A fast and bright source of single photons

Richard J. Warburton

Department of Physics, University of Basel, Switzerland

University of Basel

QSIT Quantum Science and Technology

Collaborations

University of Basel

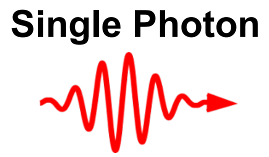
Nano-Photonics Group: Richard J. Warburton
Nadia Antoniadis, Mark Hogg, Alisa Javadi, Andreas Kuhlmann, Matthias Löbl, Daniel Najer, Giang Nguyen, Daniel Riedel, Immo Söllner, Clemens Spinnler, Natasha Tomm, Liang Zhai

Quantum Optics Theory Group: Nicolas Sangouard
Pavel Sekatski

RUHR UNIVERSITÄT BOCHUM RUB

Applied Solid-State Physics Group: Arne Ludwig and **Andreas Wieck**
Alexander Korsch, Rüdiger Schott, Sascha R. Valentin

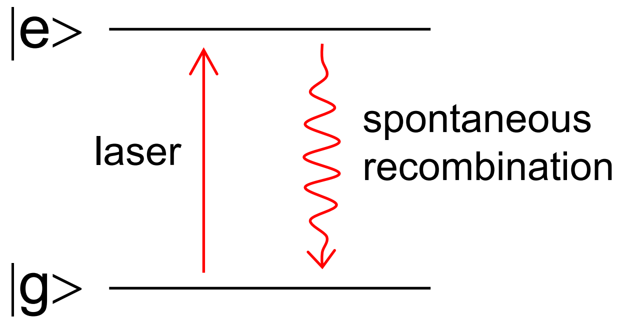
Why single photons?



- Transfer of quantum states over long distances
  - quantum key distribution
  - device-independent quantum key distribution
  - quantum communication with cluster states

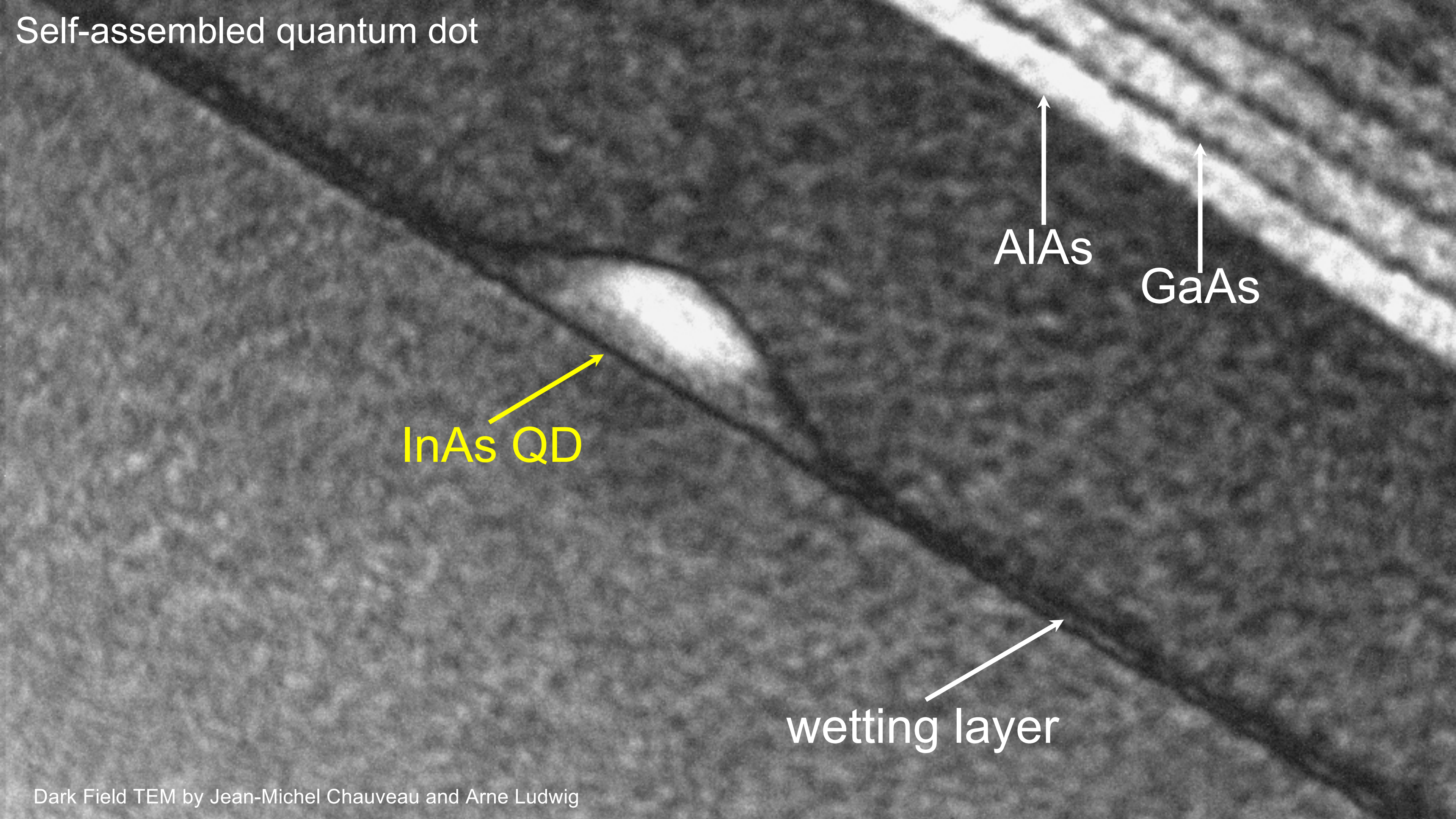
- Quantum information with photons
  - Quantum simulation with linear optics, e.g. boson sampling
  - Measurement-based quantum computing

