
aqualab
Quantum Imaging Sensors
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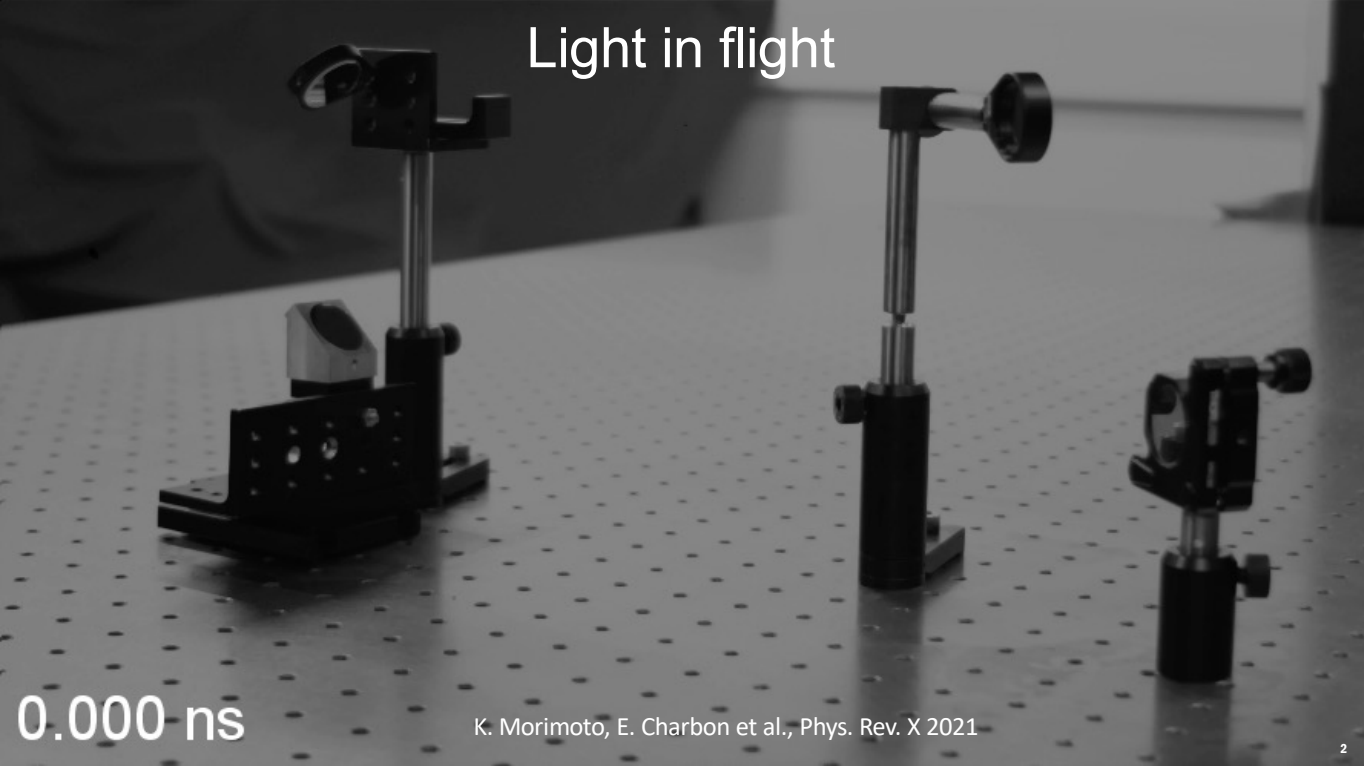
Oct. 7, 2024
EPFL

