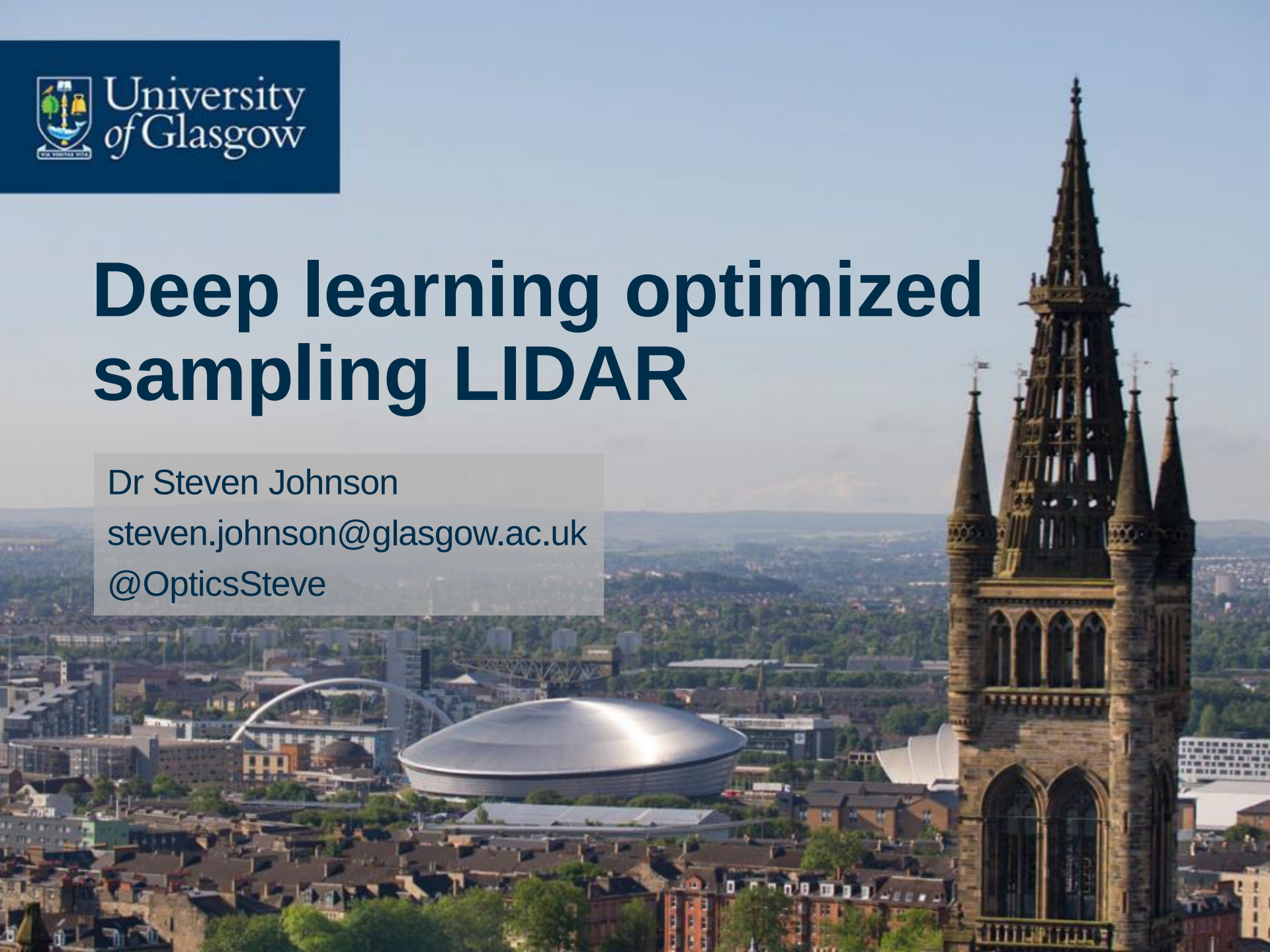

University of Glasgow

Deep learning optimized sampling LIDAR

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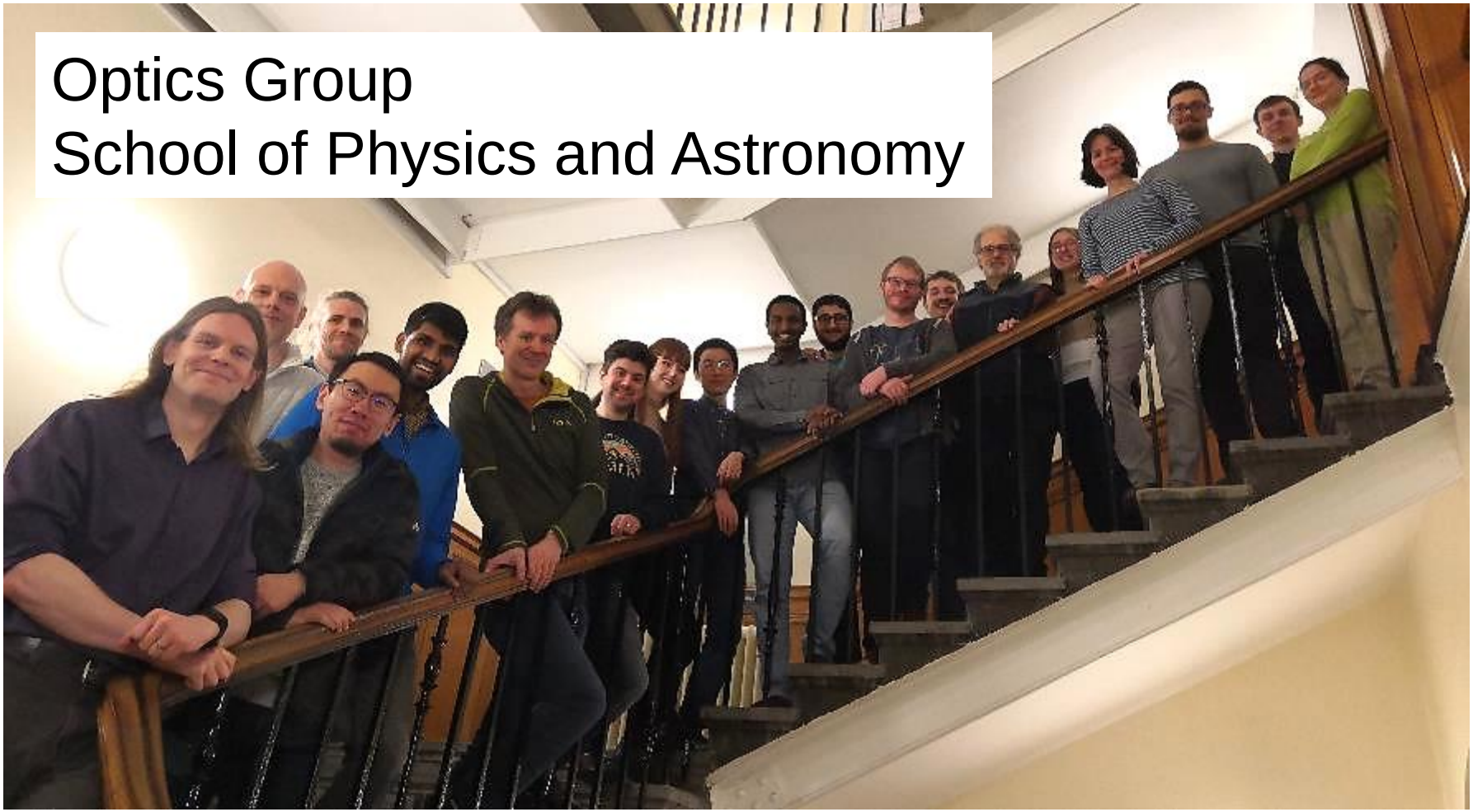
steven.johnson@glasgow.ac.uk
@OpticsSteve