Two-level system as single photon source

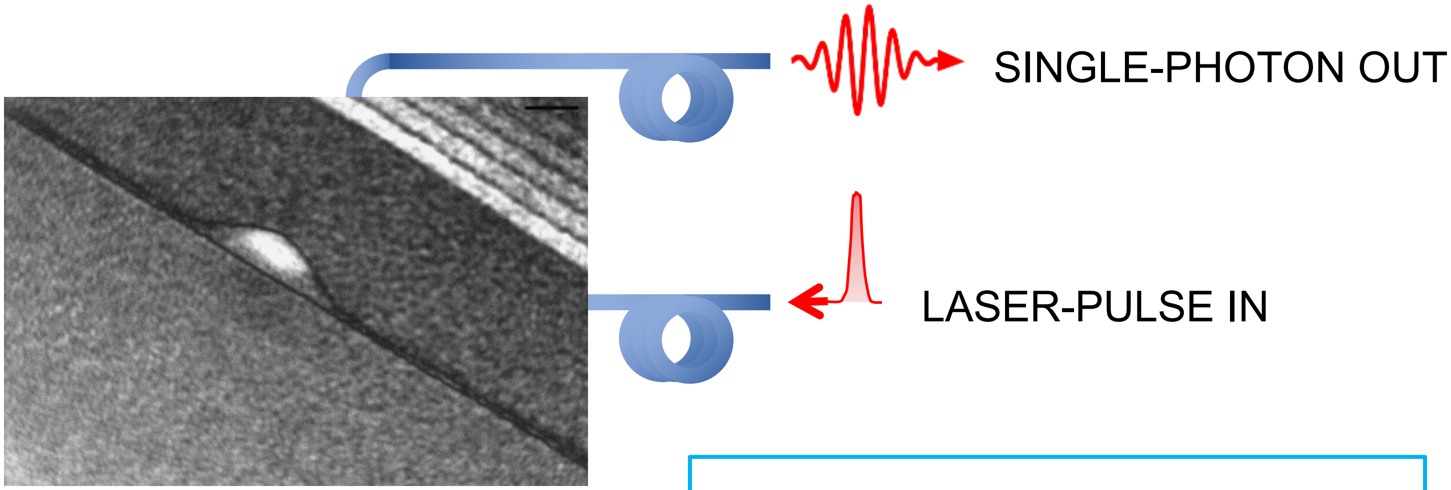


Challenges:

- How to “funnel” photons into a single optical mode?
- How to create indistinguishable photons?