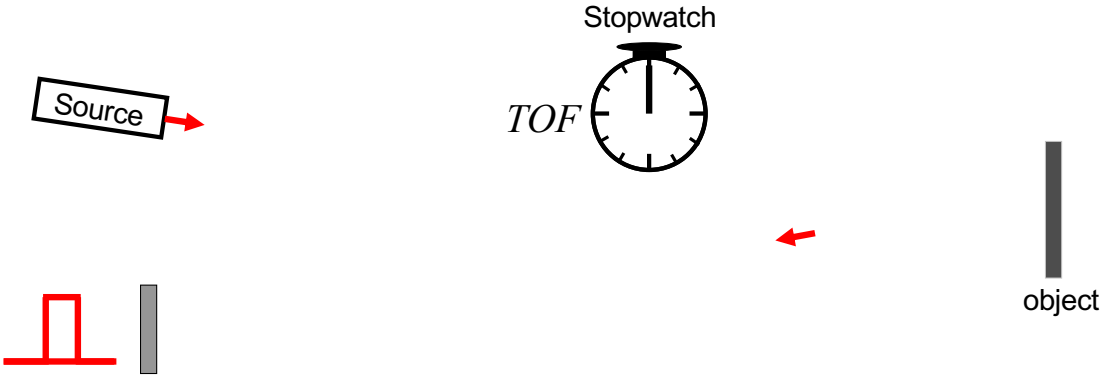
Light in flight



K. Morimoto, E. Charbon et al., Phys. Rev. X 2021

1. Light Detection and Ranging
LiDAR

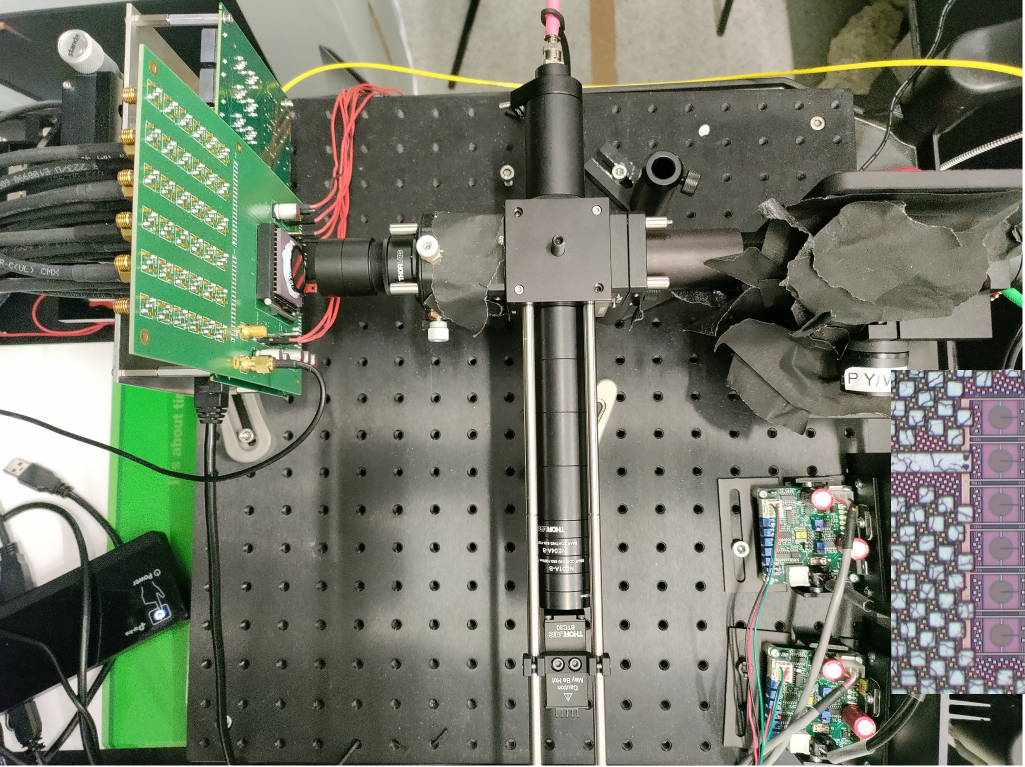
Classical LiDAR

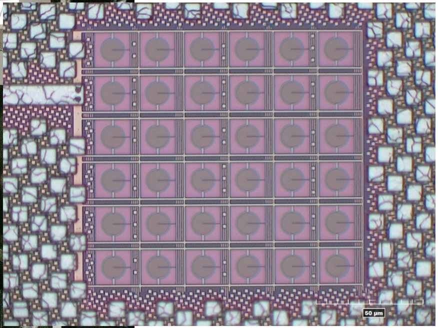


From a <u>short burst</u> or pulse of light, one can get distance d from source to receiver

