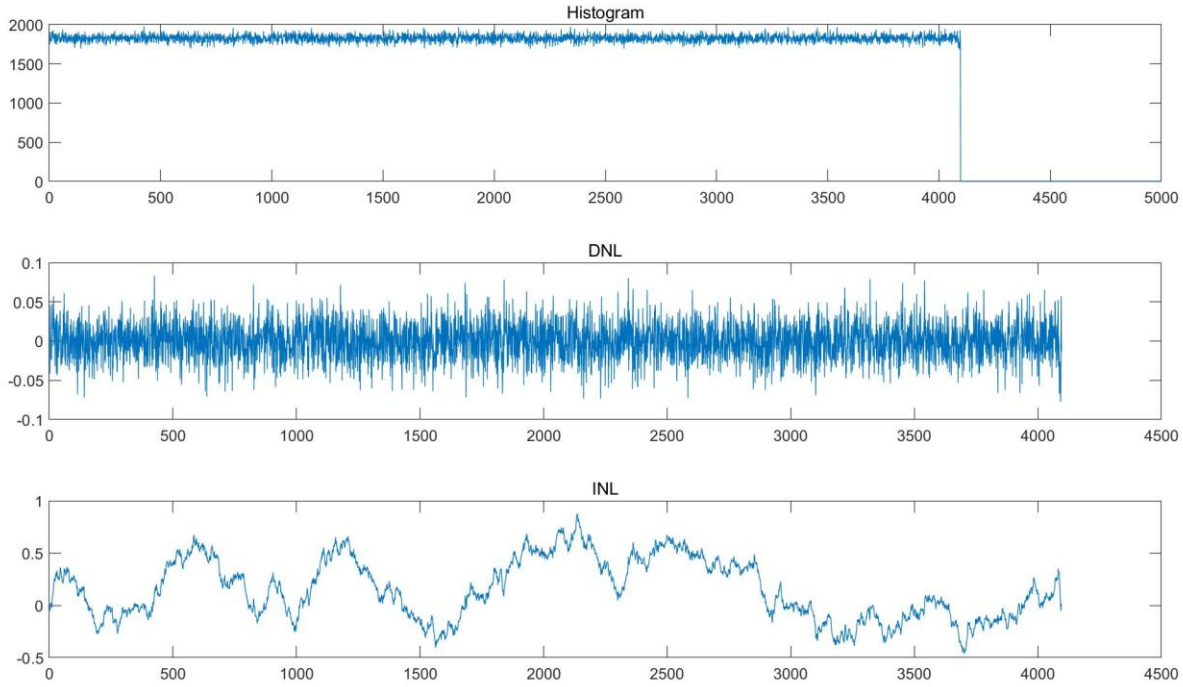


Features:

- 80 x 60 SPAD array
- 480 12-bit TDCs
- 10 x Rolling shutter
- SPI controller
- 20 high speed LVDS