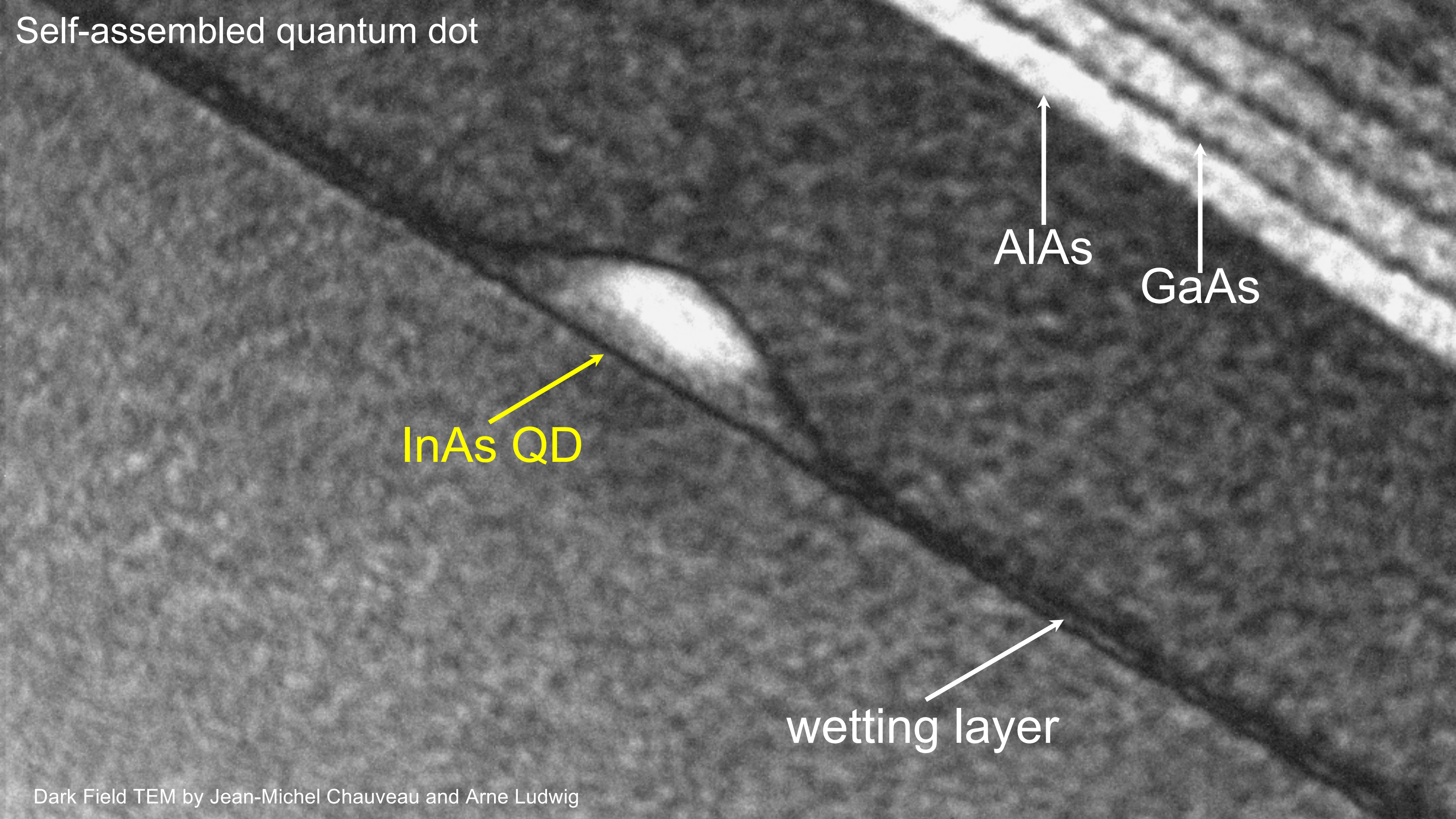

Self-assembled quantum dot
AlAs
GaAs
InAs QD
wetting layer
Dark Field TEM by Jean-Michel Chauveau and Arne Ludwig

Single photon source



Ideal properties:

- Single photons at output
- Photons indistinguishable
- Efficiency 100%
- High repetition-rate
- Entangled pairs, cluster-states