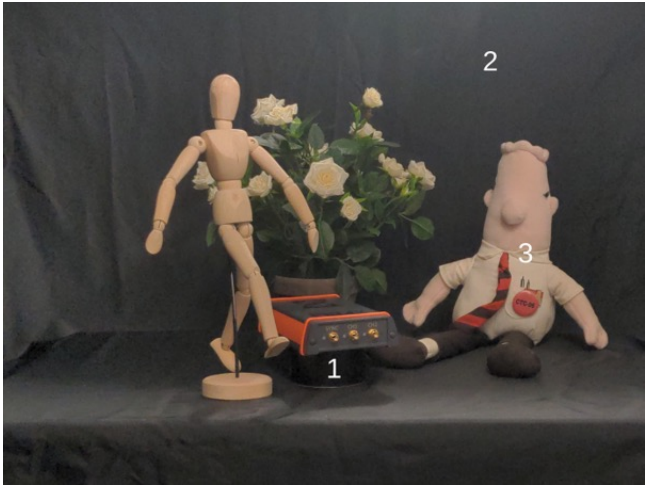
$$d = \frac{c \cdot TOF}{2}$$

Source: Alexis Rochas




50 µm

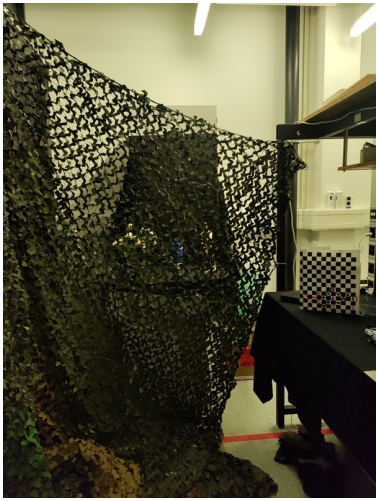
3D reconstruction



T. Milanese et al., Digital SiPM with reconfigurable back-end for LiDAR applications, *to be published*.

2. Hidden scenes

Hidden scene behind camouflage

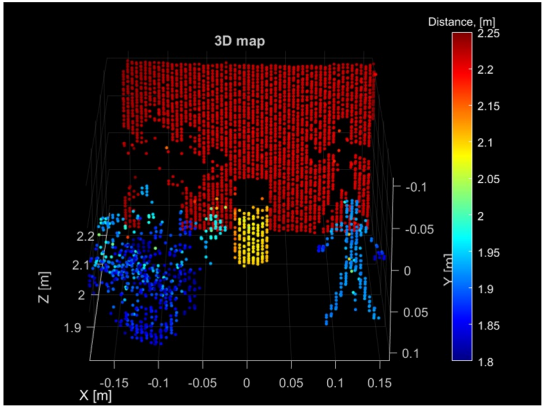


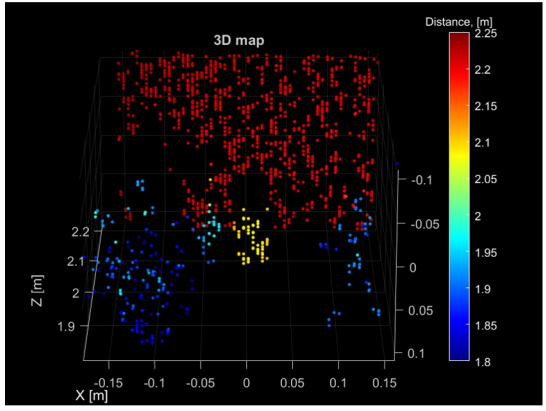
Laboratory fluorescent light (**from top**)

Halogen light (**in front of the setup**)

Hidden scene behind camouflage

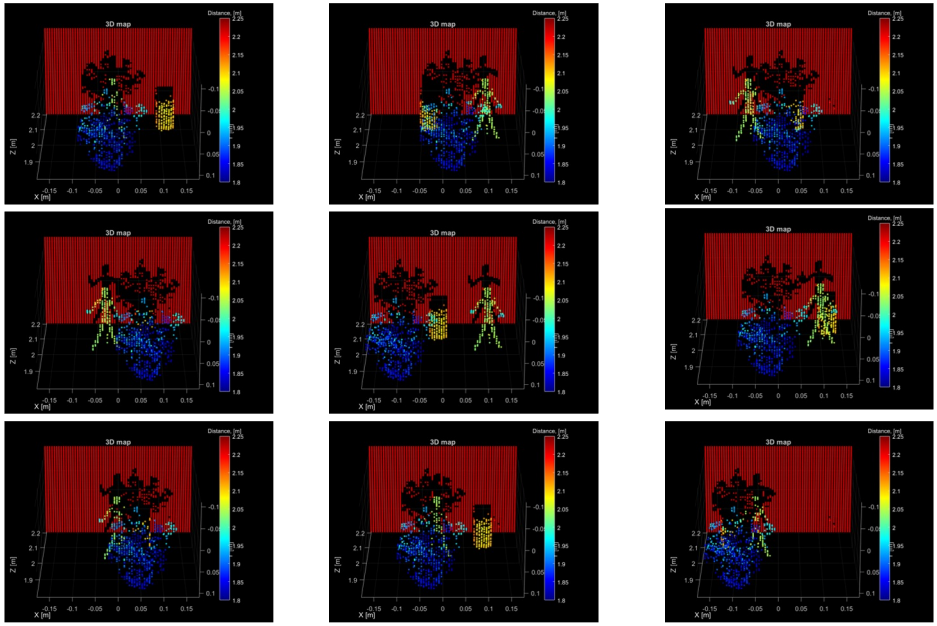
- Single channel results.
- Gating applied on point cloud.