TDC Linearity

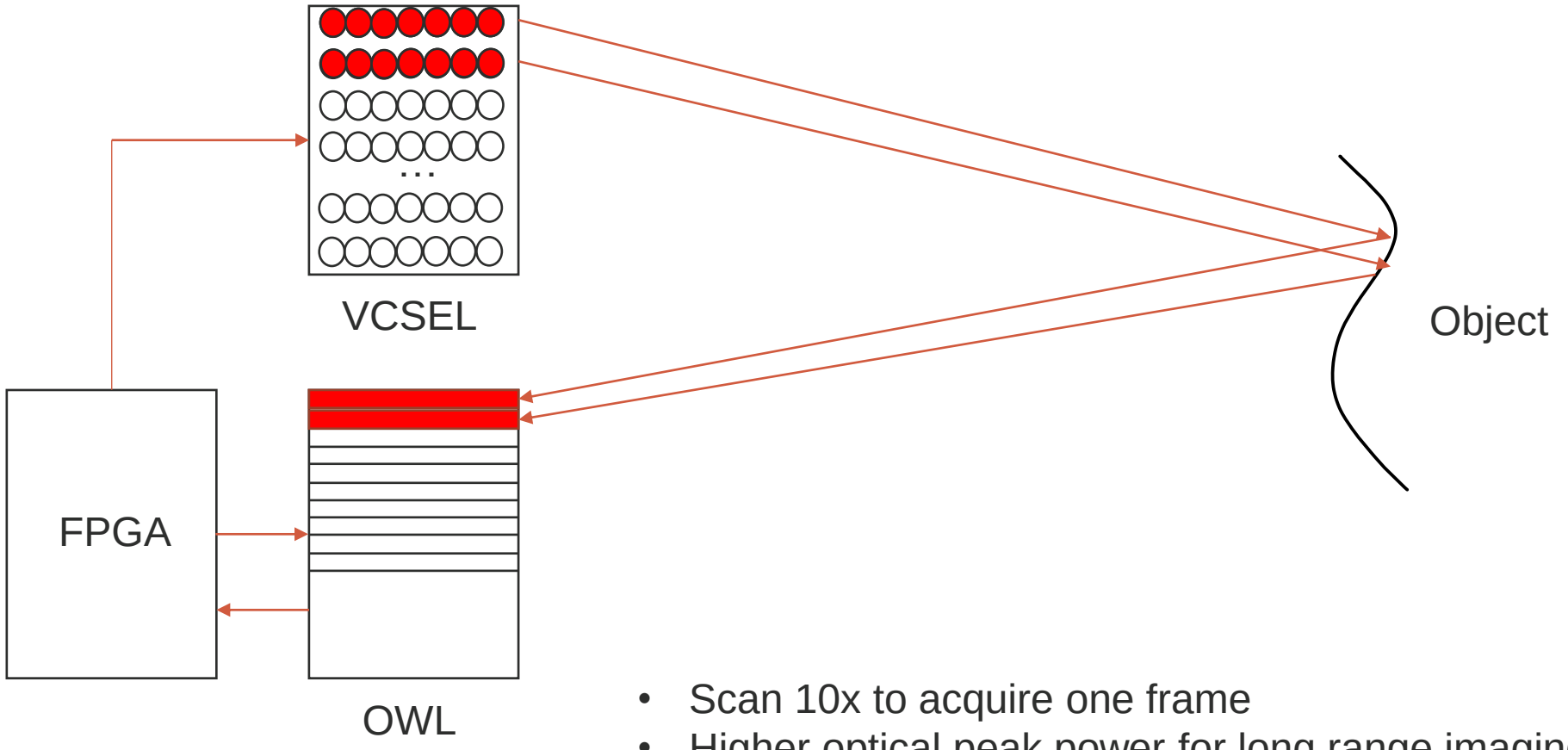




- Frequency variation is within +/- 2% over 480 VCOs

- LSB: 62.5ps
- DNL: +/- 0.08LSB
- INL: -0.38/0.87 LSB

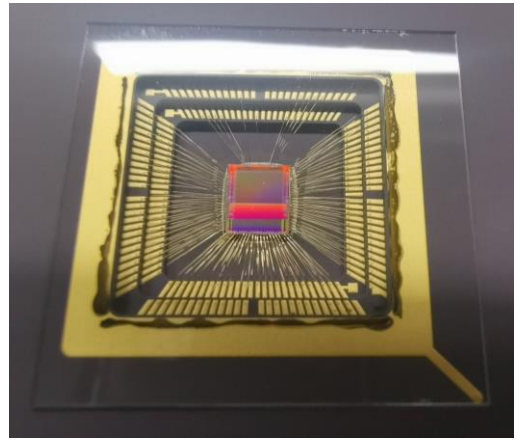
OWL Working Principle

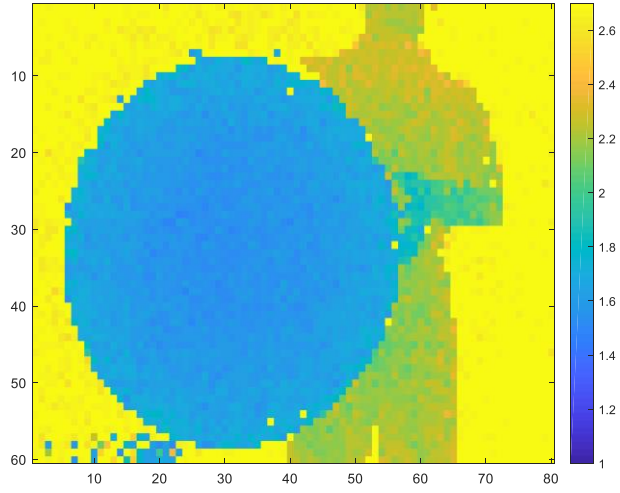


- Scan 10x to acquire one frame
- Higher optical peak power for long range imaging