Optics Group
School of Physics and Astronomy

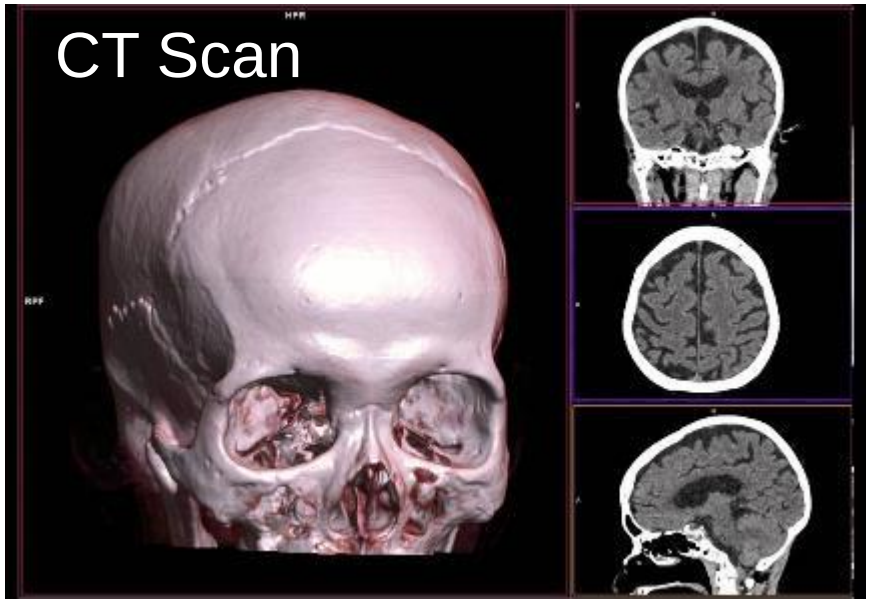
Outline

- Computational imaging
- Deep learning optimisation
- LIDAR with optimised sampling

Computational Imaging

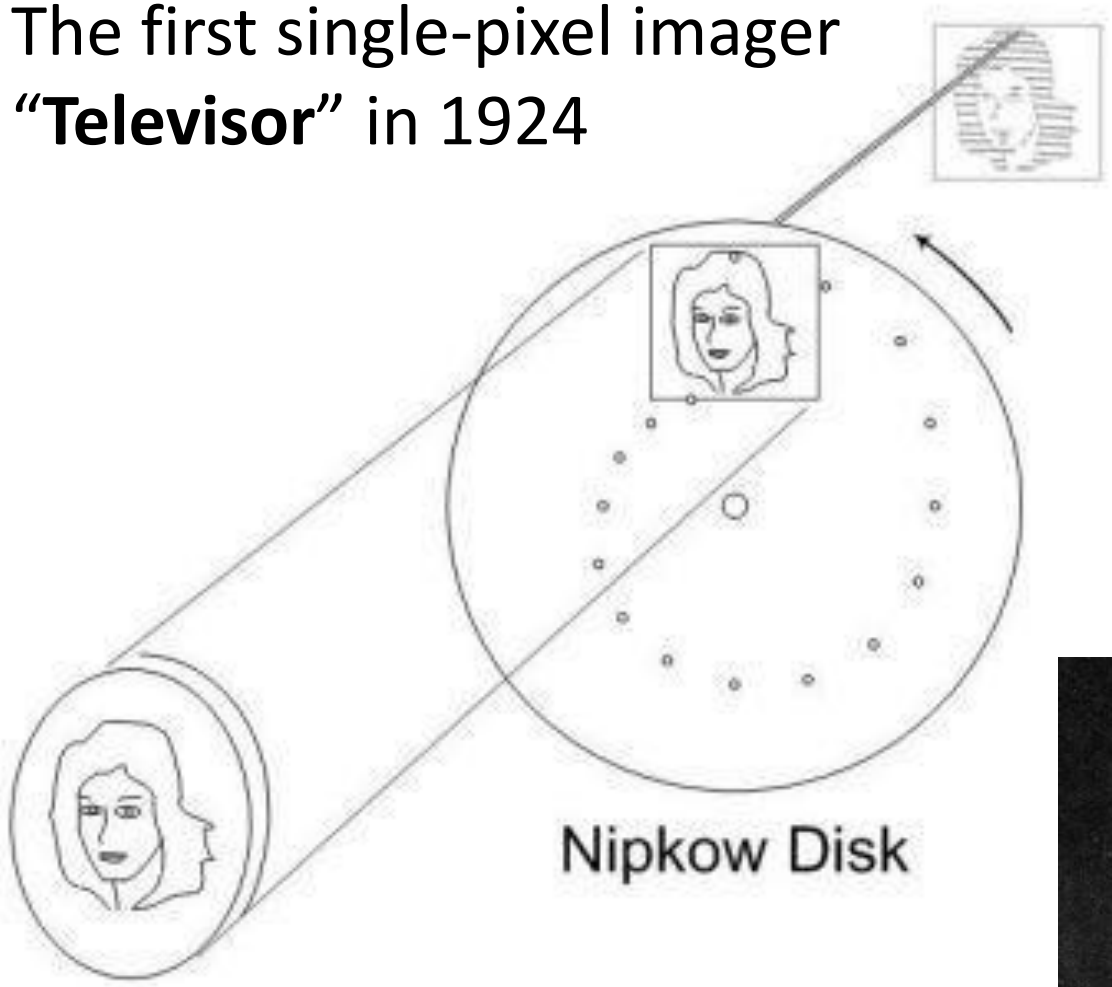
Computational Imaging

Indirectly forming images from measurements using algorithms to compute the image.