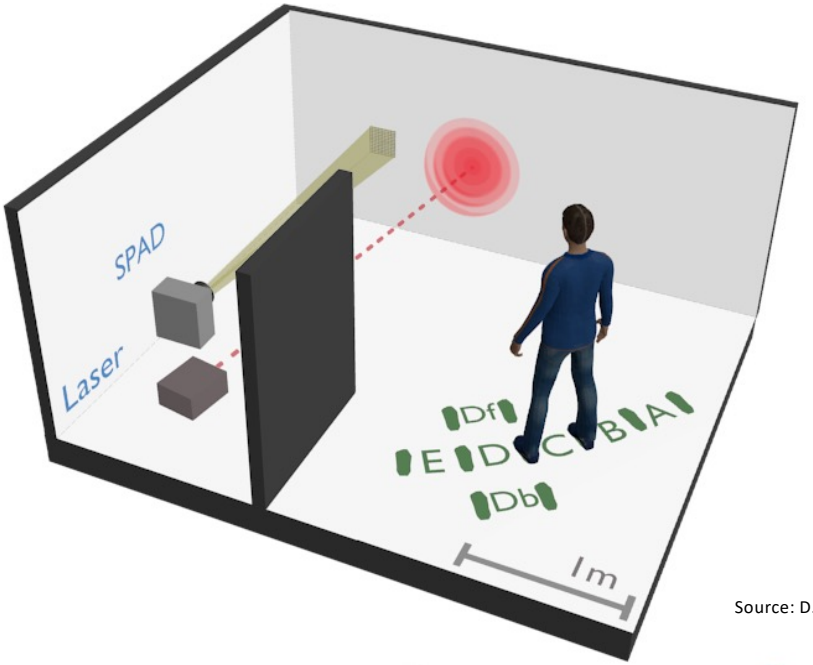
Hidden scene behind camouflage

Moving the objects manually by simulation and applying then the net as a mask.