OWL Demo

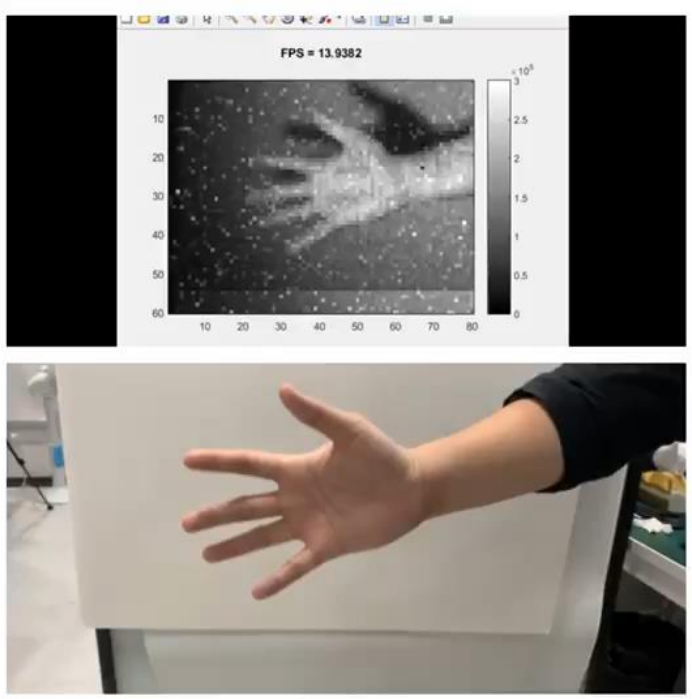
- System spec
  - 10-30 FPS (intensity and depth map)
  - FoV: 46 x 60 deg
  - Laser frequency: < 8MHz
  - Pulse width: 2ns
  - Optical peak power: 1.9 W
  - Flood illumination