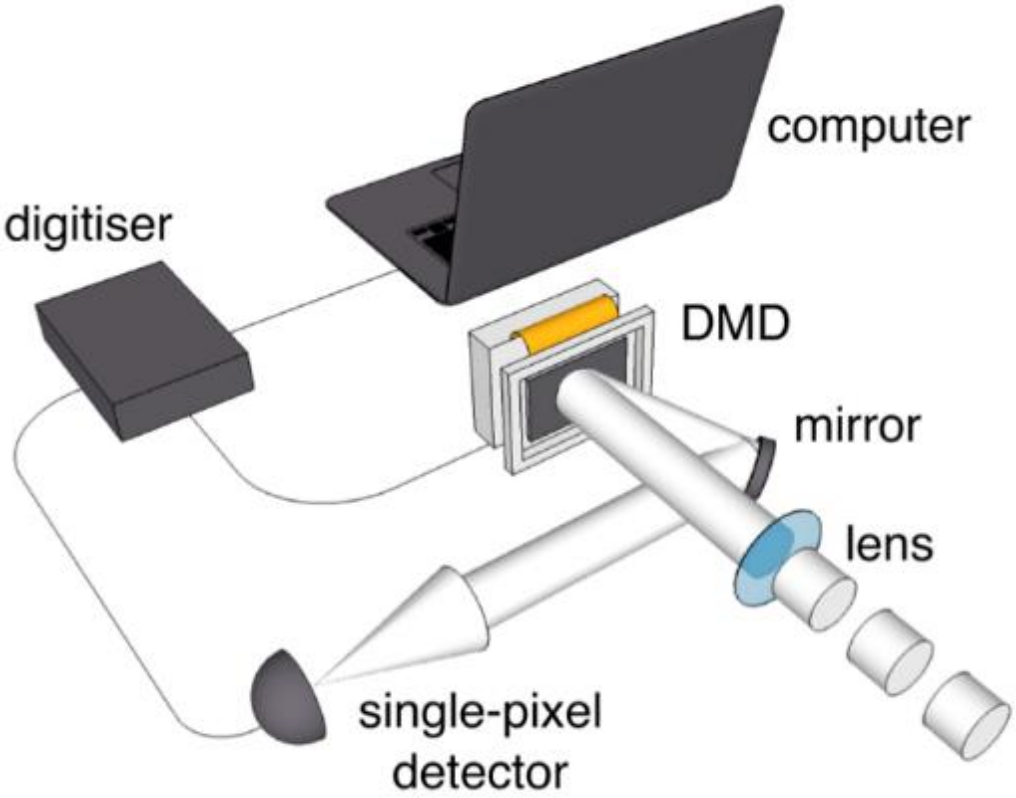
Single-pixel imaging origins

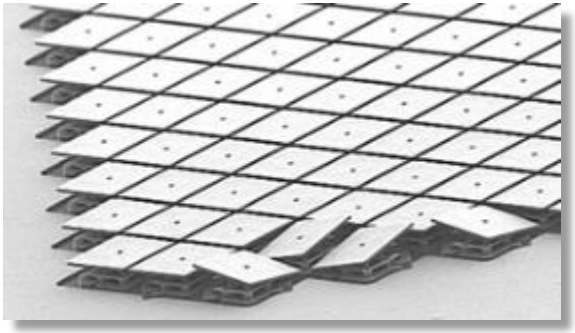
The first single-pixel imager "**Televisor**" in 1924



John Logie Baird

Single-pixel imaging



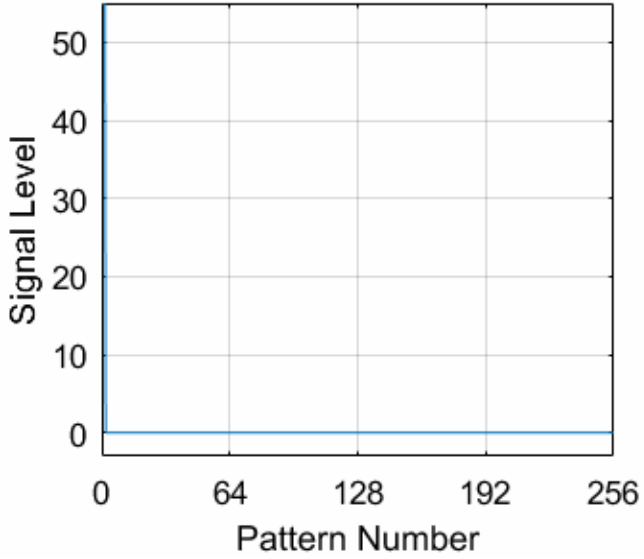


Higham et al., Deep learning for real-time single-pixel video, Scientific Reports **8**, 2369 (2018)