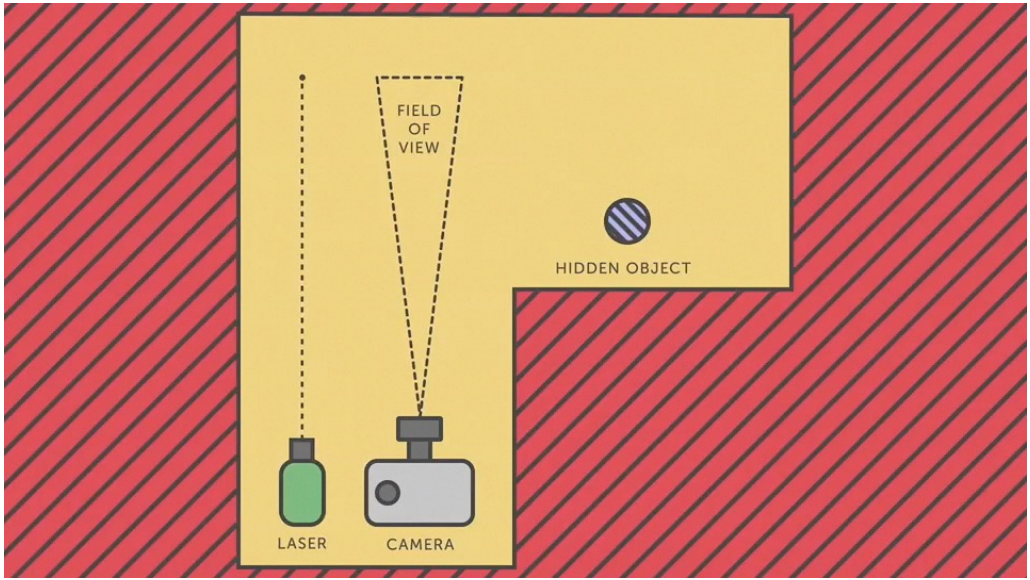
3. Non-Line-of-Sight LiDAR

Principle of NLOS



Source: D. Faccio, Univ. of Glasgow

Principle of NLOS



Source: D. Faccio, Univ. of Glasgow

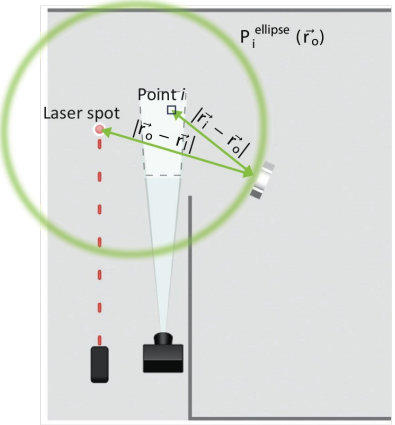
Tracking Moving Objects

$$|\vec{r}_o - \vec{r}_l| + |\vec{r}_o - \vec{r}_i| = \langle t \rangle_i \times c$$

