Quantum playground with semiconductor quantum emitters

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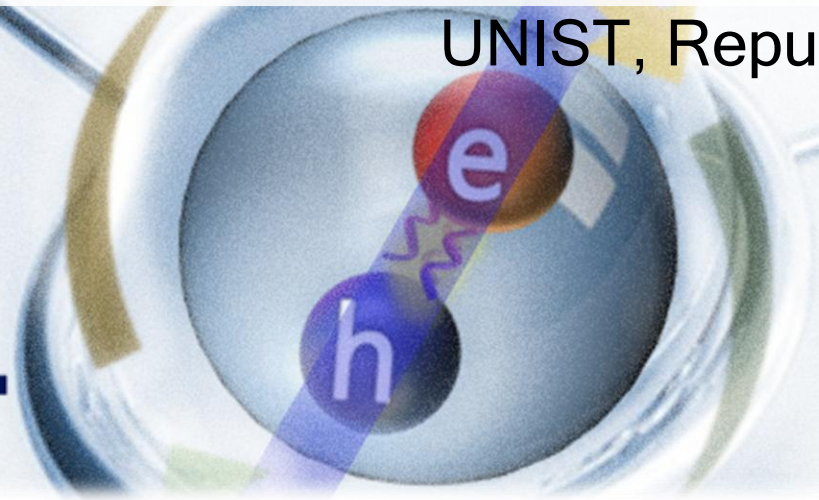


UNIST

uPiD

Quantum Photonic Integrated Device

Ulsan National Institute of Science and Technology

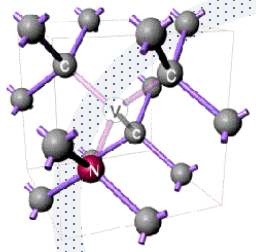
Ulsan National Institute of Science and Technology

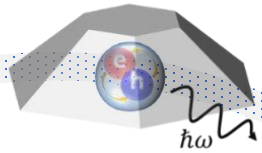
Introduction

Solid-state quantum emitters

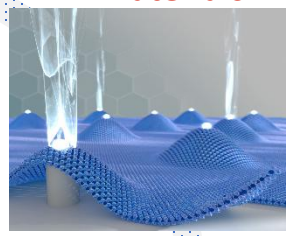
Quantum dots

Atomic defects



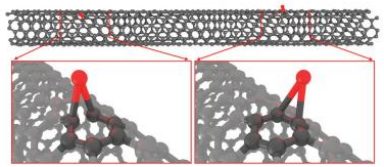


2D materials



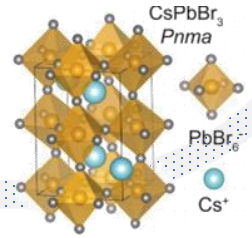
Nature Commun. 8, 15093 (2017)

Carbon nanotube

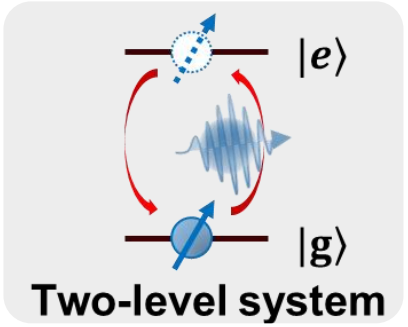


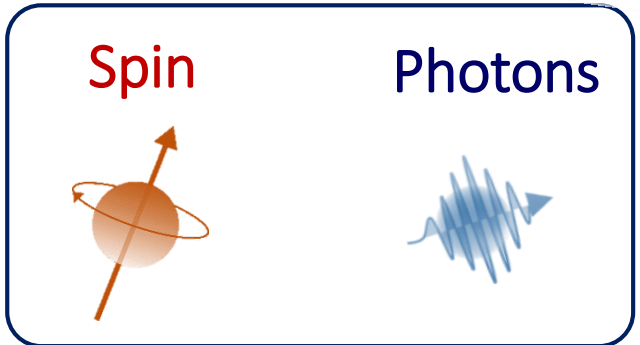
Nat. Nanotech 10, 671 (2015)

Perovskite



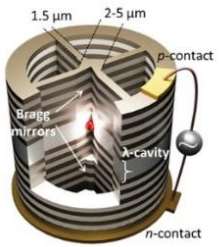
Science 363, 1068 (2019)





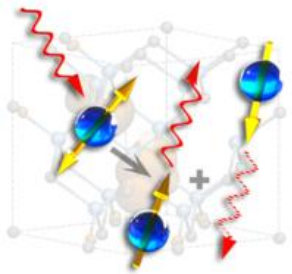
Quantum building block

Quantum light source



Nat. Photon. **10,** 340-345 (2016)

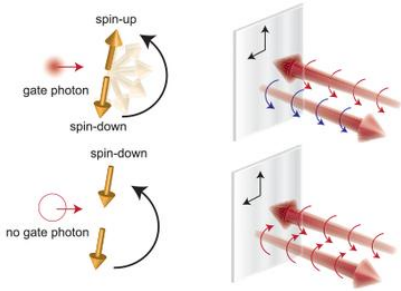
Quantum memory



Phys. Rev. X **7**, 021046 (2017)

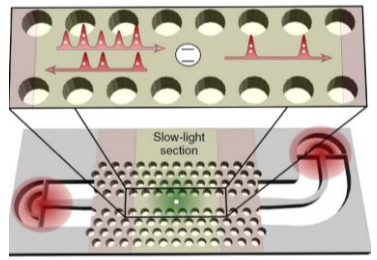
Quantum mediator

Quantum gates



Science 361, 57 (2018)

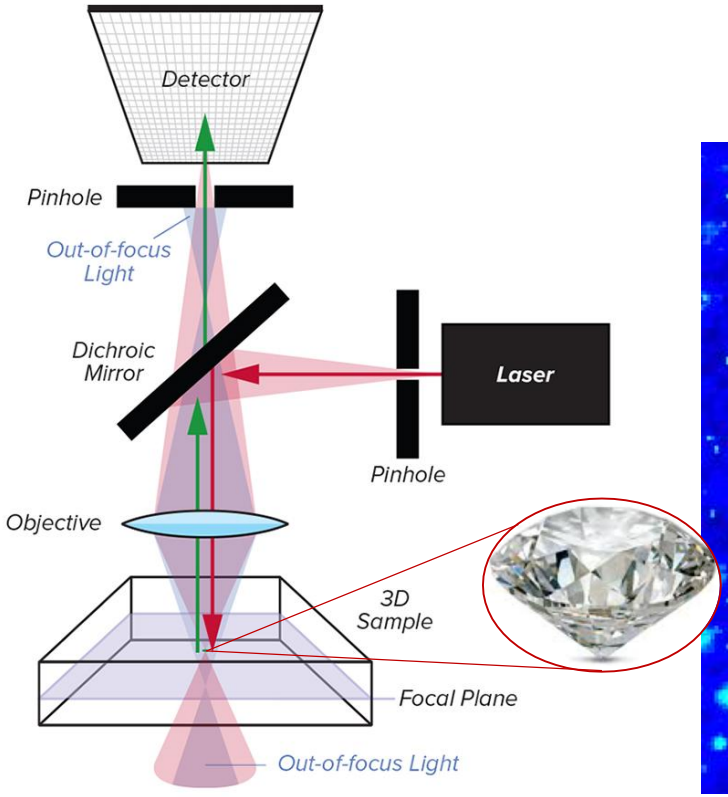
Single-photon nonlinear optics



Nature Commun. 6, 8655 (2015)

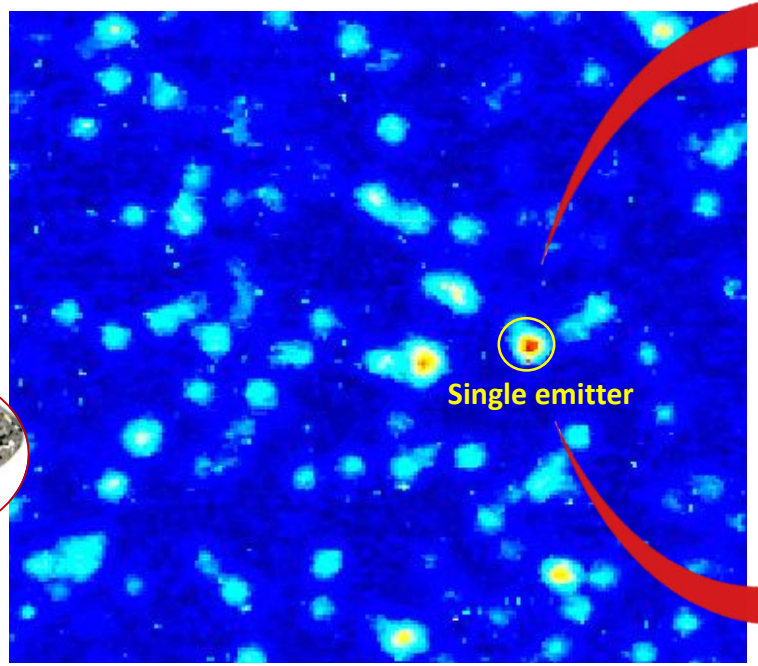
Introduction

Conventional approaches for addressing photonic and spin qubits



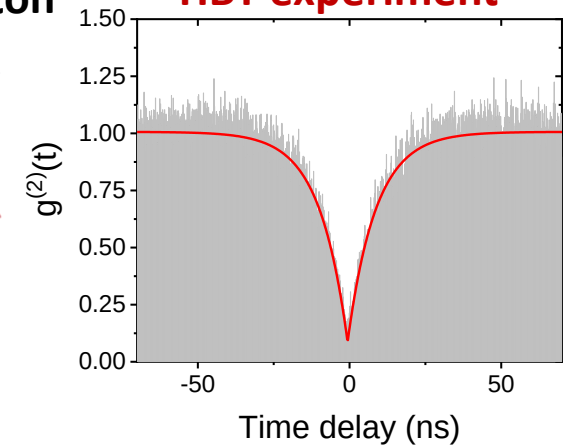
Conventional optical interface
- Confocal microscopy