Single-pixel Imaging

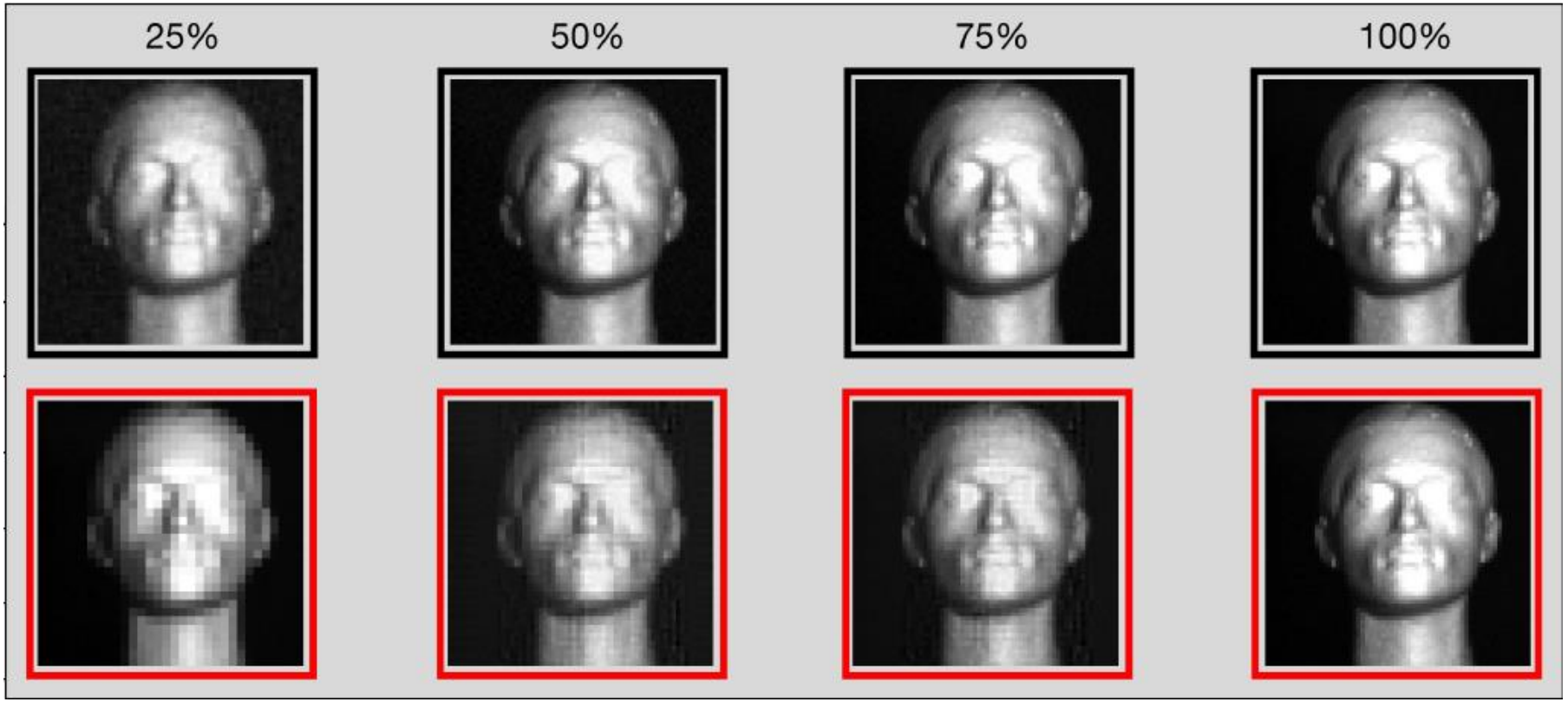
Pattern Displayed

Measured Signal



Calculated Image

Compressive sensing

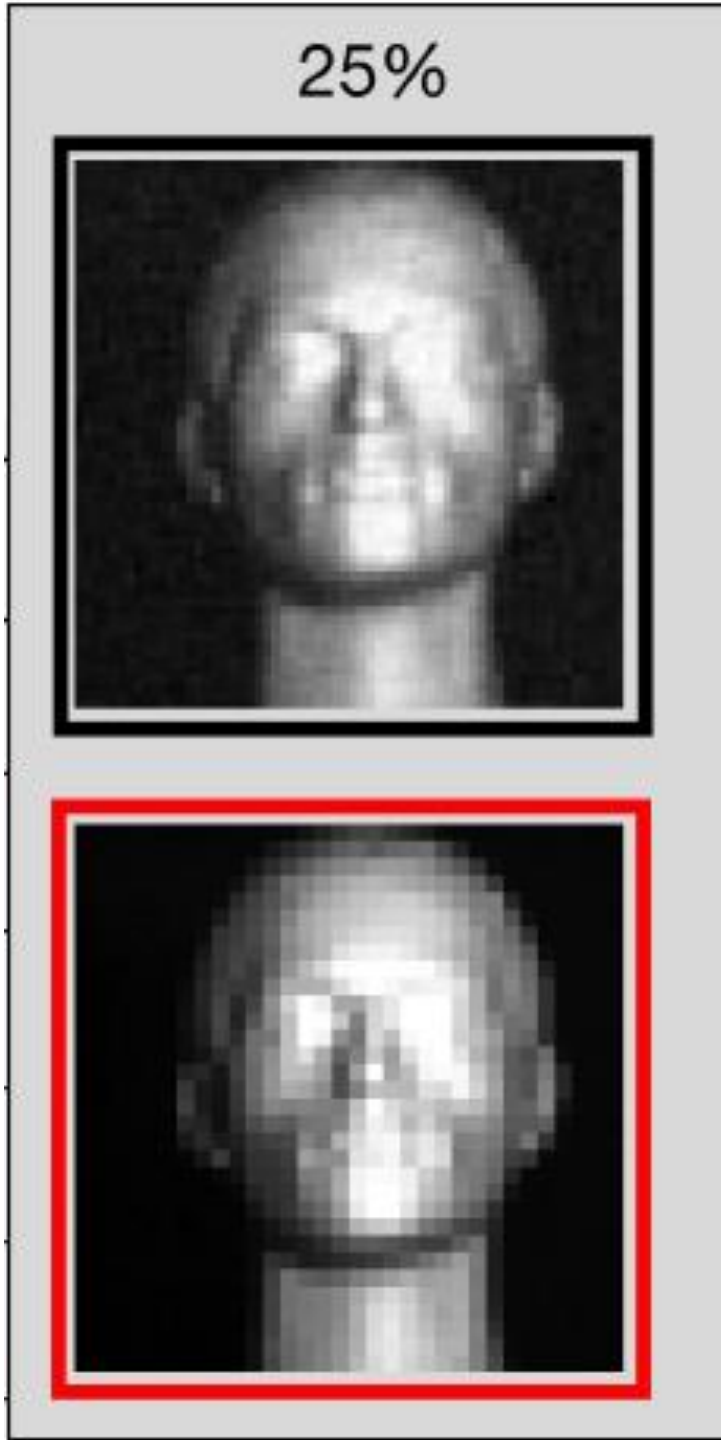


Matthew P. Edgar et al, "Real-time 3D video utilizing a compressed sensing time-of-flight single-pixel camera," Proc. SPIE 9922, (2016)

Why bother?

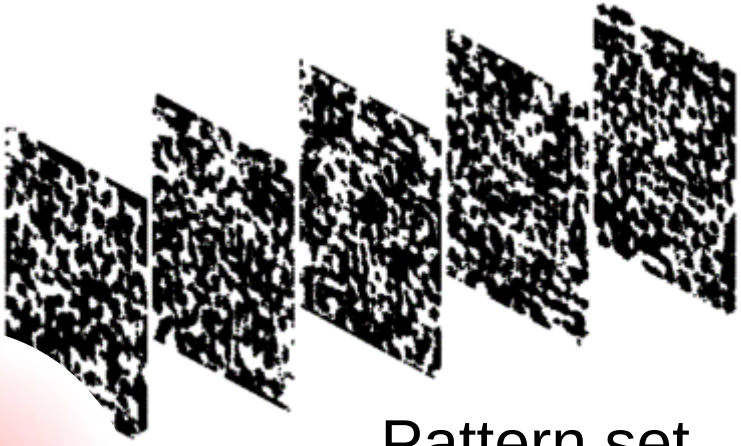
Choose patterns for imaging

Standard pattern set



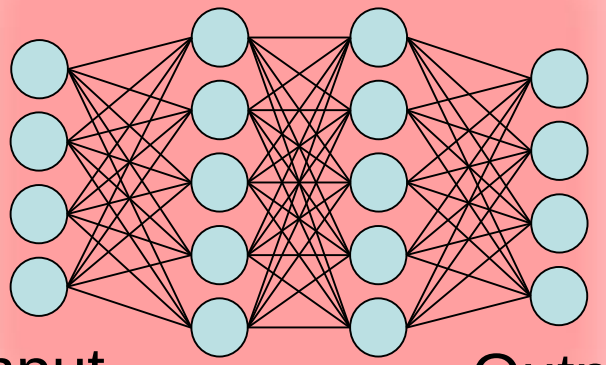
Deep Learning Optimization

Deep learning method



Pattern set

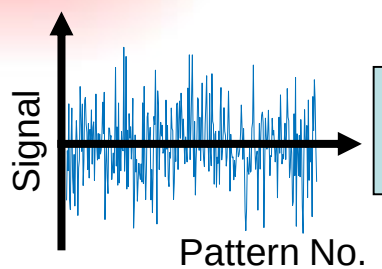
Convolutional neural network



Input Layer

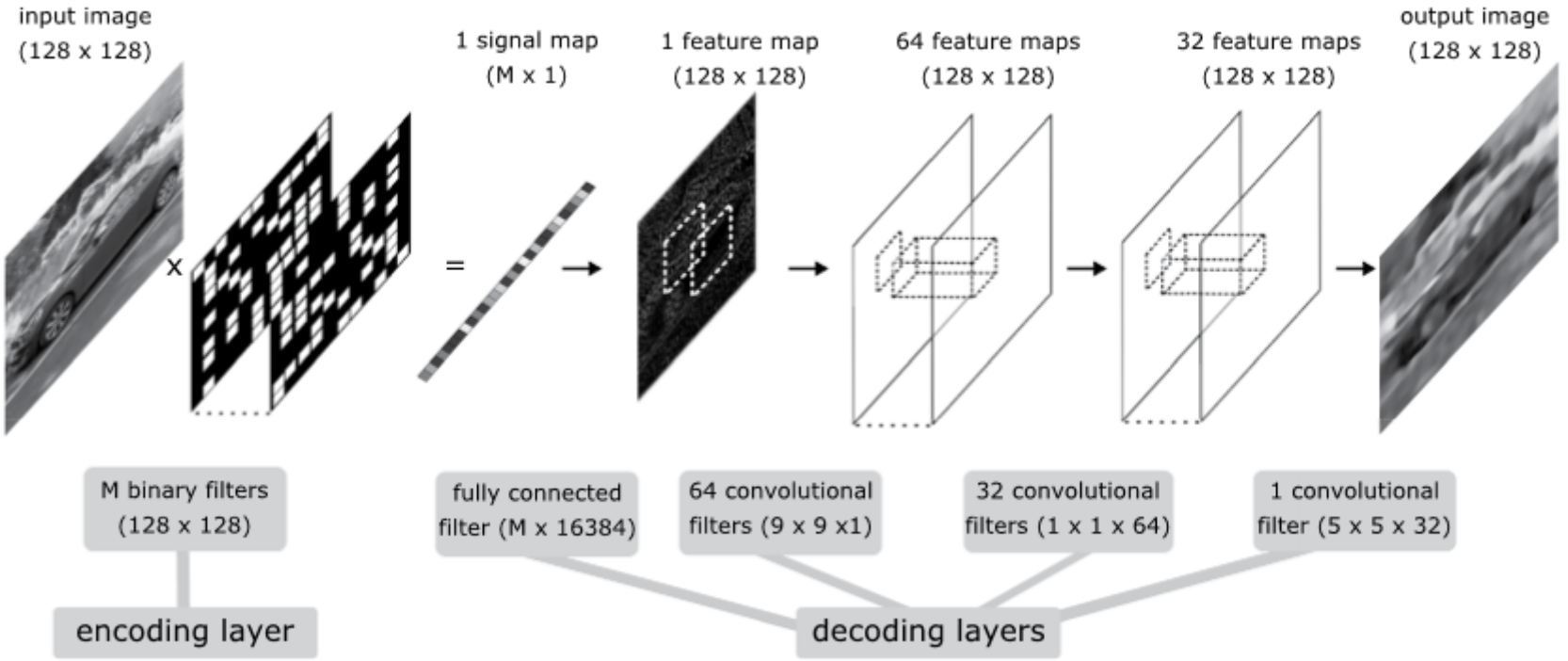
Output Layer

Algorithm



Deep Learning - Single-Pixel Cameras

Deep-learning with convolutional auto-encoder networks (DCAN)