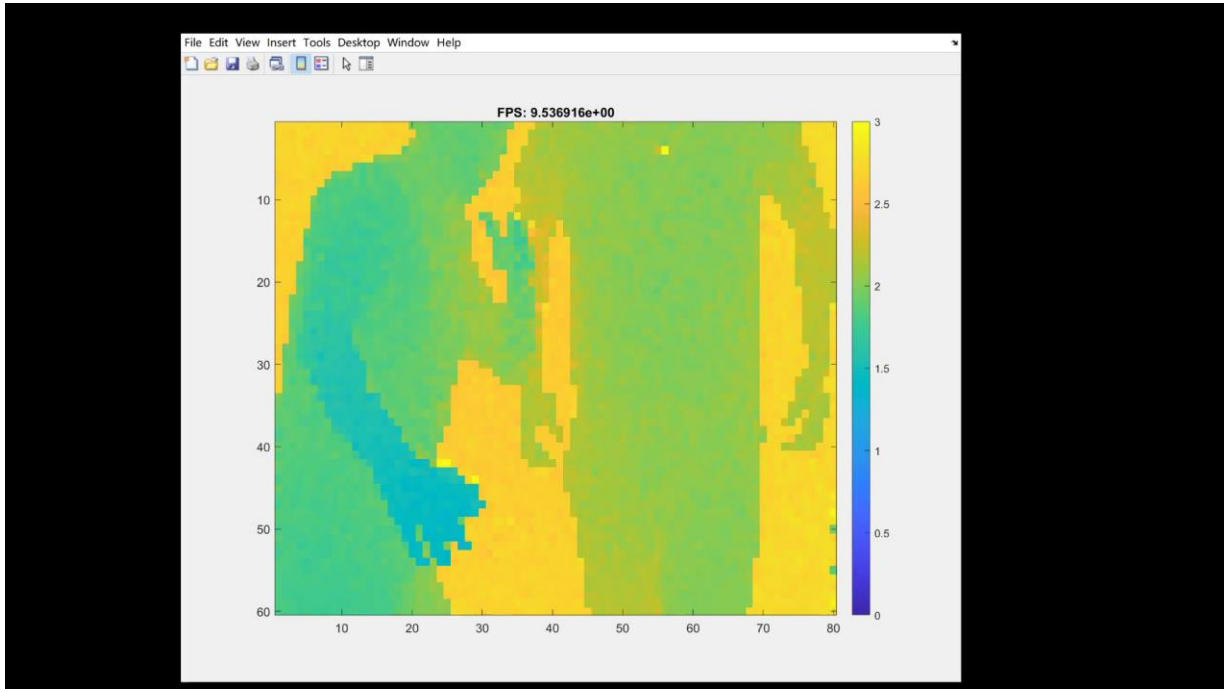


OWL 2D and 3D Imaging

Intensity imaging



Depth Imaging

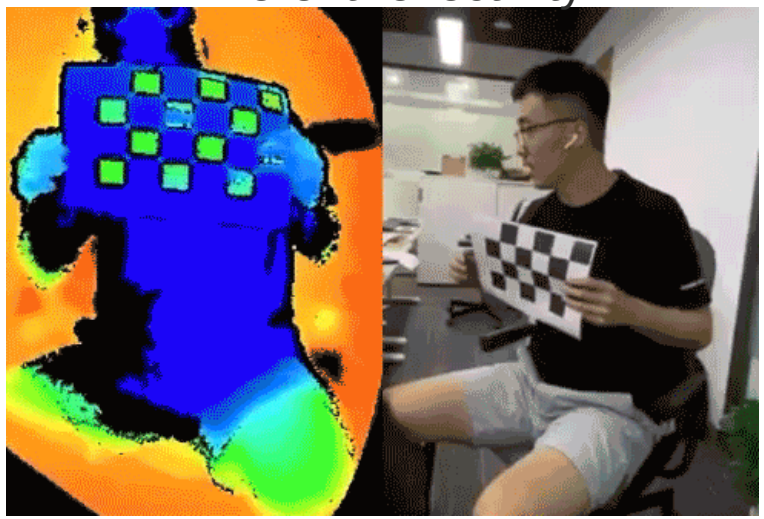


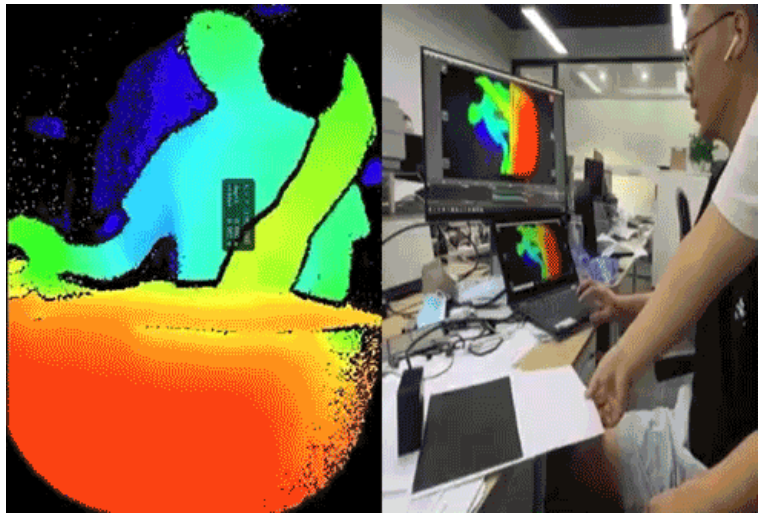
ADAPS dToF vs. iToF

Different reflectivity

Multi-path interference

iToF

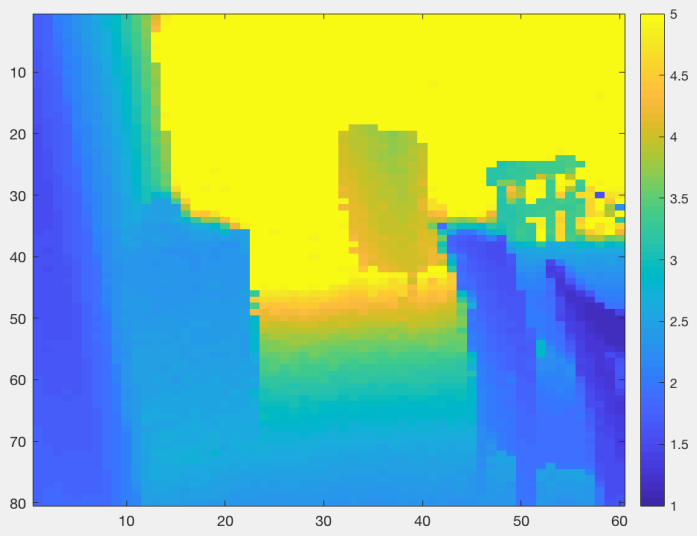




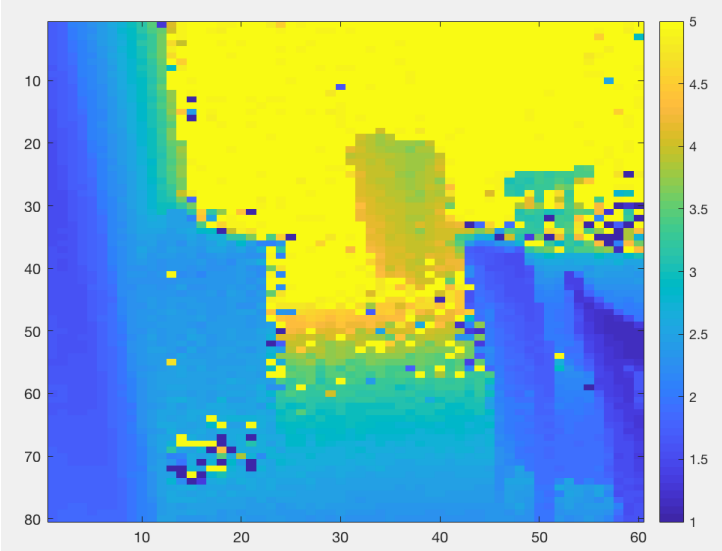
dToF