Confocal PL mapping

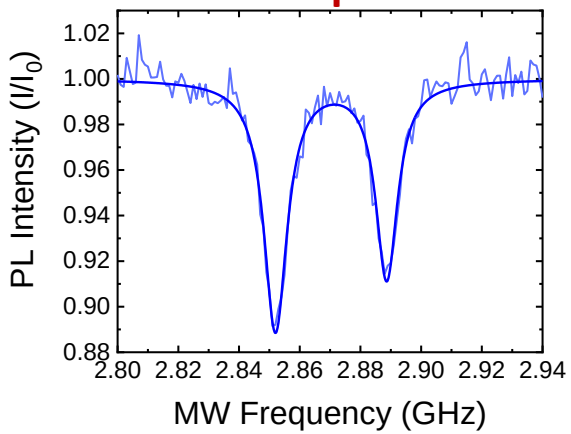


Single photon

HBT experiment



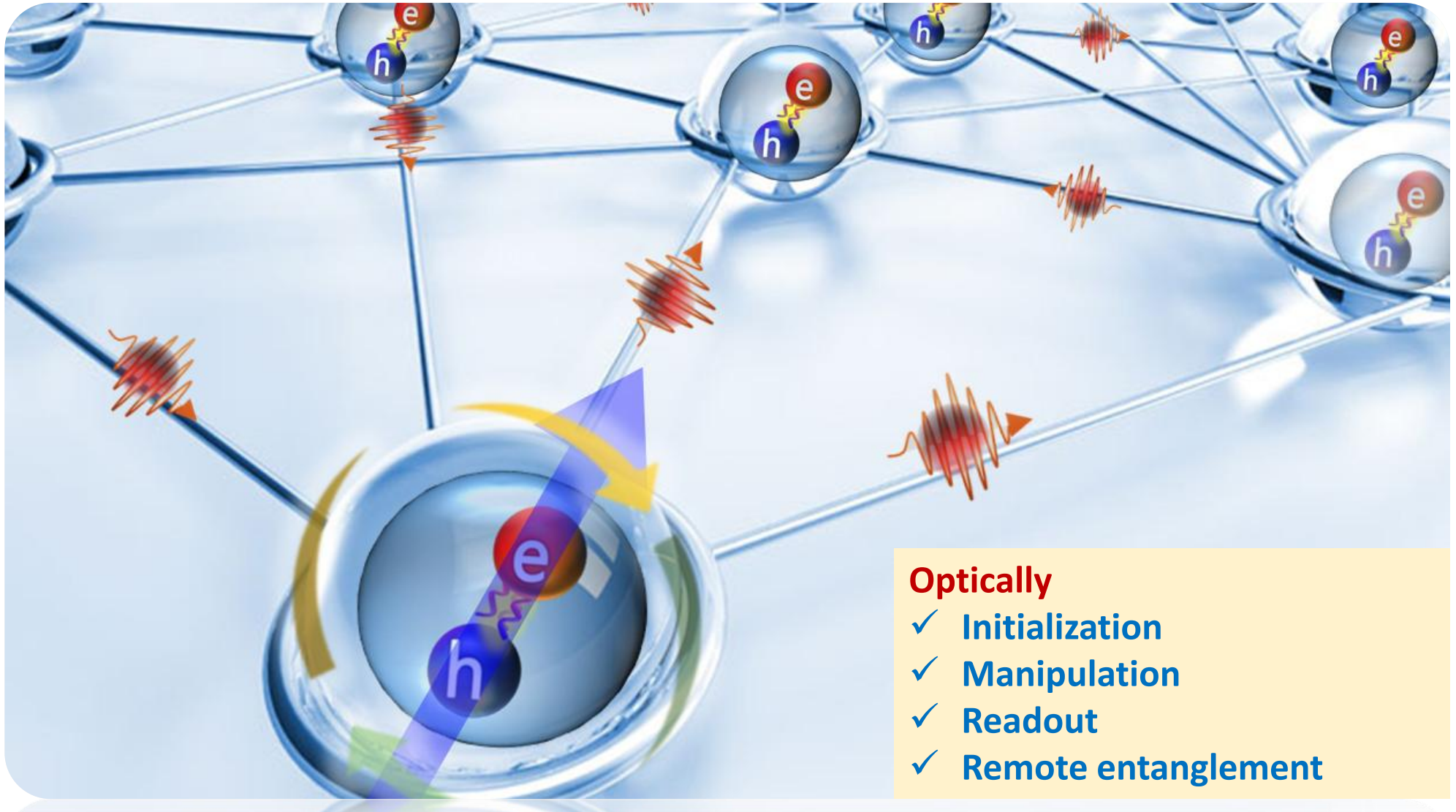
ODMR Experiment



Spin state

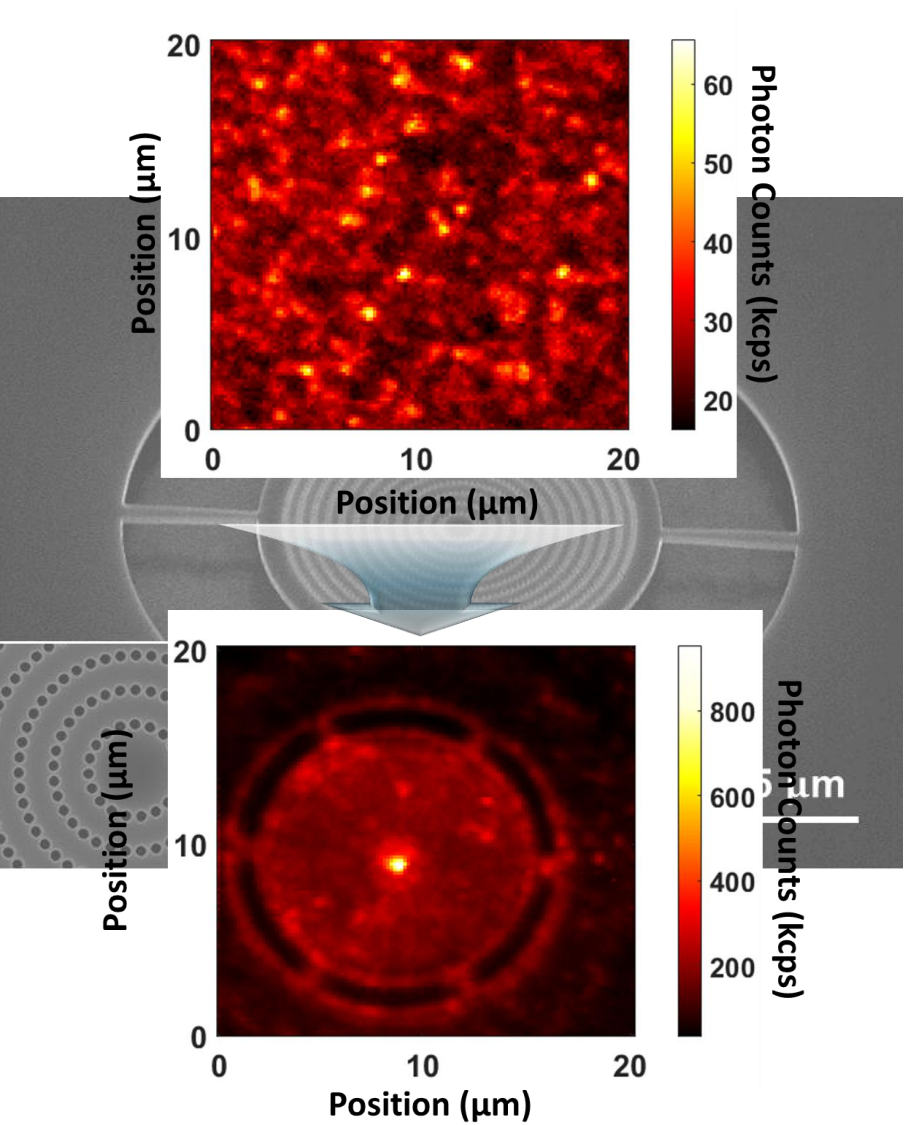
Introduction

An efficient optical interface/integration/interaction is essential for quantum emitters

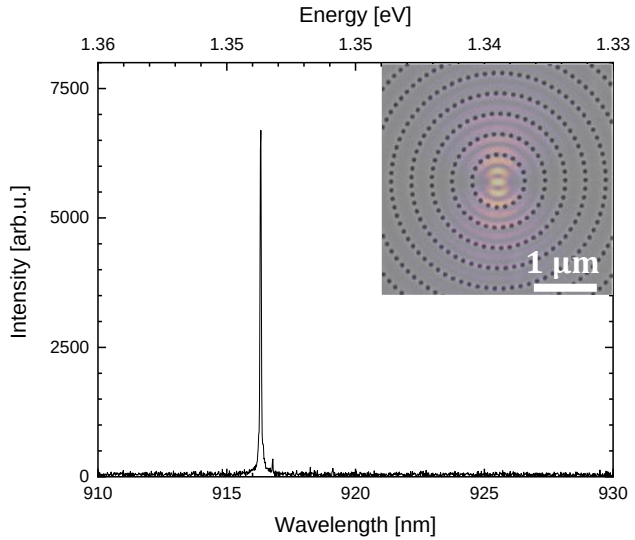


High-performance quantum emitters in a cavity

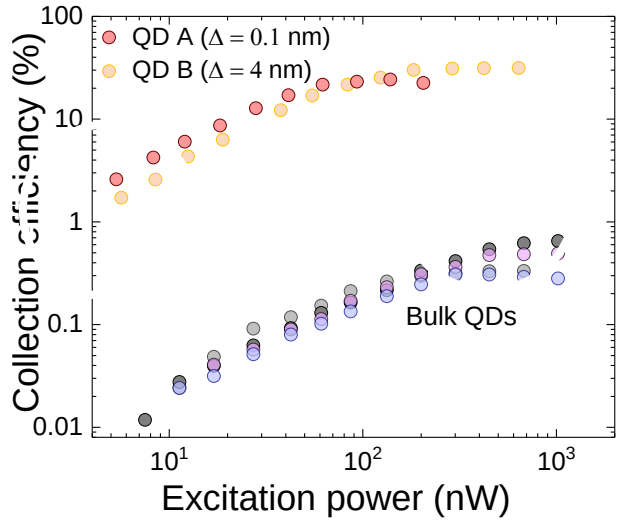
Deterministic coupling between Cavity-Quantum Emitter