Higham et al., Deep learning for real-time single-pixel video, Scientific Reports **8**, 2369 (2018)

Deep Learning - Single-Pixel Cameras

Deep-learning technique: deep-learned basis of 666 patterns and reconstruction

Previous technique: evolutionary Hadamard scan using 666 patterns

Example patterns

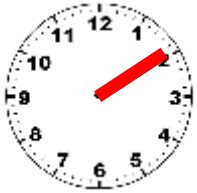
666 (x2) patterns, at 20KHz, i.e. 15 fps

LIDAR with Optimised Sampling

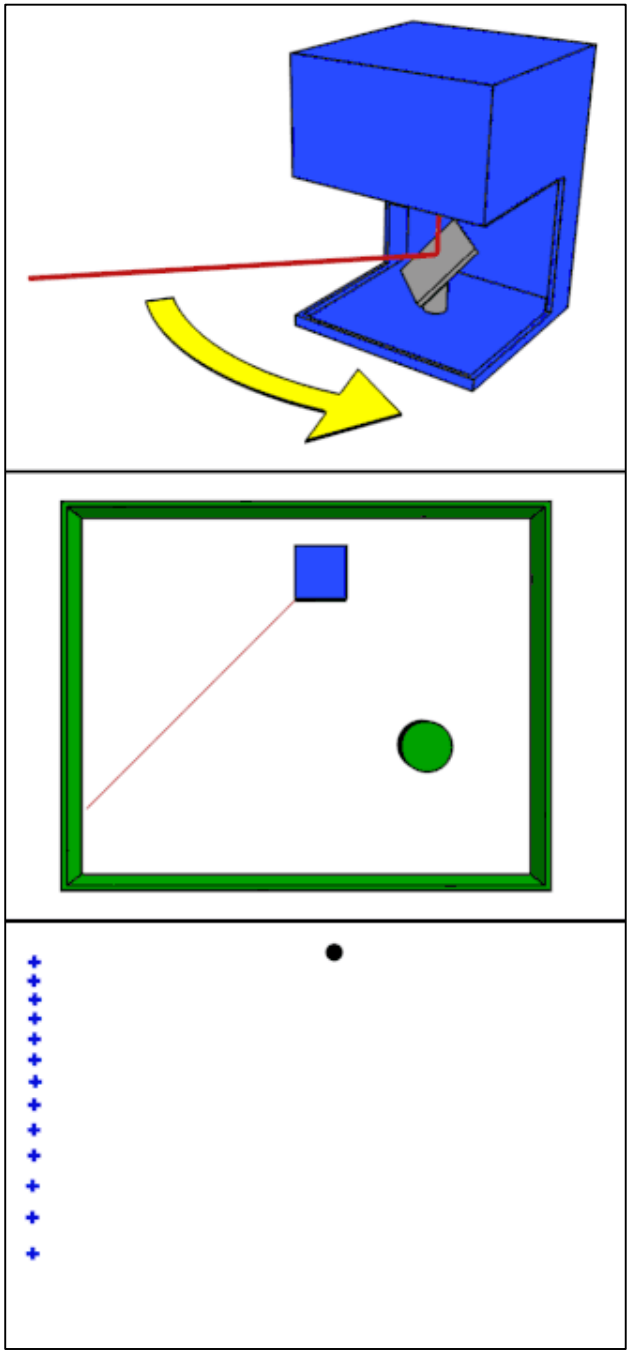
Light **D**etection and **R**anging

Emitter

Detector

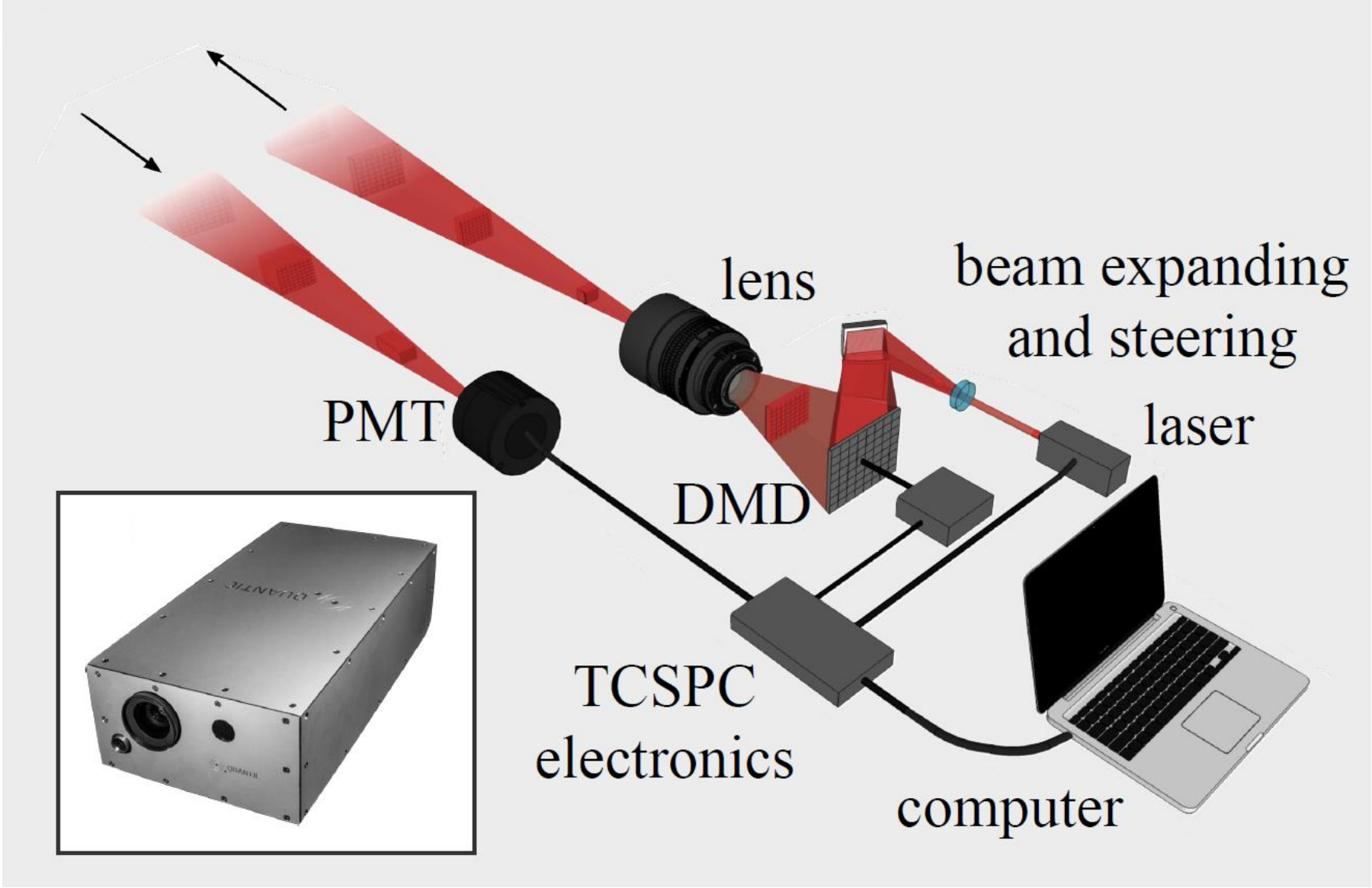


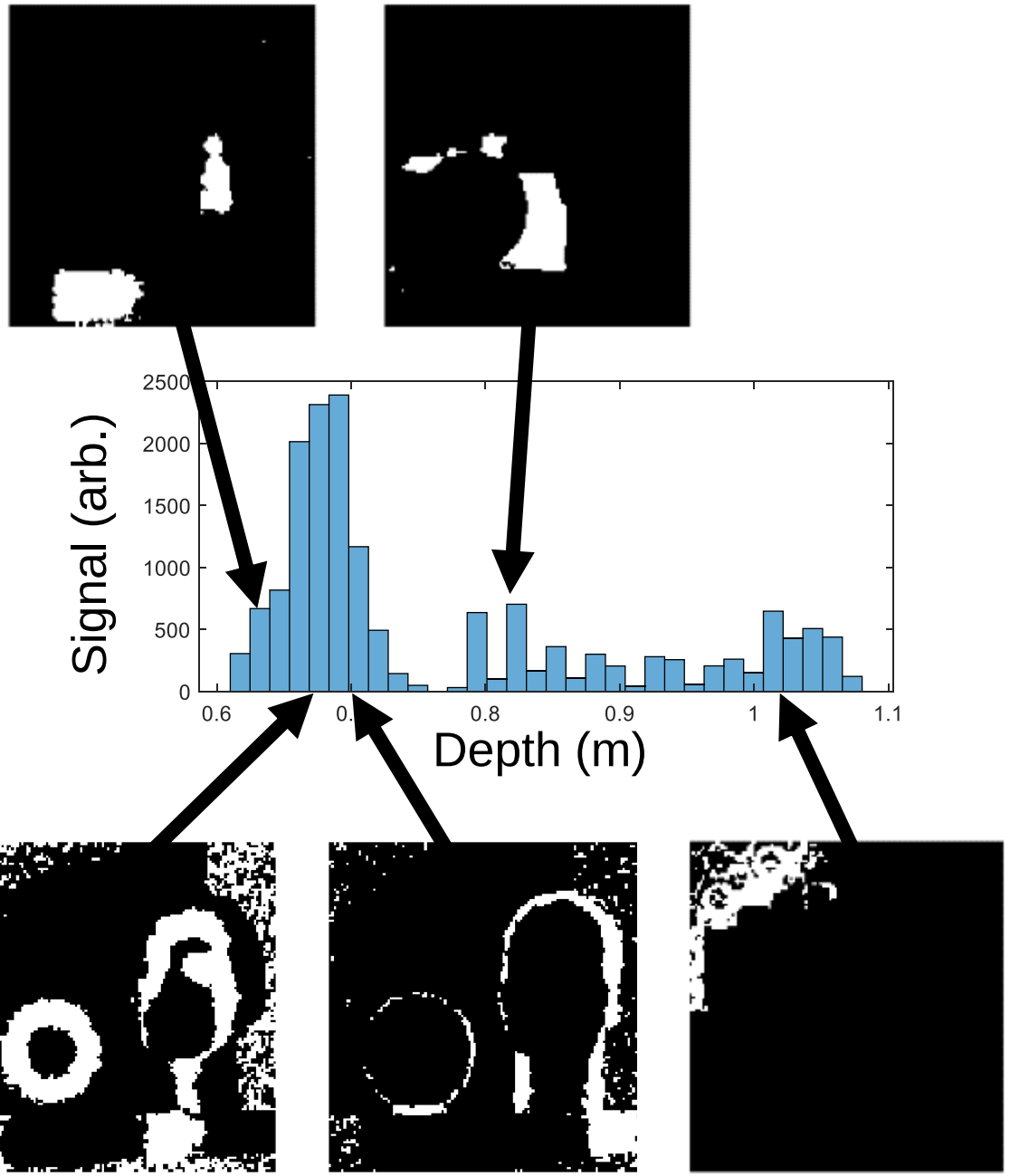
$$\text{Distance} = \text{Speed of Light} \times \text{Time}$$



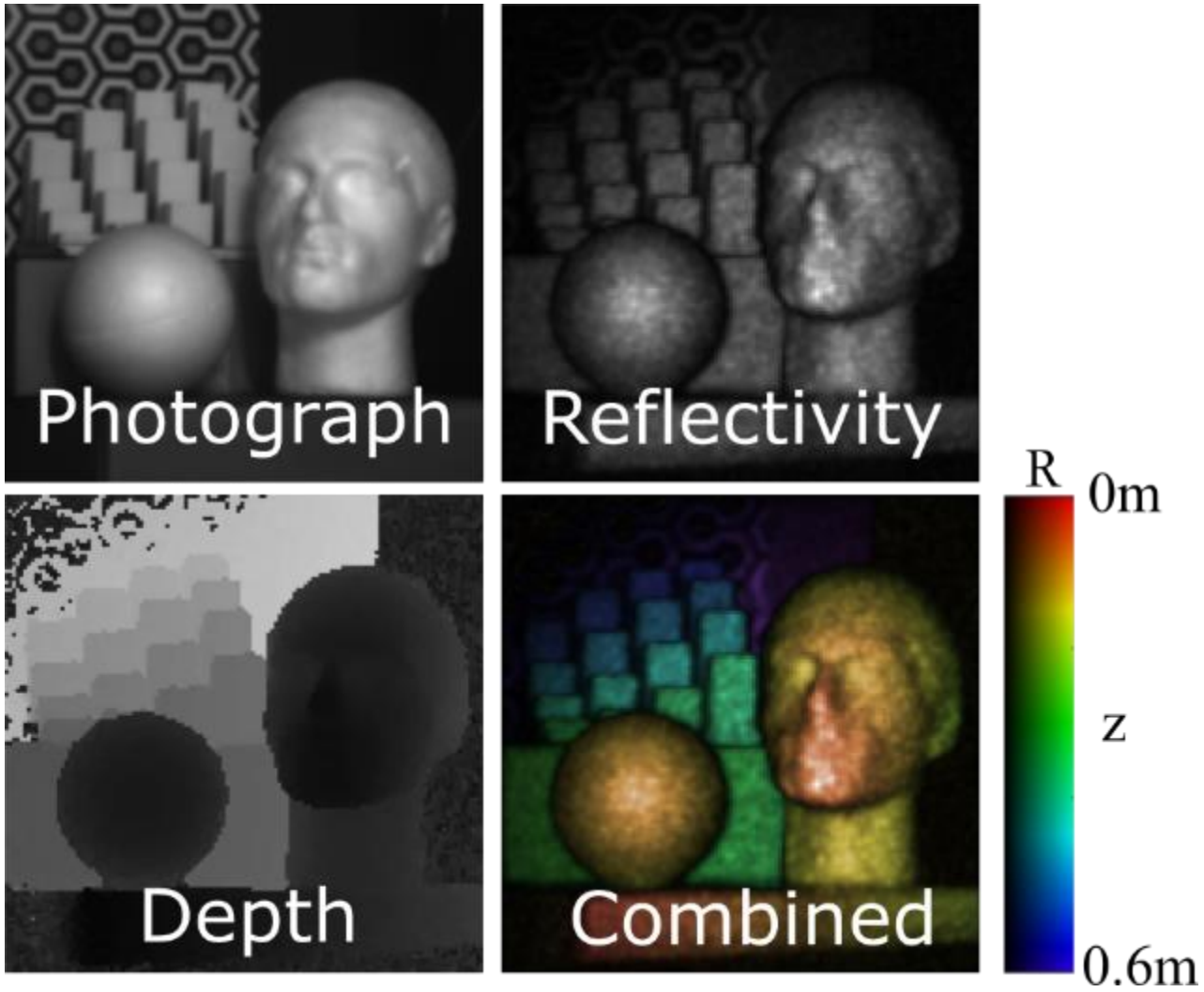
en.wikipedia.org/wiki/Lidar

LIDAR System



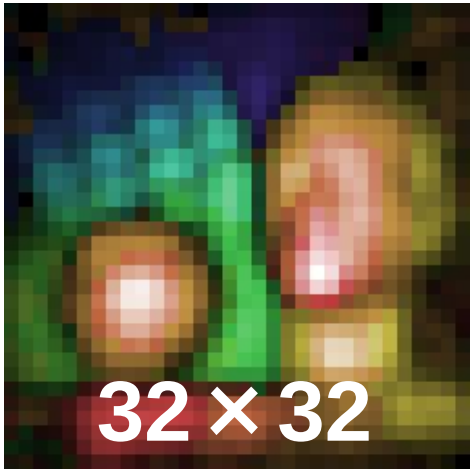

Signal (arb.)
2500
2000
1500
1000
500
0
0.6
0.8
0.9
1
1.1
Depth (m)