Laser spot – Target distance

Target – Camera pixel

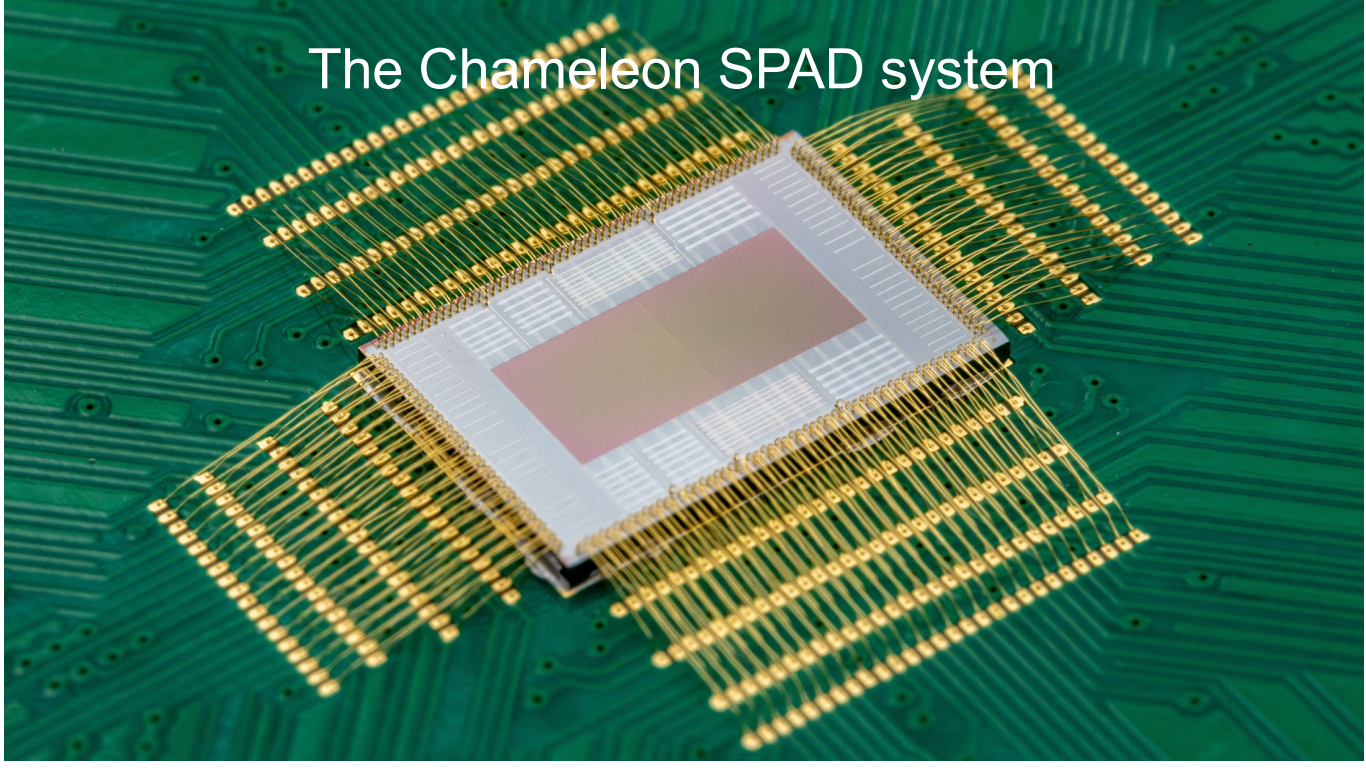
Light time of flight



$$P_i^{\text{ellipse}}(\vec{r}_o) \propto \exp\left[-\frac{(\varepsilon/c - \langle t \rangle_i)^2}{2\sigma_{t_i}^2}\right]$$

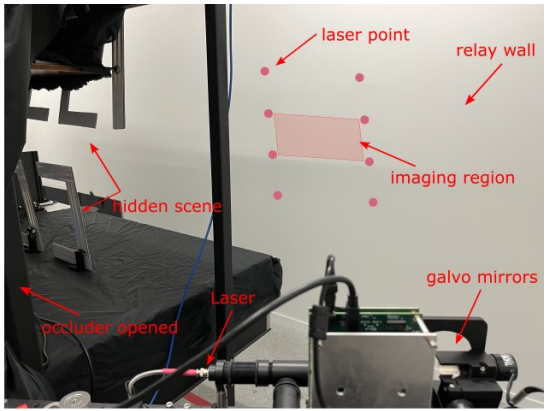
$$P(\vec{r}_o) = N \prod_{i=1}^{1024} P_i(\vec{r}_o) \longrightarrow$$ Gives target position

The Chameleon SPAD system

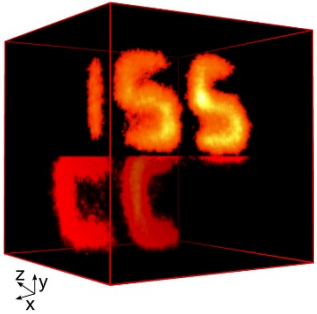


Chameleon NLOS Result

Non-confocal NLOS setup



Results using standard NLOS reconstruction algorithms



Future directions

Quantum imaging

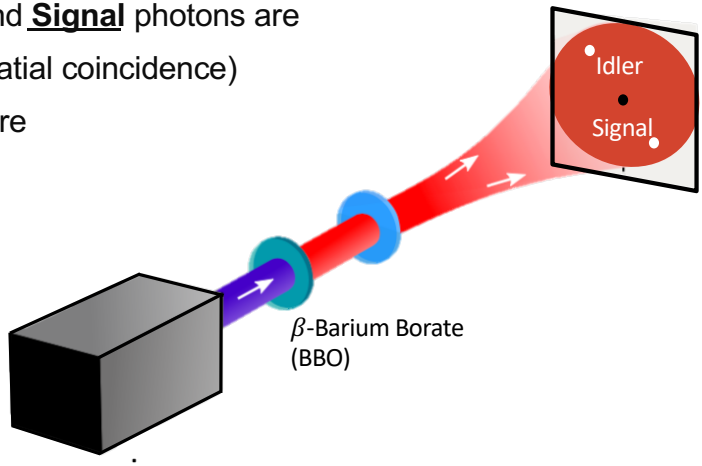
Quantum imaging

- Quantum LiDAR
- Ghost imaging
- Quantum (ultra-fast) spectroscopy
- Quantum Raman spectroscopy
- Quantum distillation
- Quantum state tomography
- Quantum holography
- Quantum super-resolution
- Quantum plenoptic cameras
- Quanta burst photography

Entangled photons: time and spatial correlations

- Entangled photons must be anti-correlated in momentum and correlated in position
- In the far field, **Idler** and **Signal** photons are
  anti-symmetric (spatial coincidence)
- In the near field they are
  adjacent

Always: time coincident



Quantum LiDAR

- Goal: improvement of SNR in complex scenes
- Method
    1. Classical image = background
    2. Quantum image = object of interest
    3. Add time-of-flight and a reconstruction algorithm and this yields a quantum LiDAR

Quantum NLOS

Thank You

http://aqua.epfl.ch

1st User Group Meeting, Les Diablerets, 2022

Next UGM: Feb. 2026