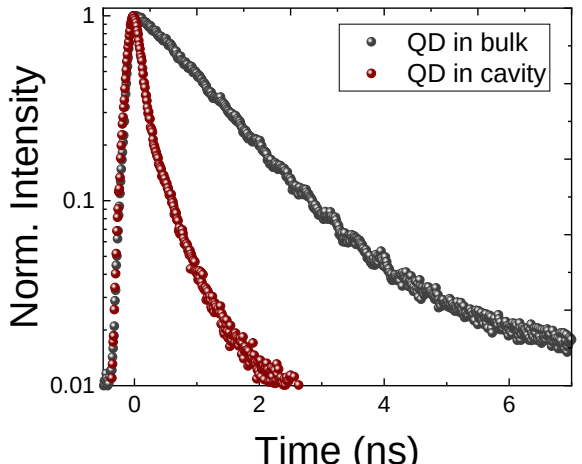
Emission spectrum



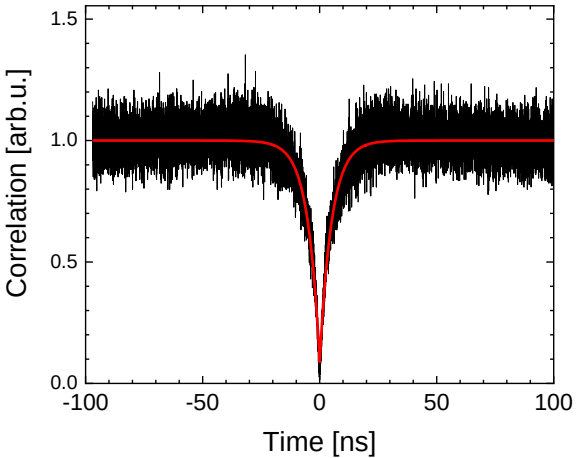
High Brightness



Fast operation



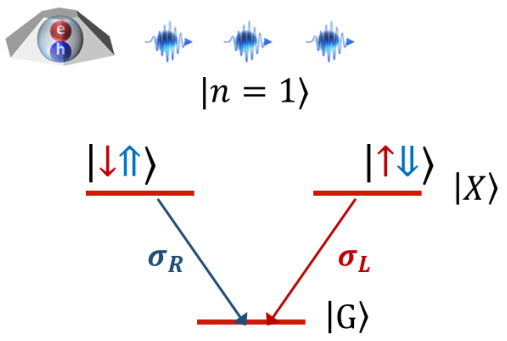
Single-photon emission



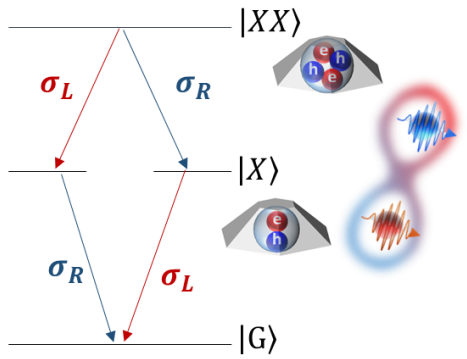
Integrating quantum emitters into Real-world platforms

Quantum resources

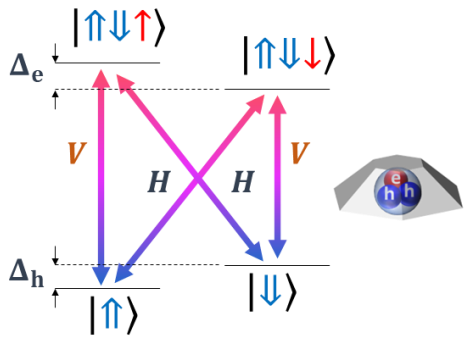
Single photons



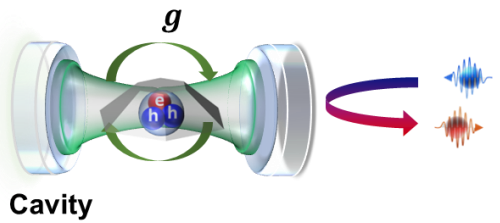
Entangled photon pair

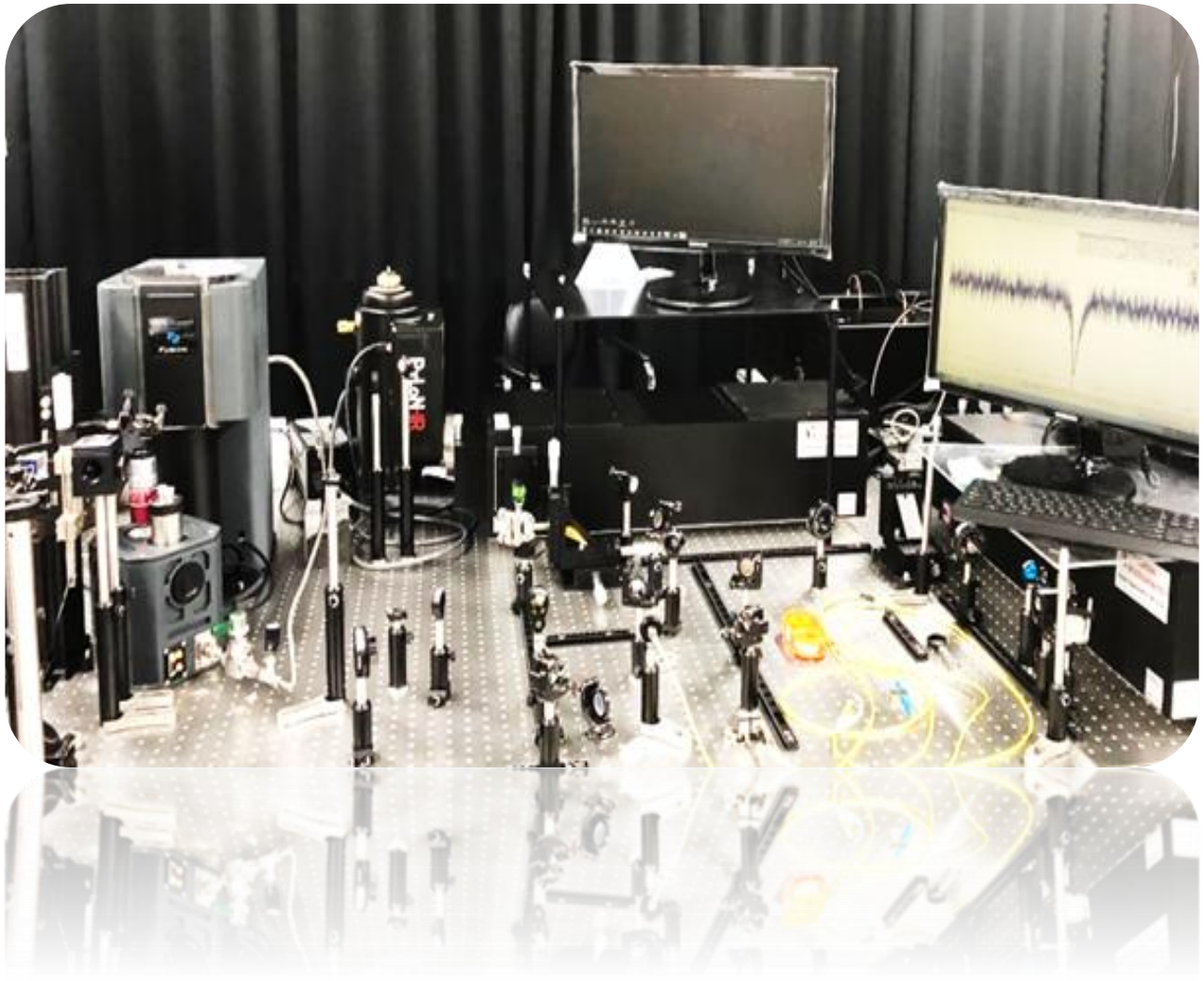


Quantum memories



Spin-photon interface

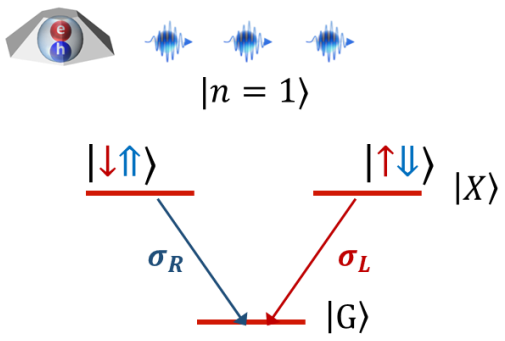




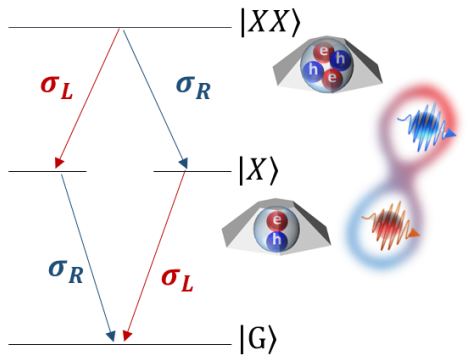
Integrating quantum emitters into Real-world platforms