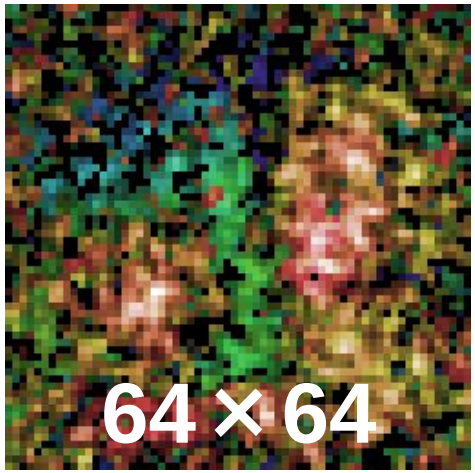
Measurement

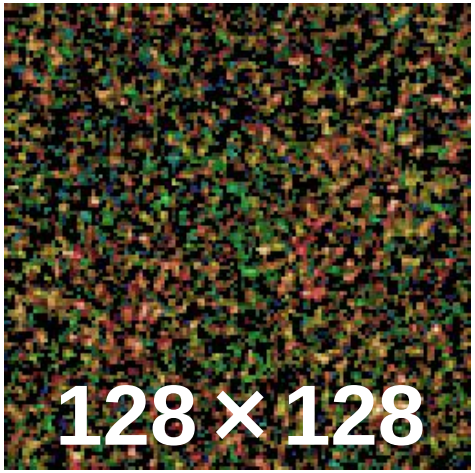


Results at 2 seconds integration

Hadamard



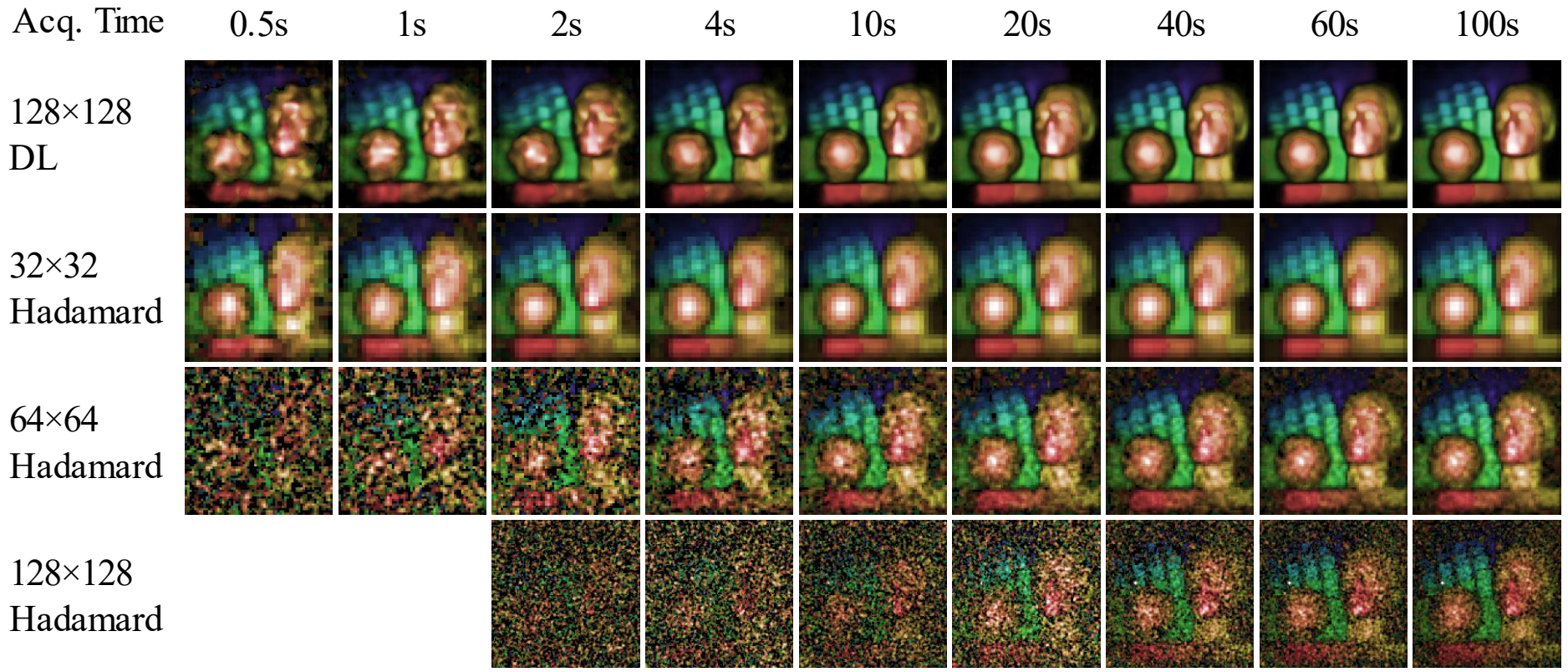




Deep Learning

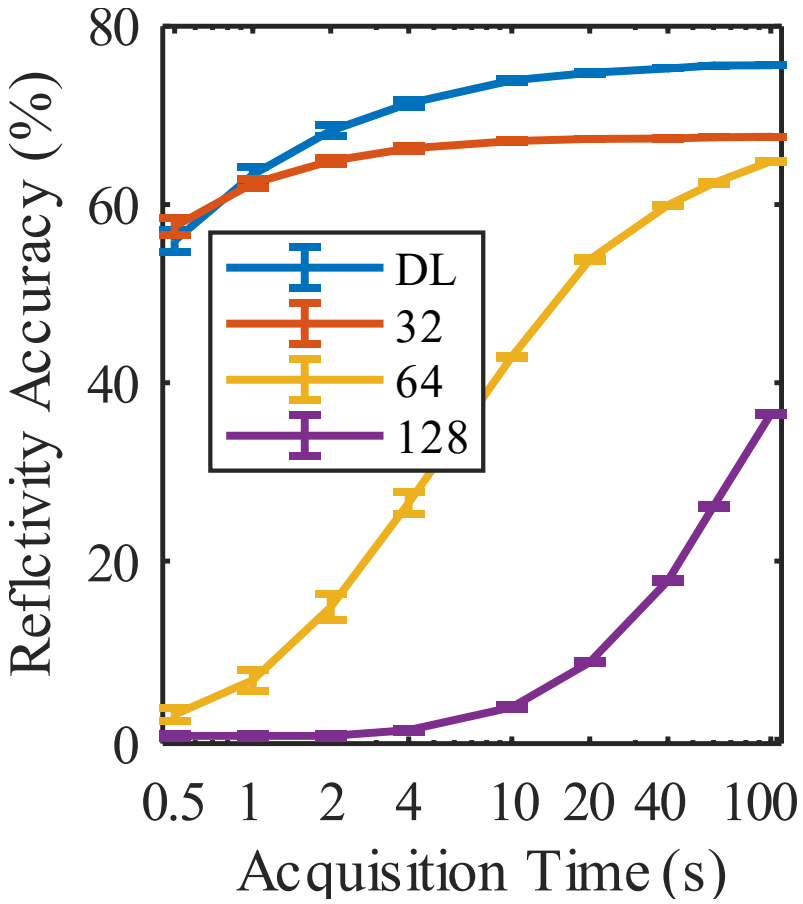
Appl. Phys. Lett. **115,** 231101 (2019)