Self-assembled quantum dot
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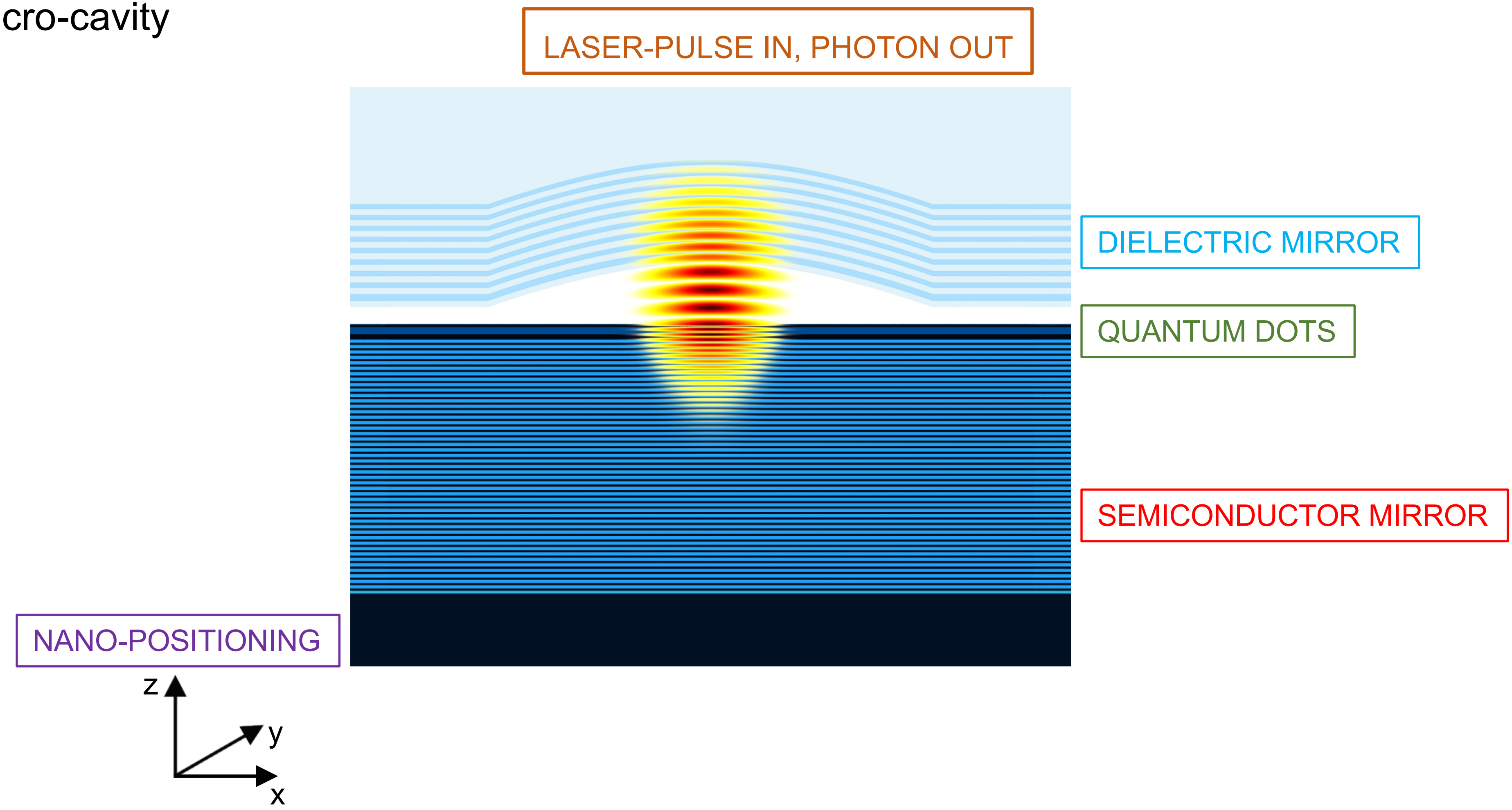
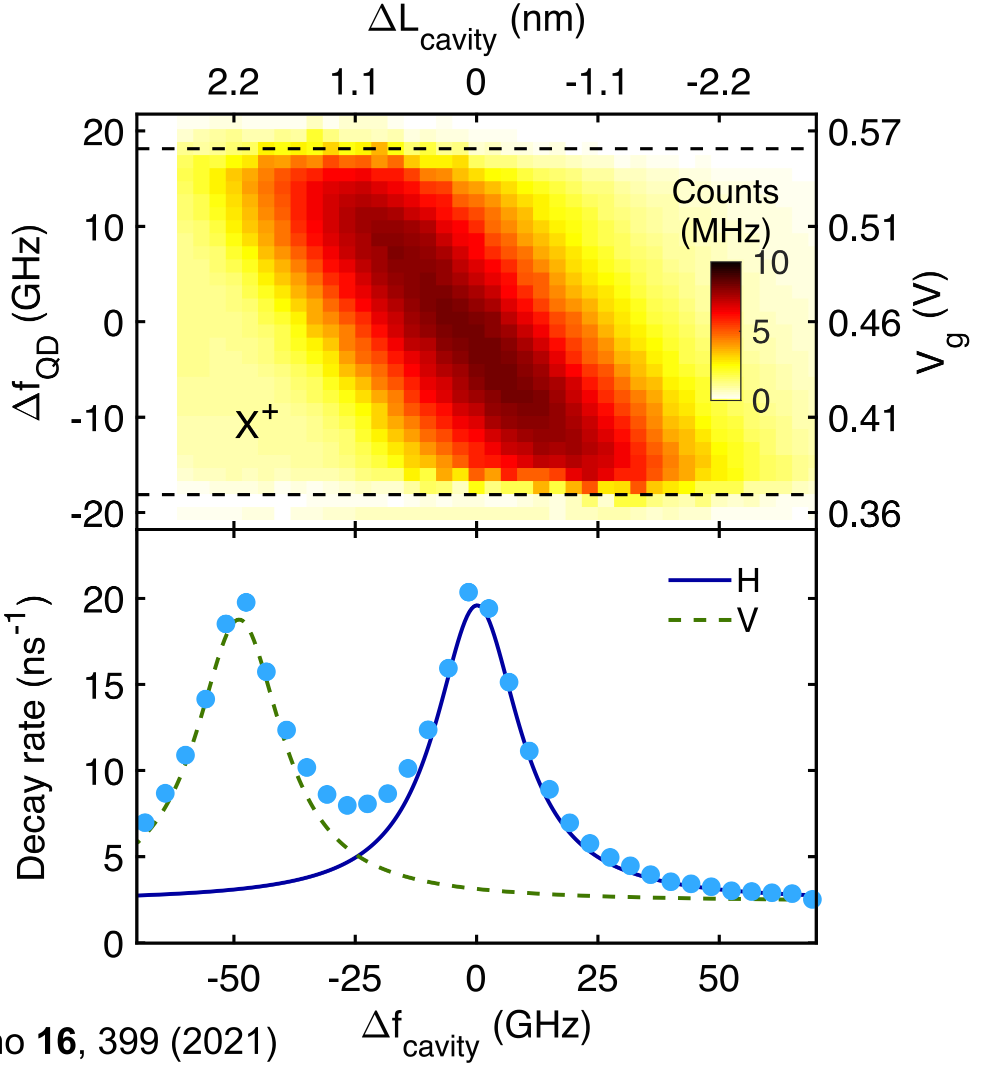
Micro-cavity