Quantum resources

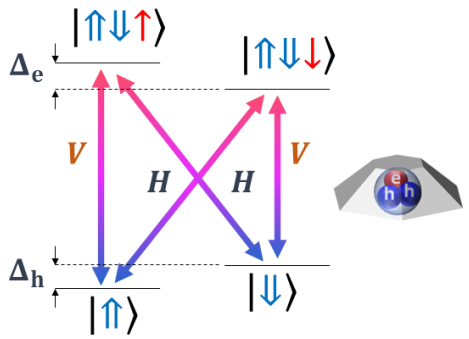
Single photons



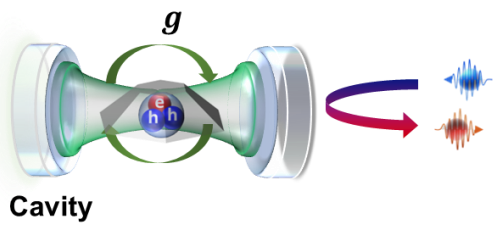
Entangled photon pair



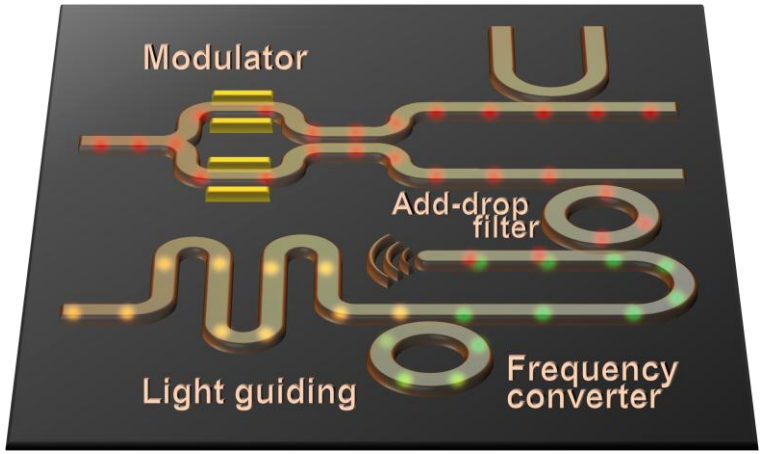
Quantum memories



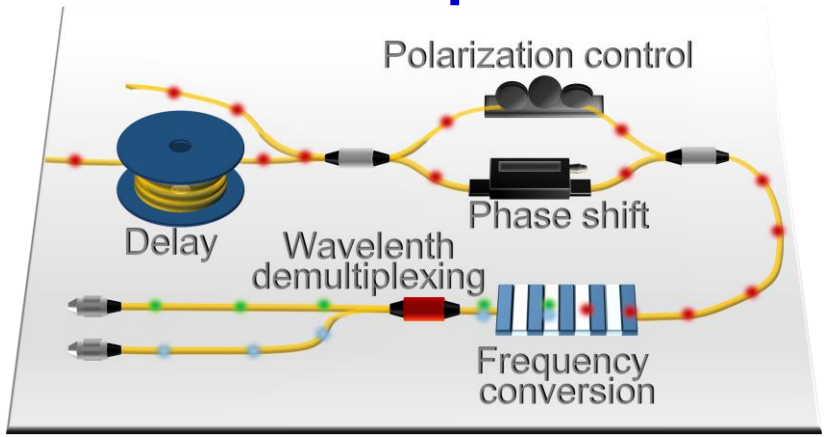
Spin-photon interface



Photonic integrated circuits

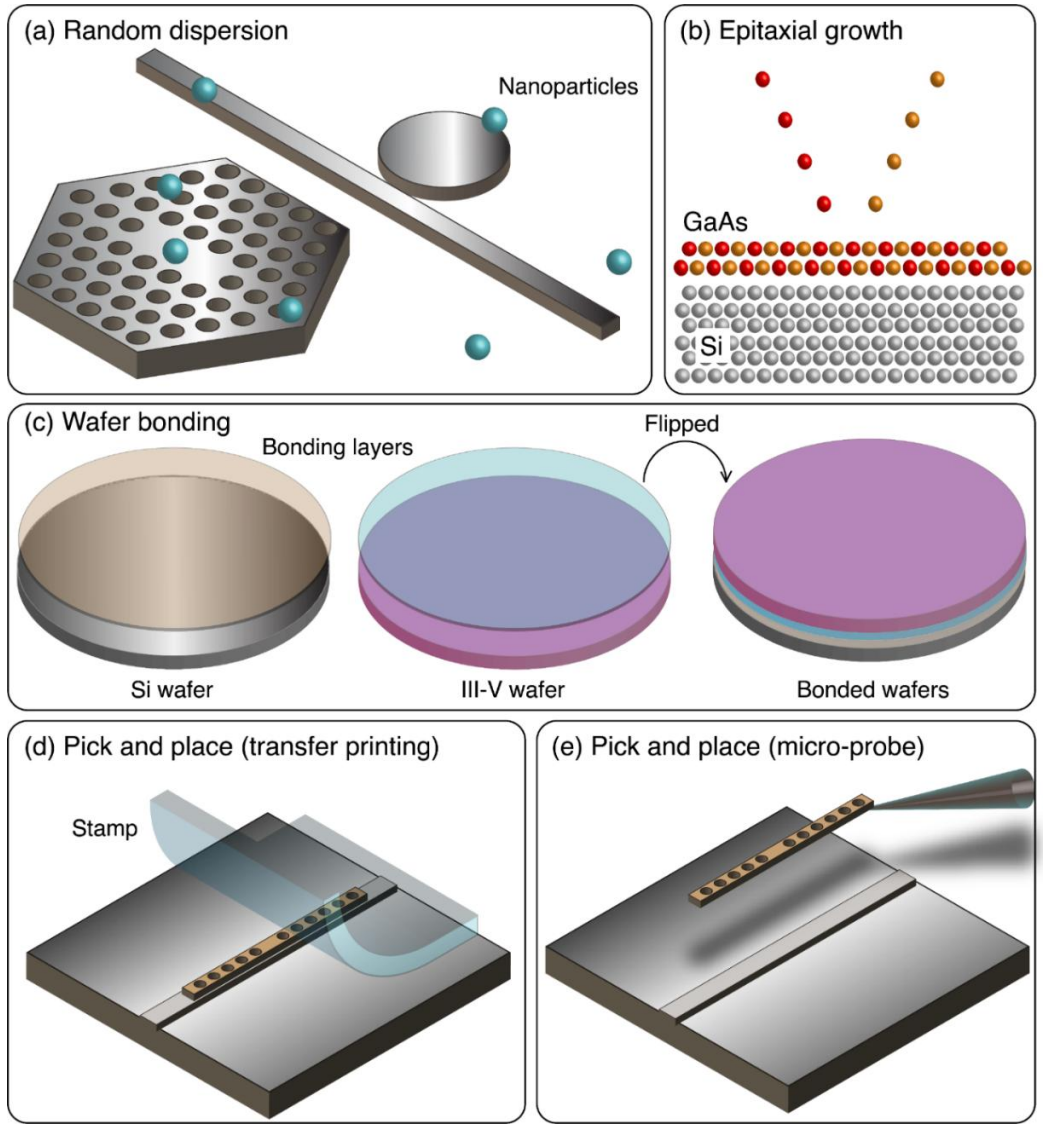


Fiber optics



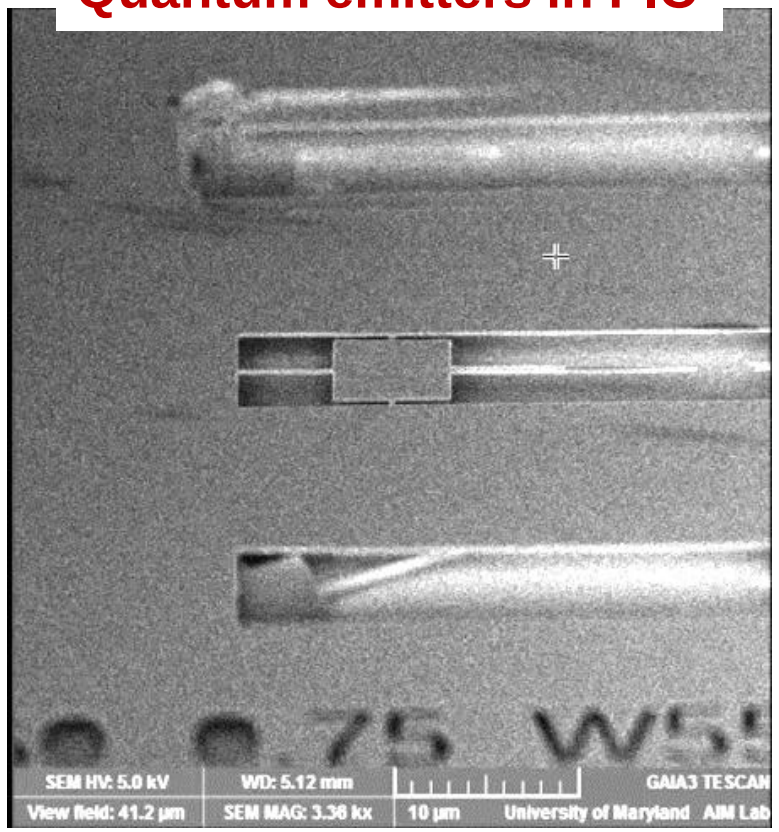
Hybrid integration of quantum emitters with PIC

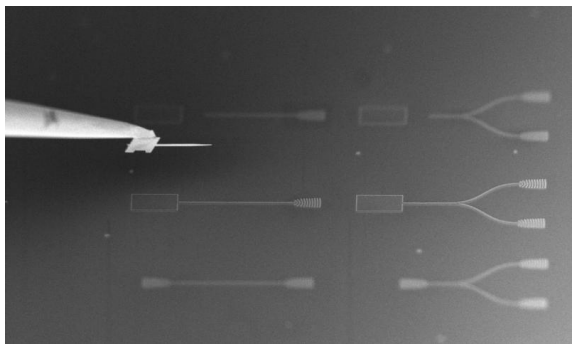
Hybrid integration of dissimilar platforms

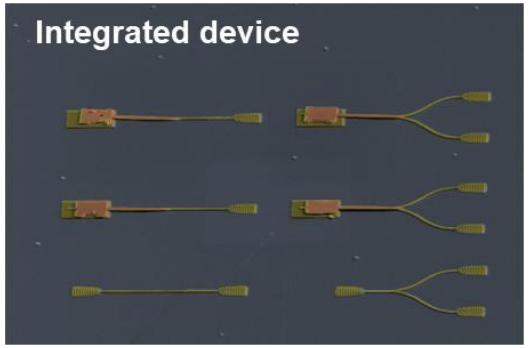


Optica 7, 291 (2020)