Coincidence Detection

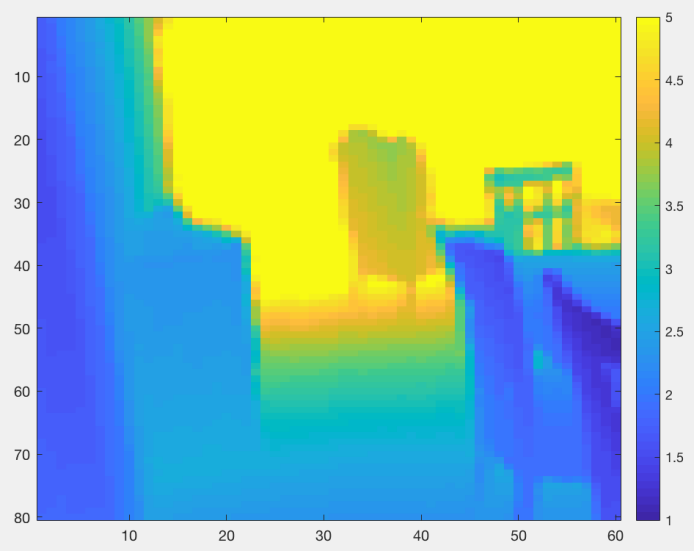
- Theoretically can raise SNR
- Practically will add in shot noise and is not very helpful in simulations



5e4 times, 1klux,
without coincidence
Rel abs diff = 1.4%



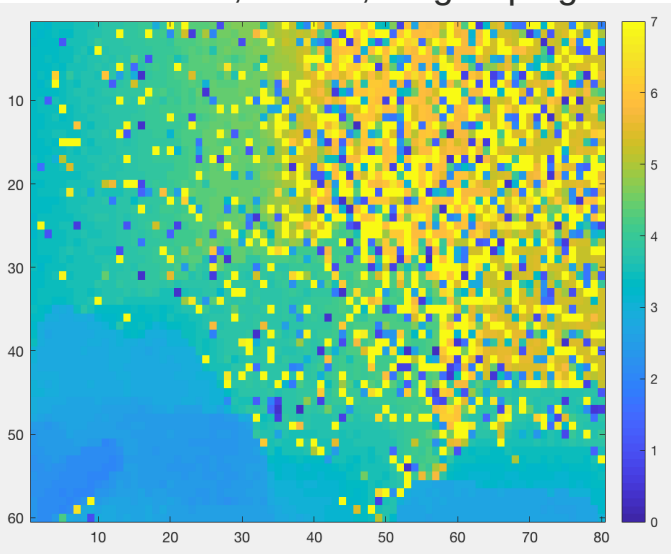
5e4 times, 1klux,
coincidence frame = 10,
threshold = 2, window = 4ns
Rel abs diff = 5.4%