R. J. Barbour *et al.*, J. Appl. Phys. **110**, 053107 (2011) ; L. Greuter *et al.*, Phys. Rev. B **92**, 045302 (2015)

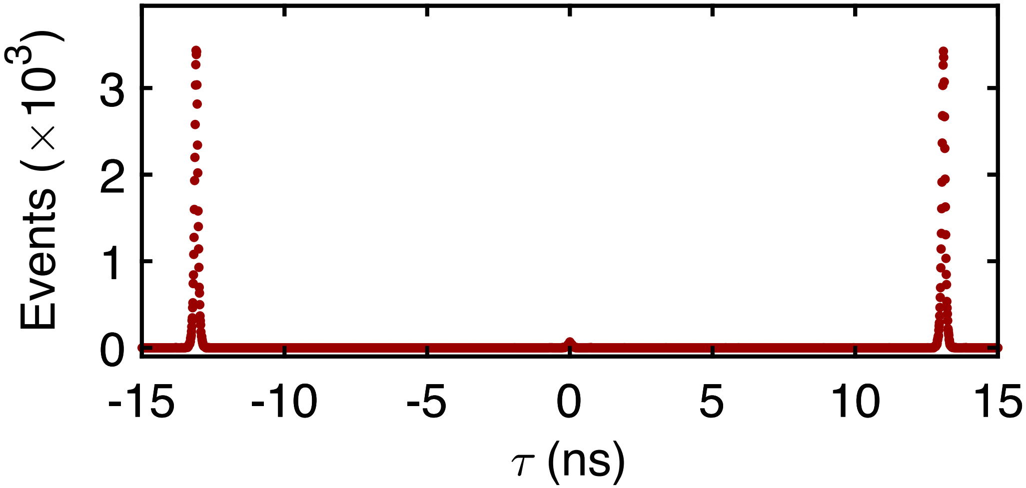
Purcell effect



N. Tomm *et al.,* Nature Nano **16**, 399 (2021)

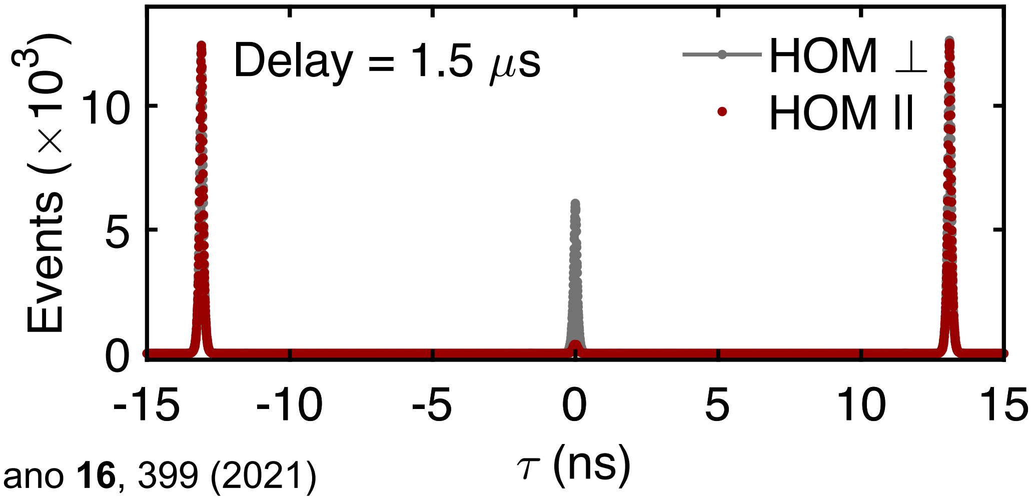
Photon analysis

ANTI-BUNCHING



$g^{(2)}(0)$ = 2.1%

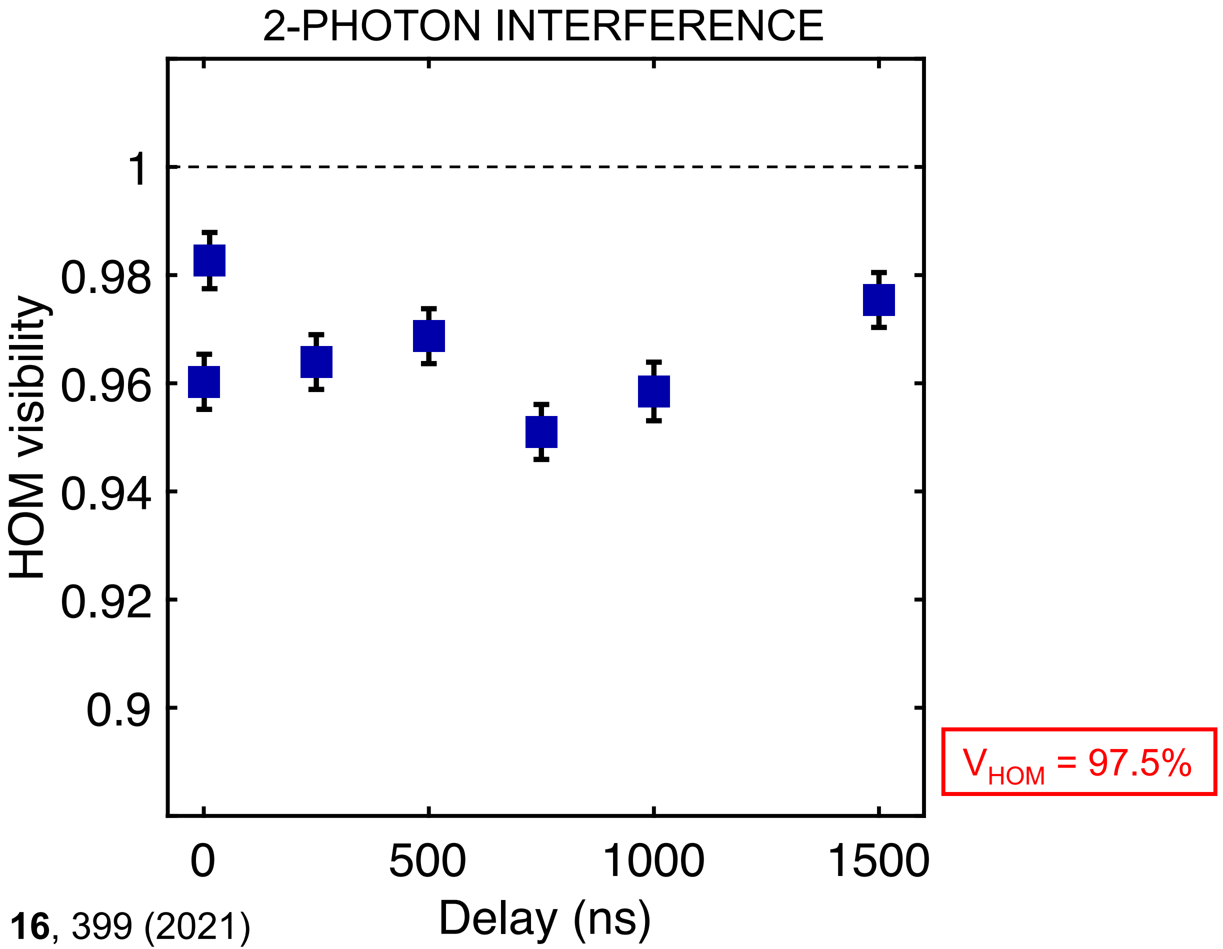
2-PHOTON INTERFERENCE



V_{HOM} = 97.5%

N. Tomm *et al.,* Nature Nano **16**, 399 (2021)

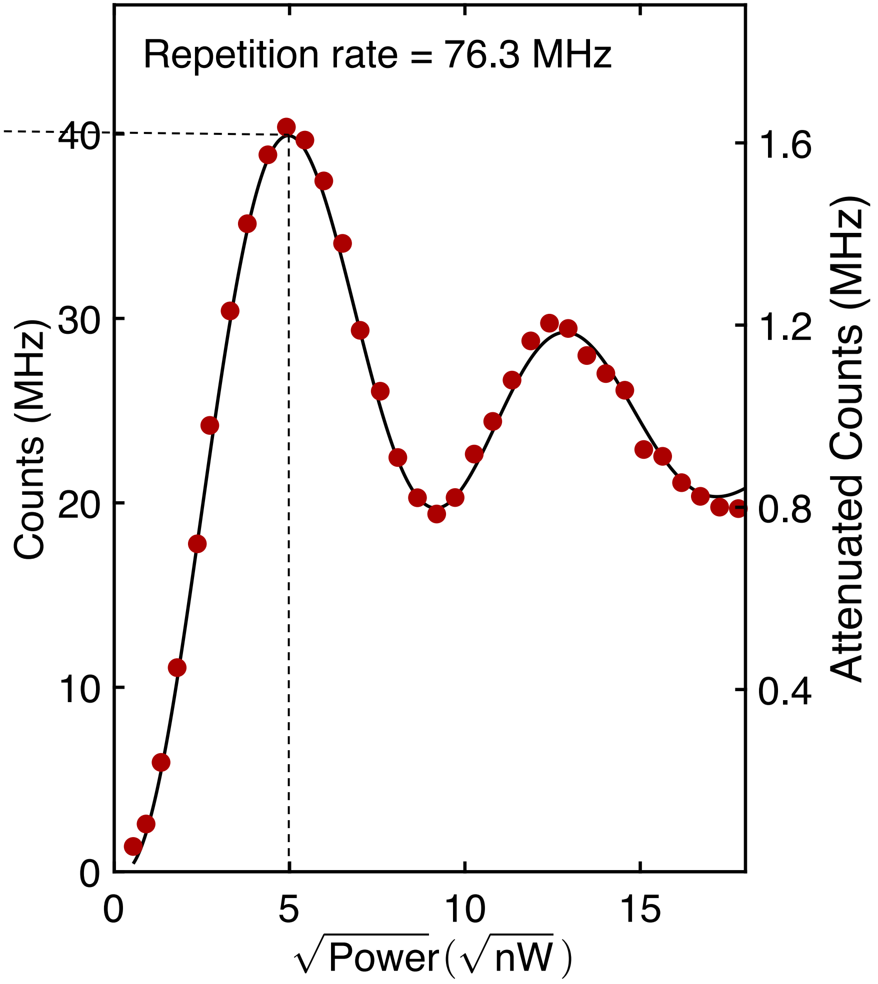
Single photon source: *coherence*



N. Tomm *et al.,* Nature Nano **16**, 399 (2021)