Quantum emitters in PIC



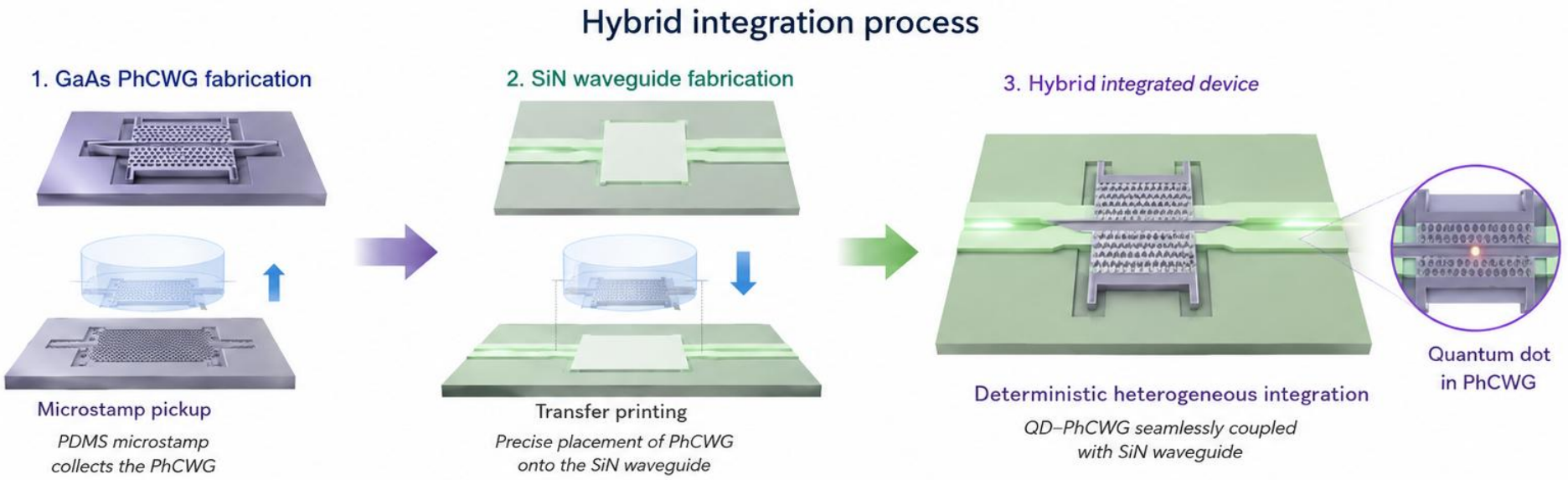


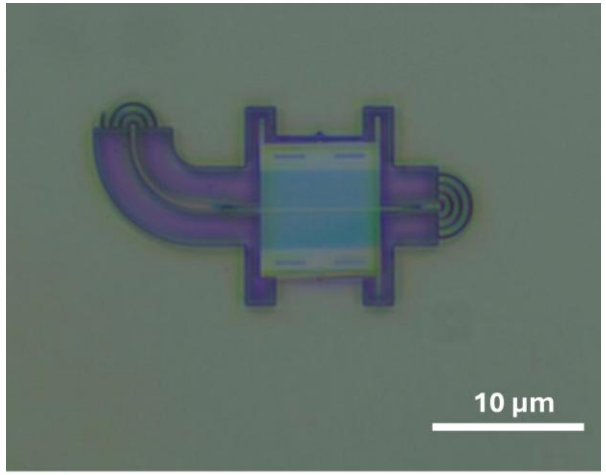


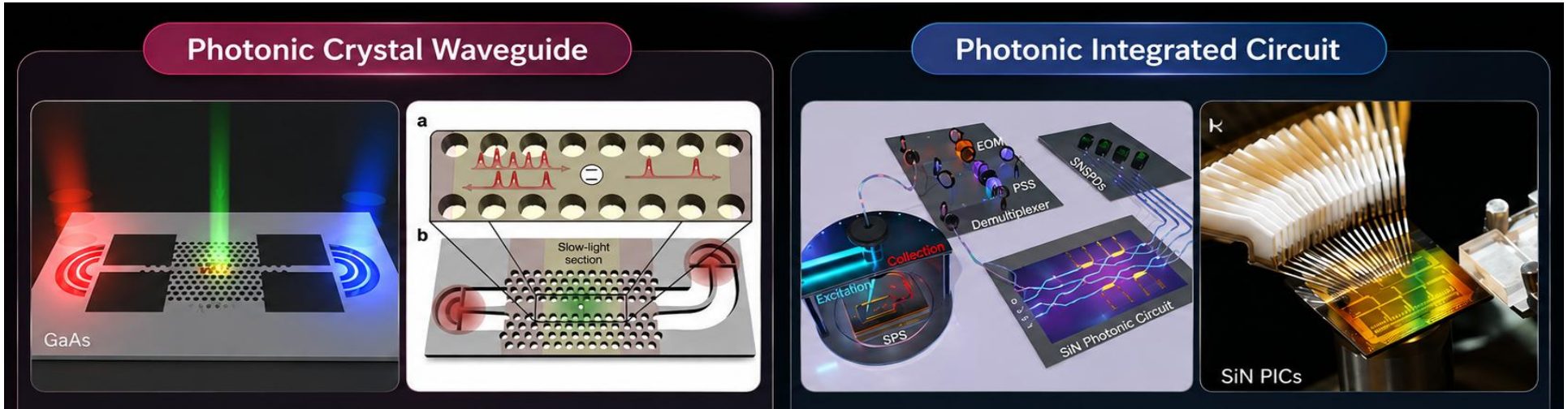
Nano Letters, 17, 7394 (2017)

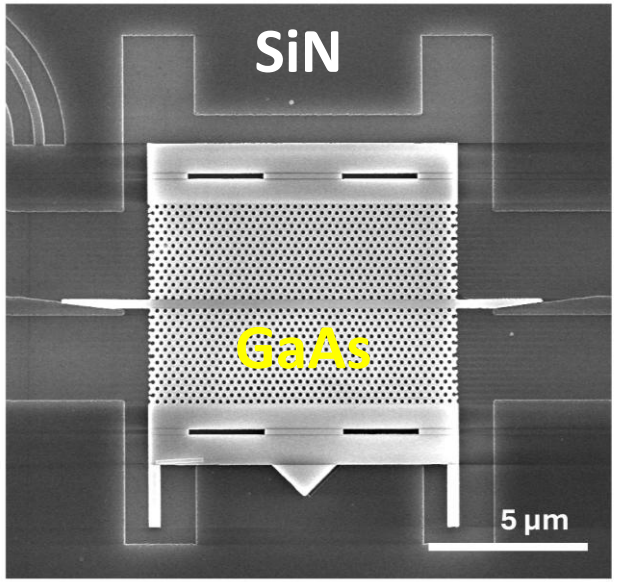
Hybrid integration of quantum emitters with PIC

Hybrid integration of dissimilar platforms





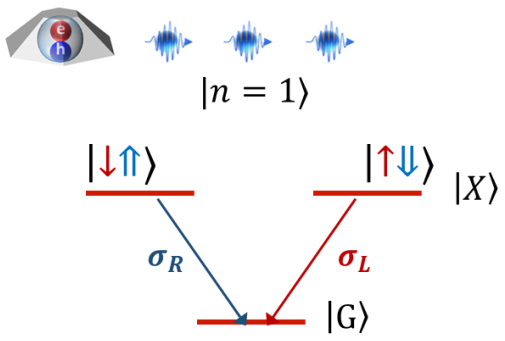




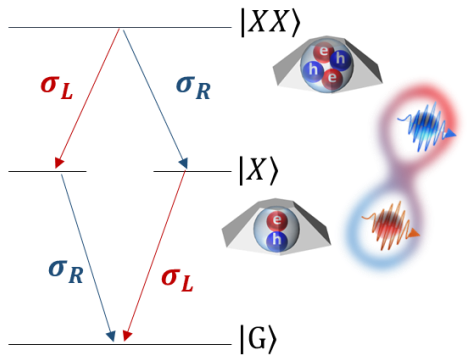
Integrating quantum emitters into Real-world platforms