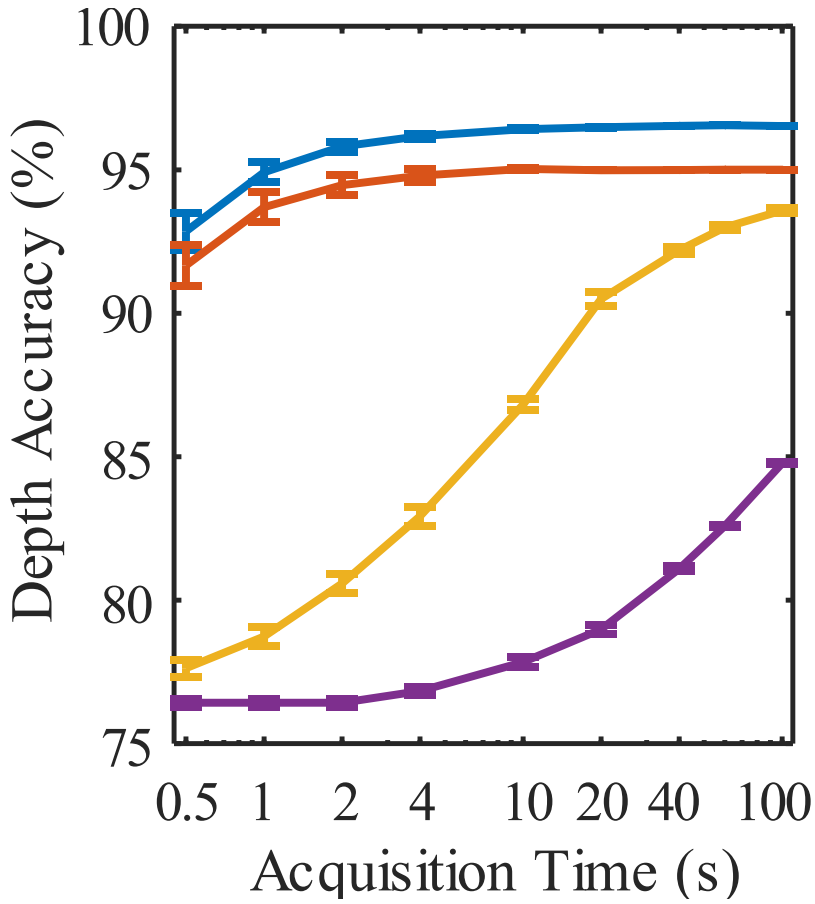
Results



Appl. Phys. Lett. **115,** 231101 (2019)

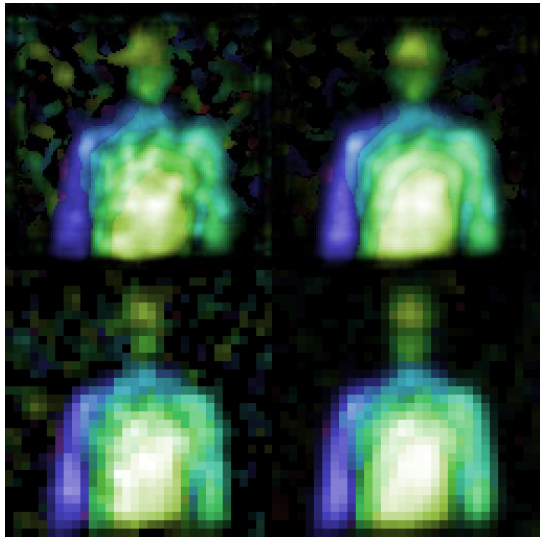
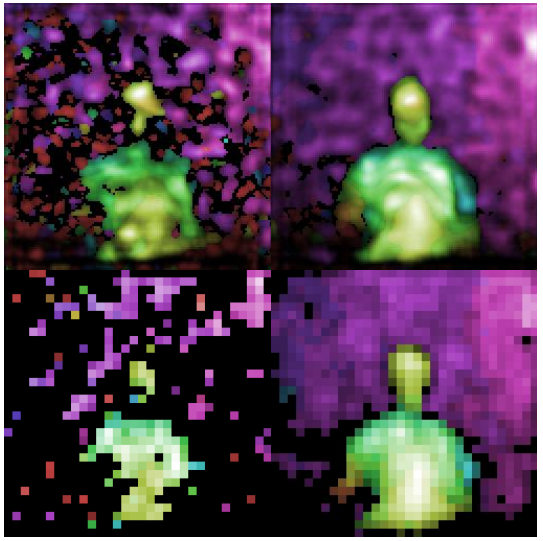
Results





Appl. Phys. Lett. **115,** 231101 (2019)

Longer-range results

Range	5m		30m	
Acq. Time	1s	10s	1s	10s
128×128 DL				
32×32 Hadamard				

Future Applications

- Non-imaging sampling for fast response
- Computers do not need a picture
- Can they react quicker?

Acknowledgements


Miles Padgett


Neal Radwell


Matt Edgar


Catherine Higham


Rod Murray-Smith

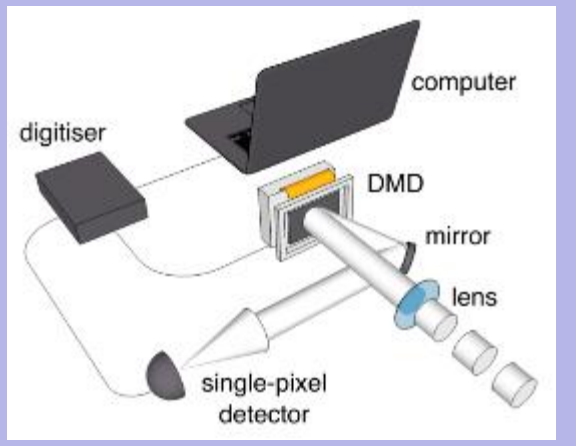
QUANTIC

erc European Research Council

UKRI Engineering and Physical Sciences Research Council

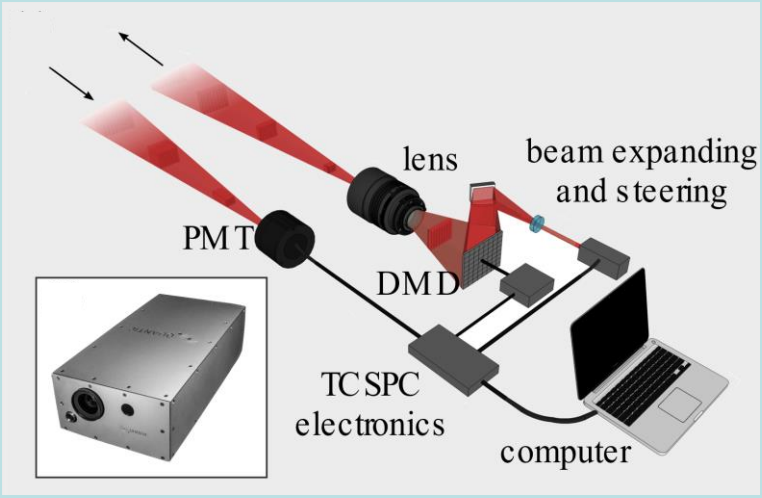
Summary

Single pixel

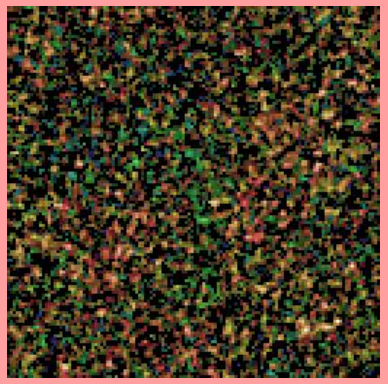


Deep learning

LIDAR



Hadamard



Deep learning