Single photon source: *efficiency*

END-TO-END EFFICIENCY 55%



$\eta = \pi \, . \, \beta_H \, . \, \kappa_{TOP} / \kappa_{TOTAL} \, . \, \eta_{OPTICS}$

$\pi = 96\%$

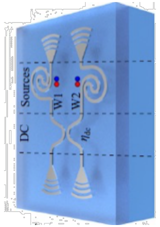
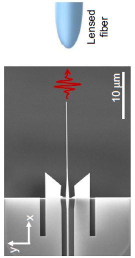
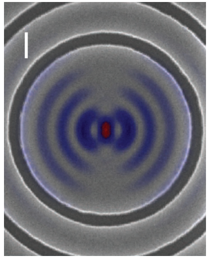
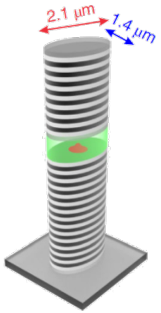
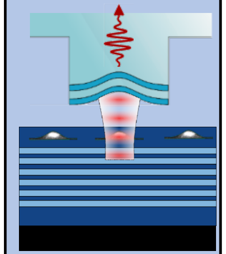
$\beta_H = 86\%$

$\kappa_{TOP} / \kappa_{TOTAL} = 96\%$

$\eta_{OPTICS} = 69\%$

} 55%

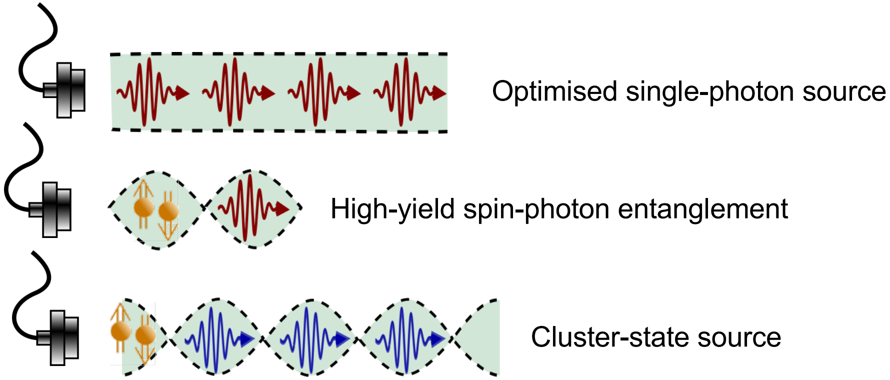
Single photon sources

	Parametric down conversion[1]	Planar waveguides[2]	Bull's eye[3]	Micropillars[3]	This work
					
Efficiency (η)	**≈3%**	**5–6%**	**20%**	**24%**	**57%**
$g^2(0)$	**≈5%**	**1–2%**	**1%**	**2.5%**	**2.1%**
HOM visibility	**≈95%**	**90%**	**80–90%**	**91.3%**	**97.5%**

[1]Faruque *et al.*, Phys. Rev. Applied **12**, 054029 (2019)
[2]Kiršanskė *et al.*, Phys. Rev. B **96**, 165306 (2017)
[3]Wang *et al.*, Nature Photonics **13**, 770 (2019)

Success rate of an algorithm involving N photons: η^N

Outlook


Optimised single-photon source
High-yield spin-photon entanglement
Cluster-state source