Quantum resources

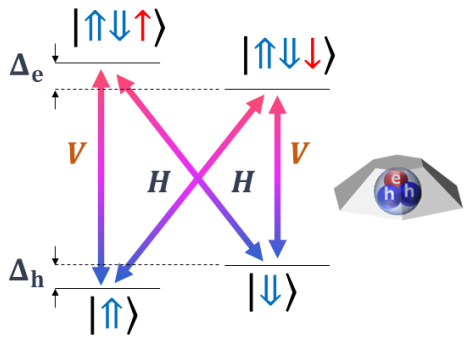
Single photons



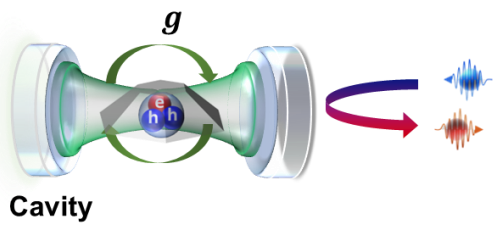
Entangled photon pair



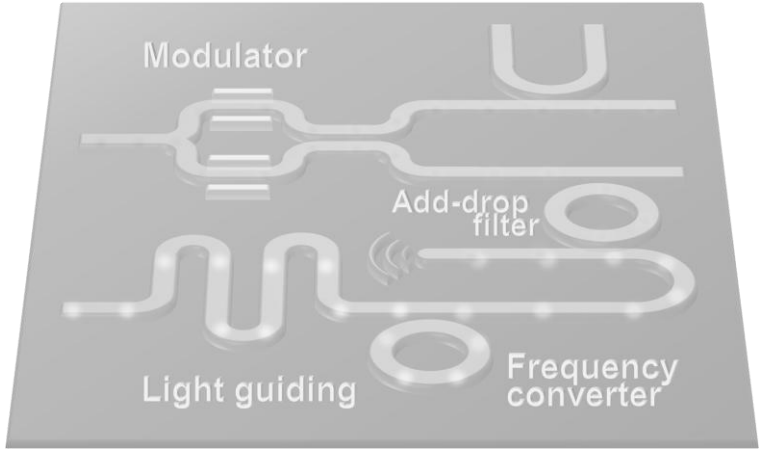
Quantum memories



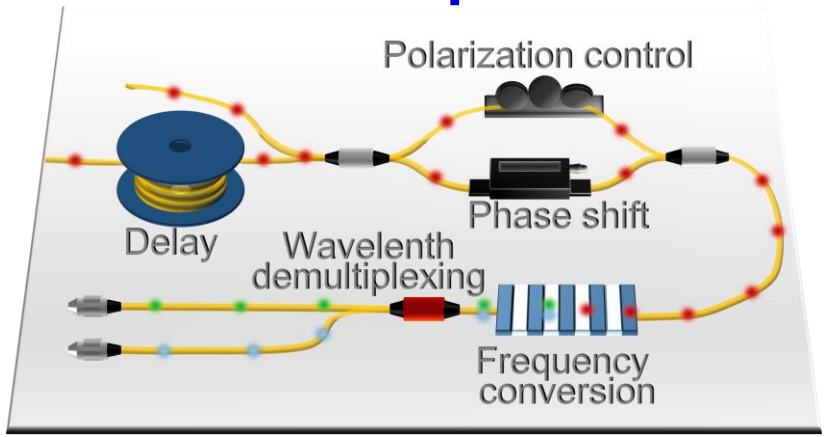
Spin-photon interface



Photonic integrated circuits



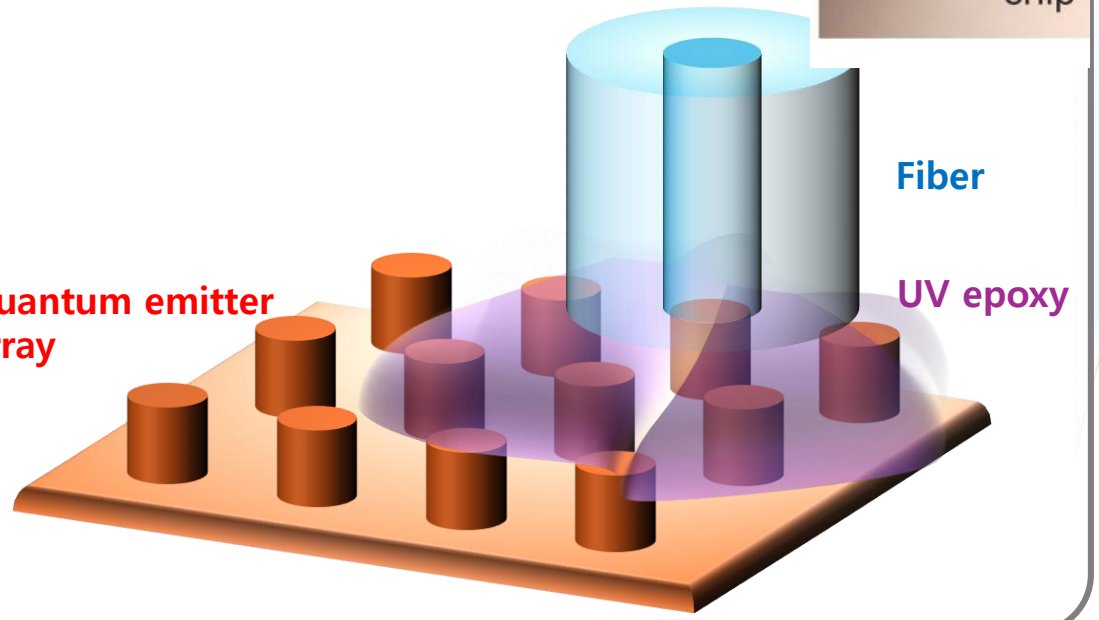
Fiber optics



Hybrid integration of quantum emitters with an optical fiber

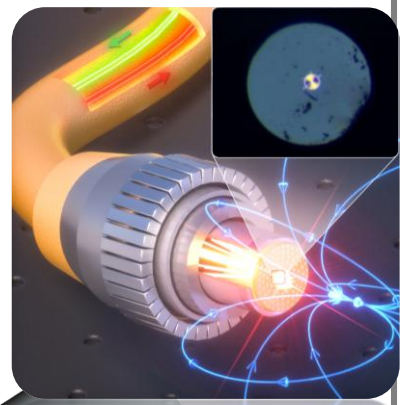
Fiber-to-chip integration

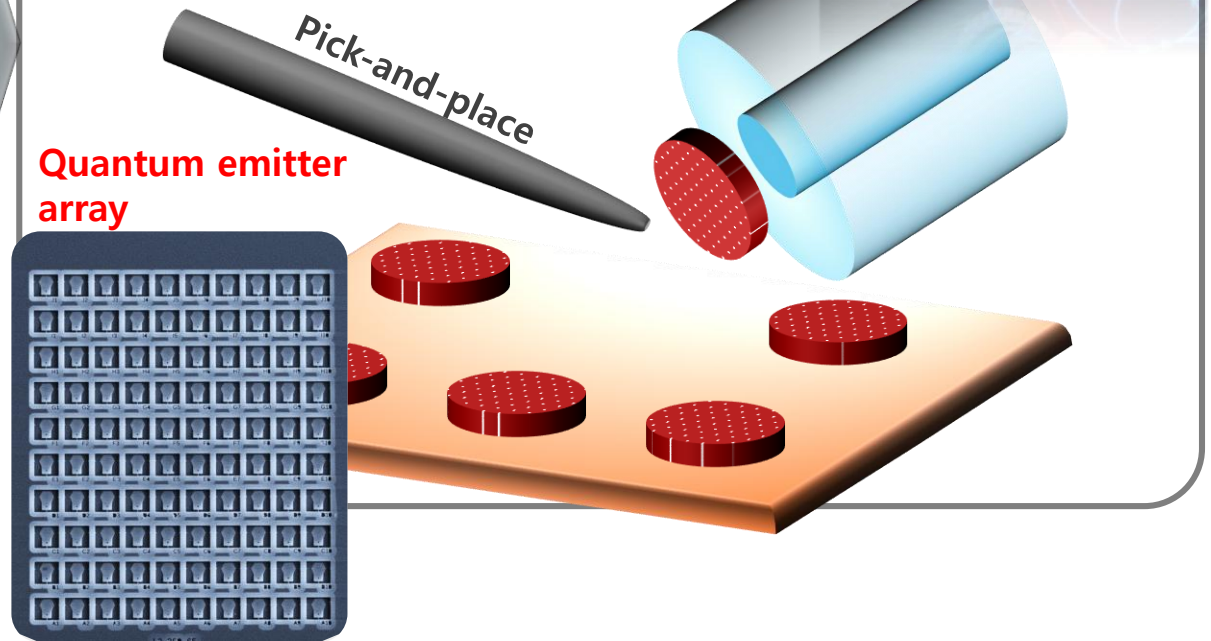
- ✓ Attachment: Epoxy gluing
- ✓ Whole chip integration
- ✓ Low stability and handling
- ✓ Low Scalable integration



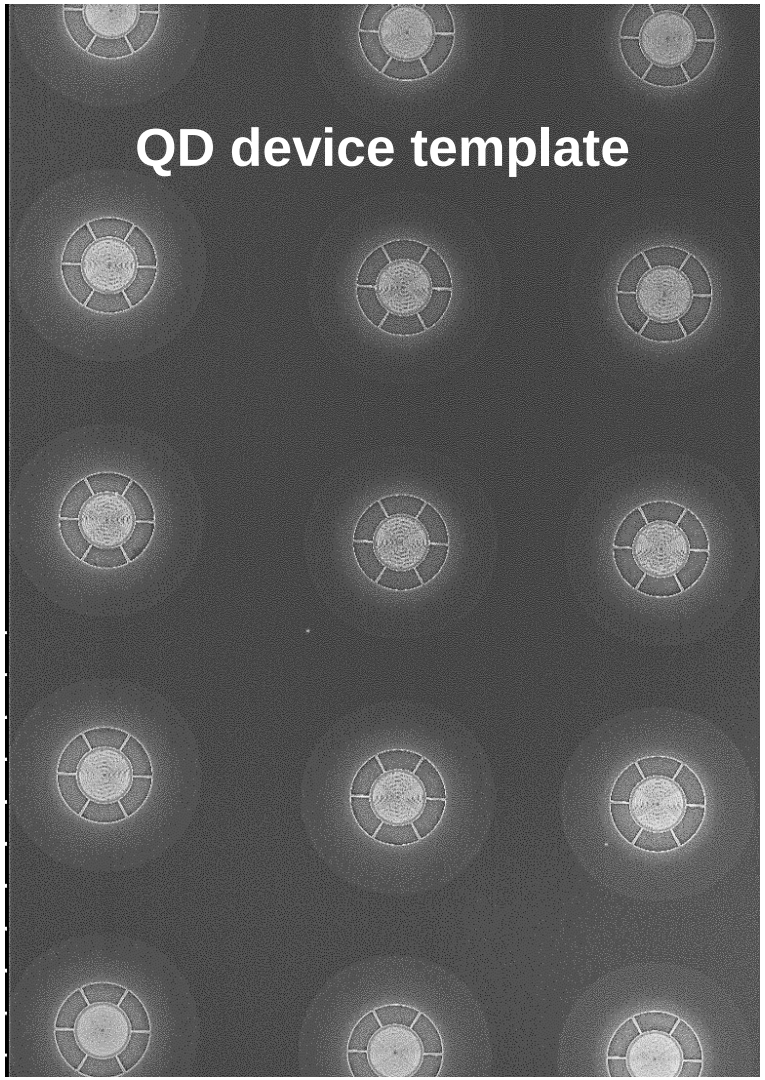
Device-to-fiber integration

- ✓ Attachment: Van der Waals
- ✓ Pick & Place integration
- ✓ Good Stability and handling
- ✓ Goold Scalable integration

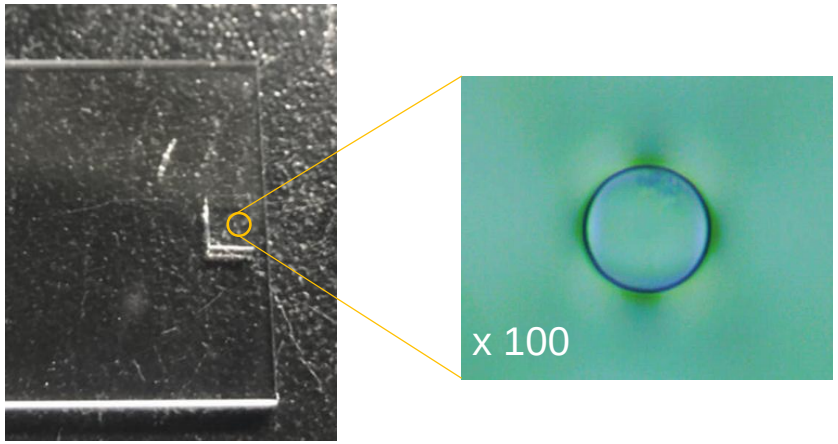


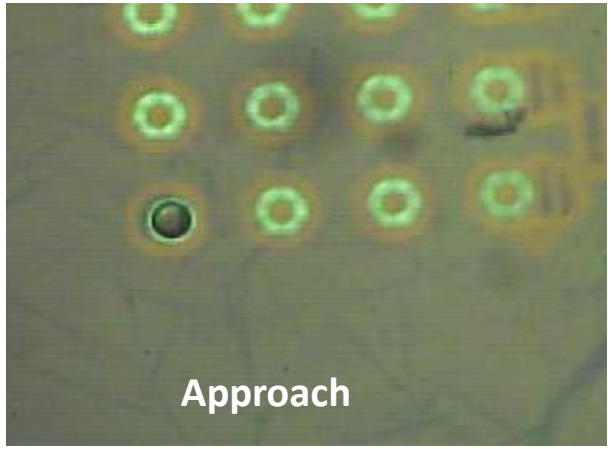


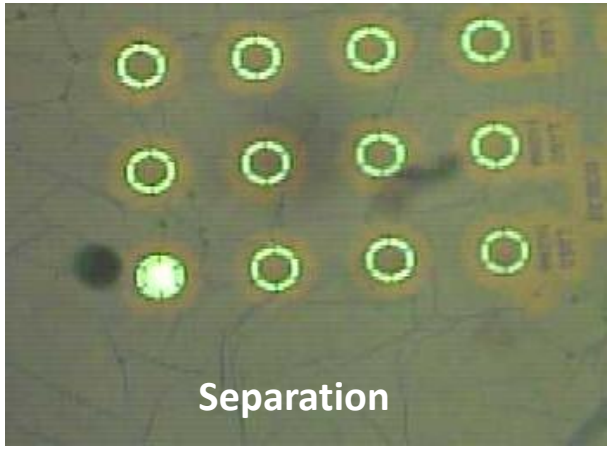
Hybrid integration of an optical fiber and a single QD



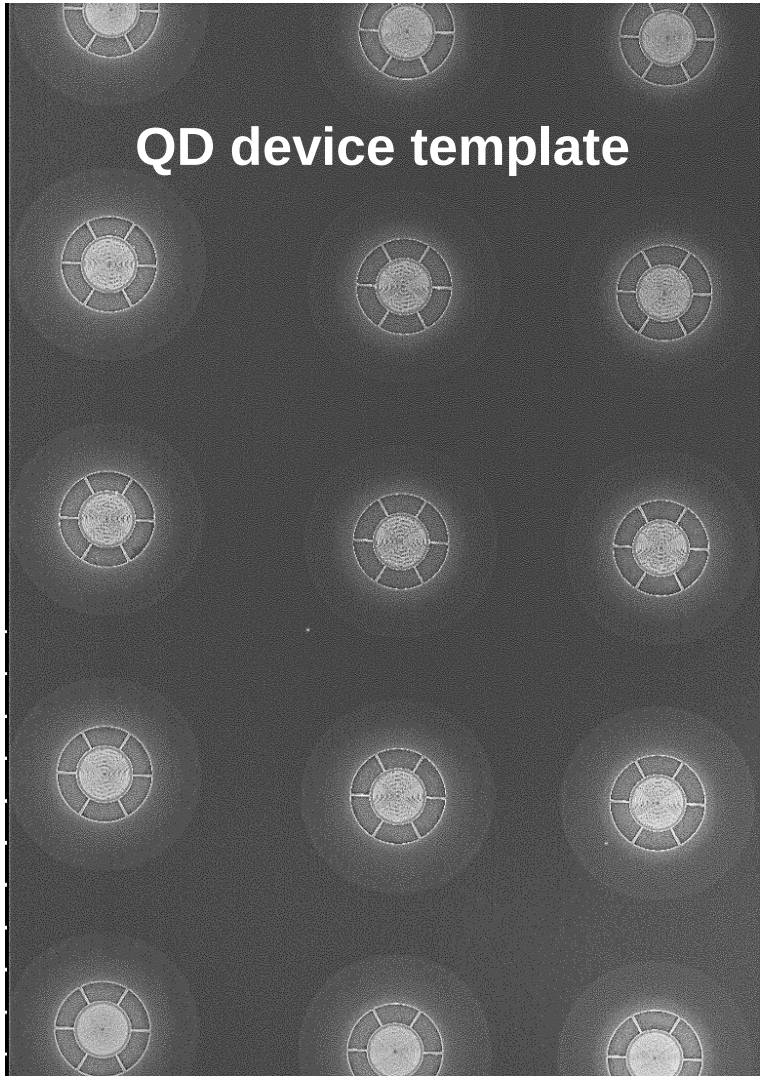
Selective pattern transfer with a micro-stamp