Ground truth

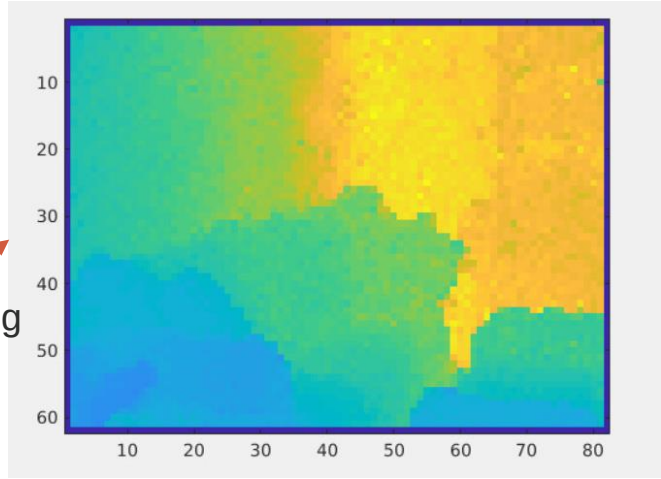
Denoising

1e5 times, 50klux, no grouping



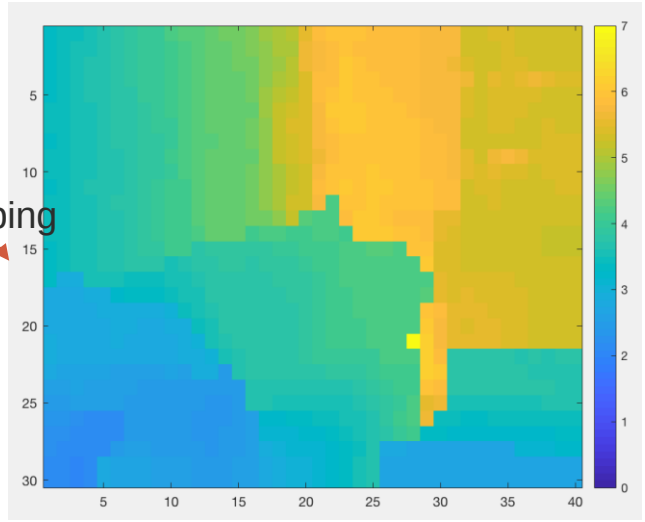
Original noisy image

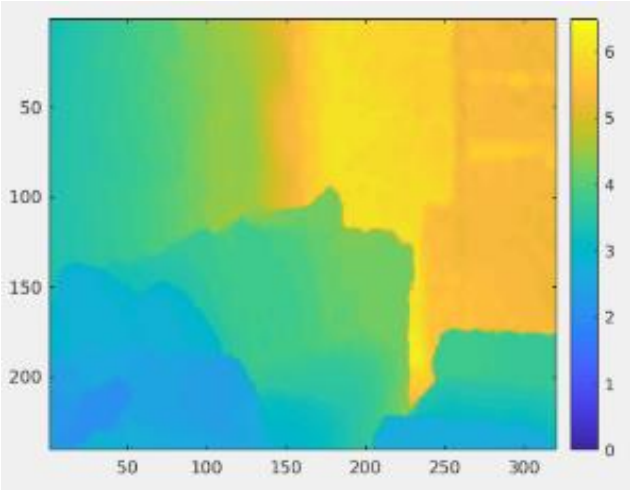
Smart grouping



After denoising

blind 2x2 grouping





Ground truth

- Intra-and-inter frame grouping could be helpful for SNR imrpovement

Conclusion

- Two SPADIS in rolling-shutter mode are demonstrated
- Imaging comparison between iToF and dToF is presented
- Coincidence detection is not that helpful due to the shot noise increasing
- Grouping based denoising significantly improves the image quality

Challenges

- Histogram is a beautiful thing, but too many histograms are nightmares.
- With the help of histogram, image quality can be improved significantly. But the computational power is high.
- Will the low resolution, Ipad-like Lidar scanner be the benchmark of next generation SPADIS ?
- Too many factors limit the design of SPADIS, e.g. memory, electrical & optical power, module assembly, cost, iToF competition, etc. One SPADIS can’t meet all the requirements, and it all depends on the applications.
- What will be the killer App of ToF sensors ?

Thank you for your attention !

Super resolution algorithm performance

RGB picture

Depth Ground Truth

Emulated 80x60 Adaps SPADIS
Original depth map

320x240
Adaps 4X super resolution