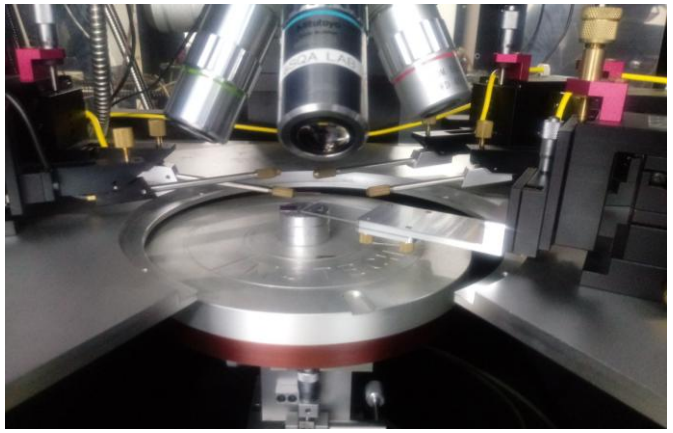




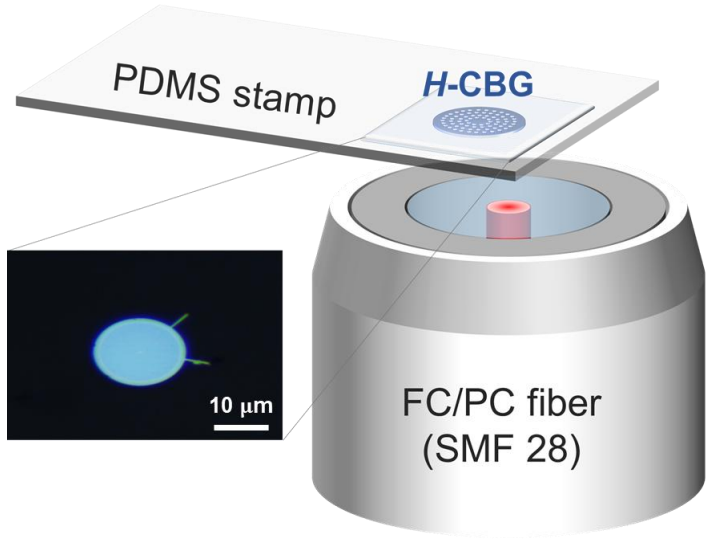


Hybrid integration of an optical fiber and a single QD

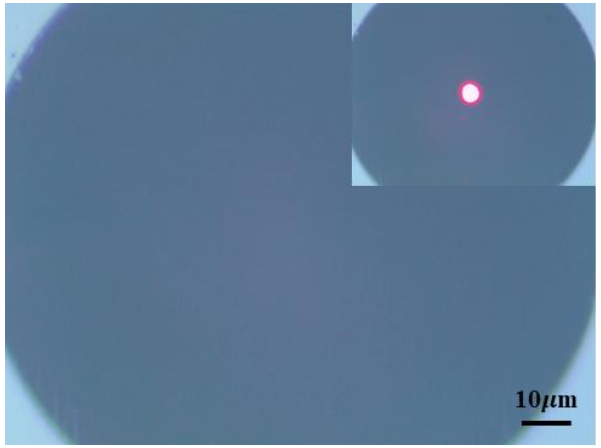




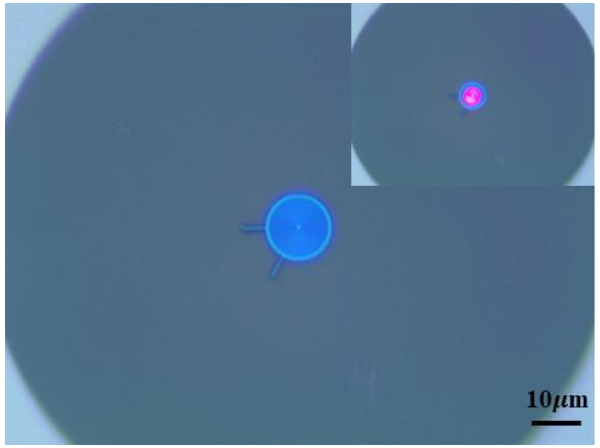
Pattern transfer system



Before integration

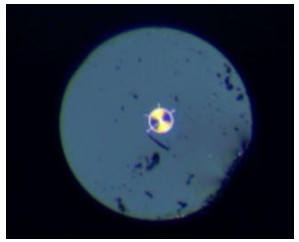


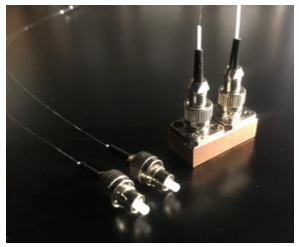
After integration

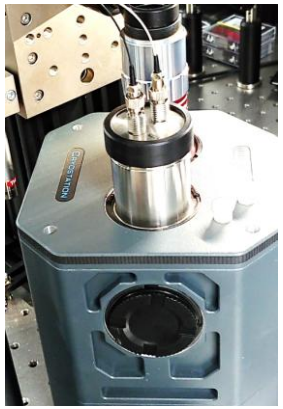


Hybrid integration of quantum emitters with an optical fiber

All-fiber connected quantum system

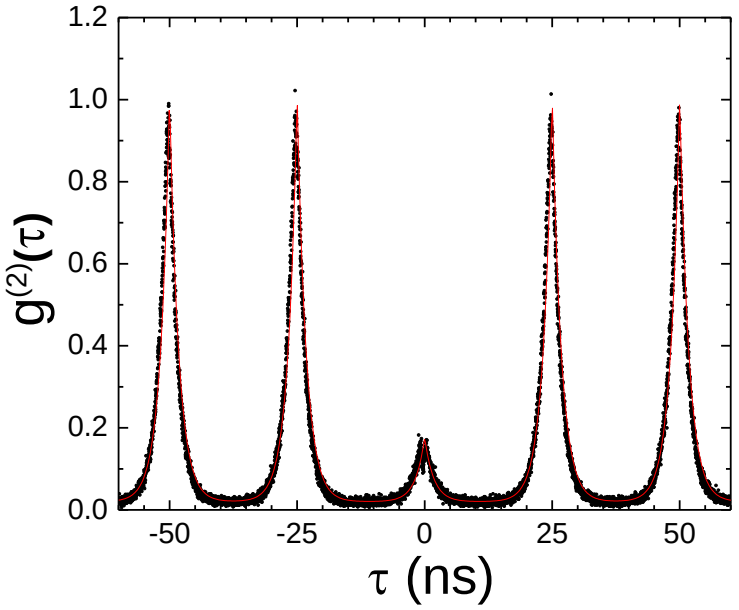




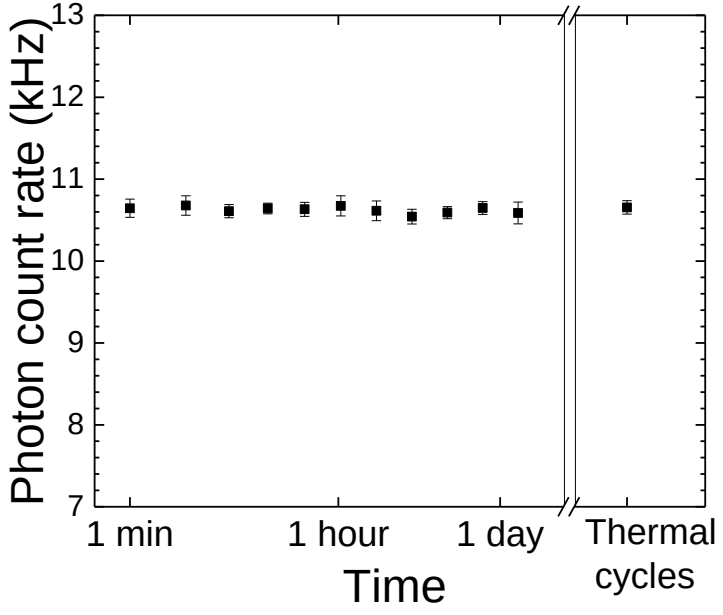


Bright, Stable single photons
from a source to a detector over fiber platforms

Single-photon emission



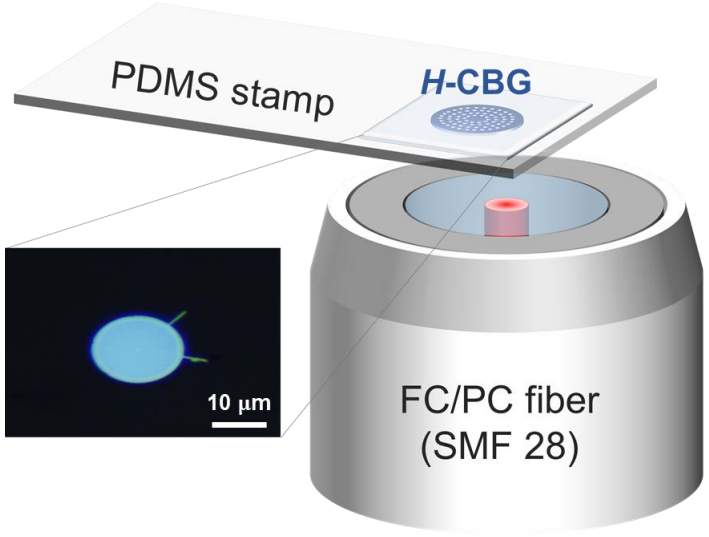
Stability

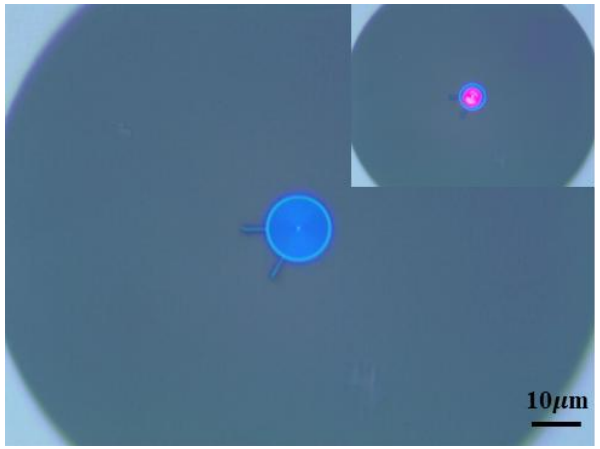


Adv. Quantum. Technol. 2200022 (2022)

Hybrid integration of quantum emitters with an optical fiber

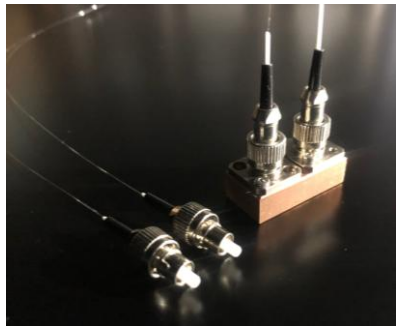
All-fiber integrated quantum photonic devices

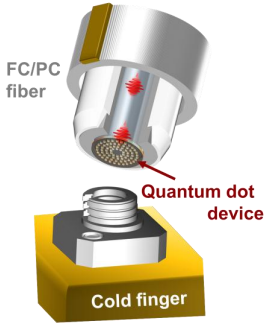




Quantum light device

Fiber-integrated Quantum light sources



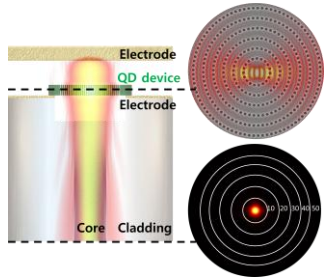


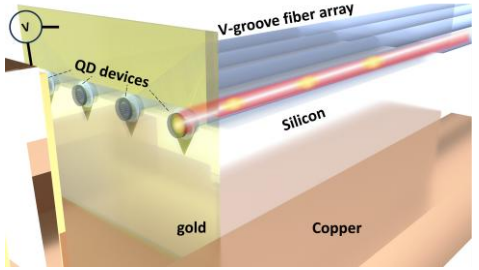
Plug & Play quantum light sources

Adv. Quantum. Tech. 2200022 (2022)

Multi-channel devices

Multi-channel, functional Quantum devices



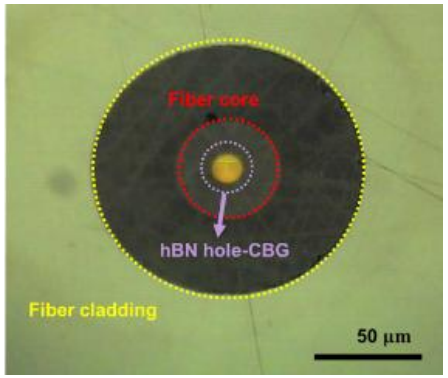


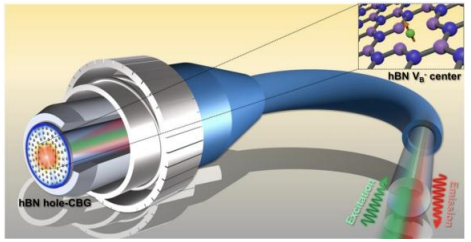
Multi-channel, tunable Fiber Quantum platforms

Adv. Opt. Mater. (2025)

Quantum sensing device

Fiber-integrated Quantum sensor

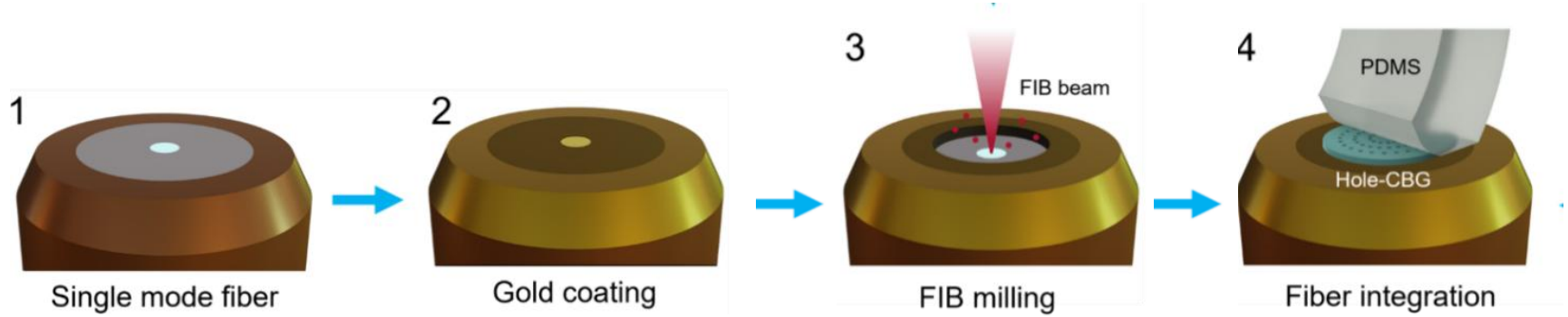


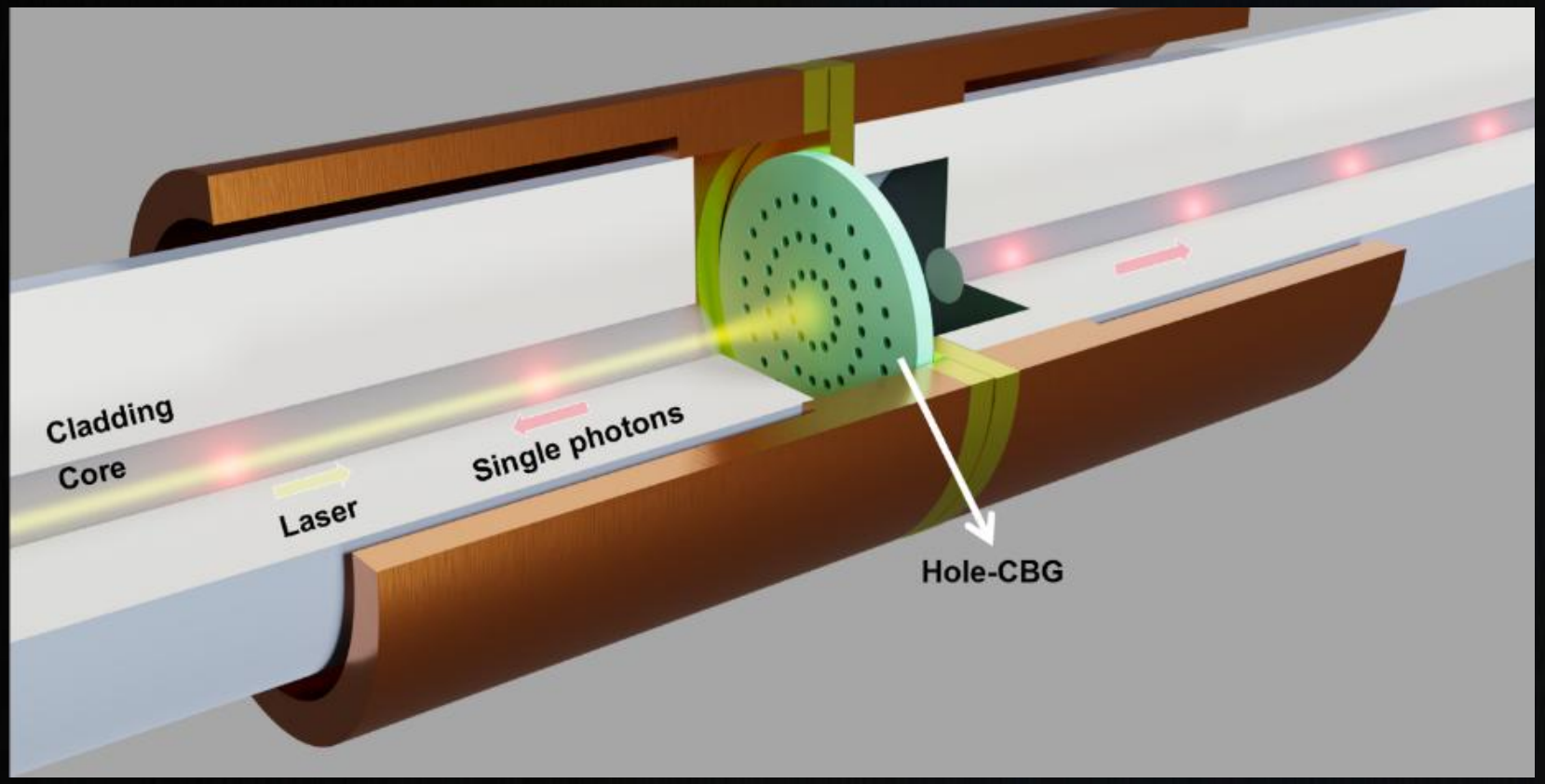


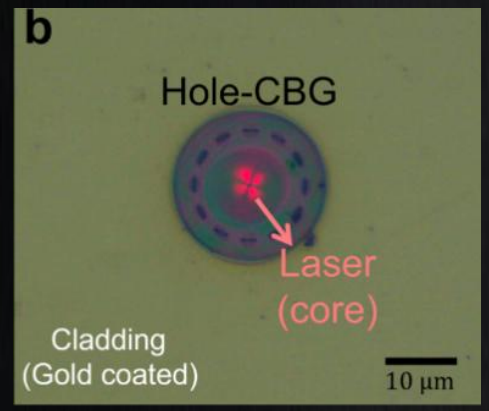
Quantum sensors on a fiber-integrated platform

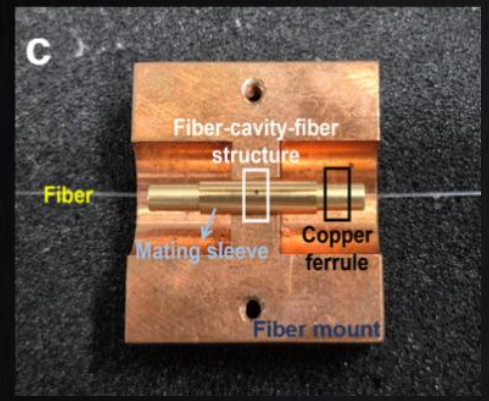
Adv. Opt. Mater. 2401987 (2024)

Hybrid integration of quantum emitters with an optical fiber

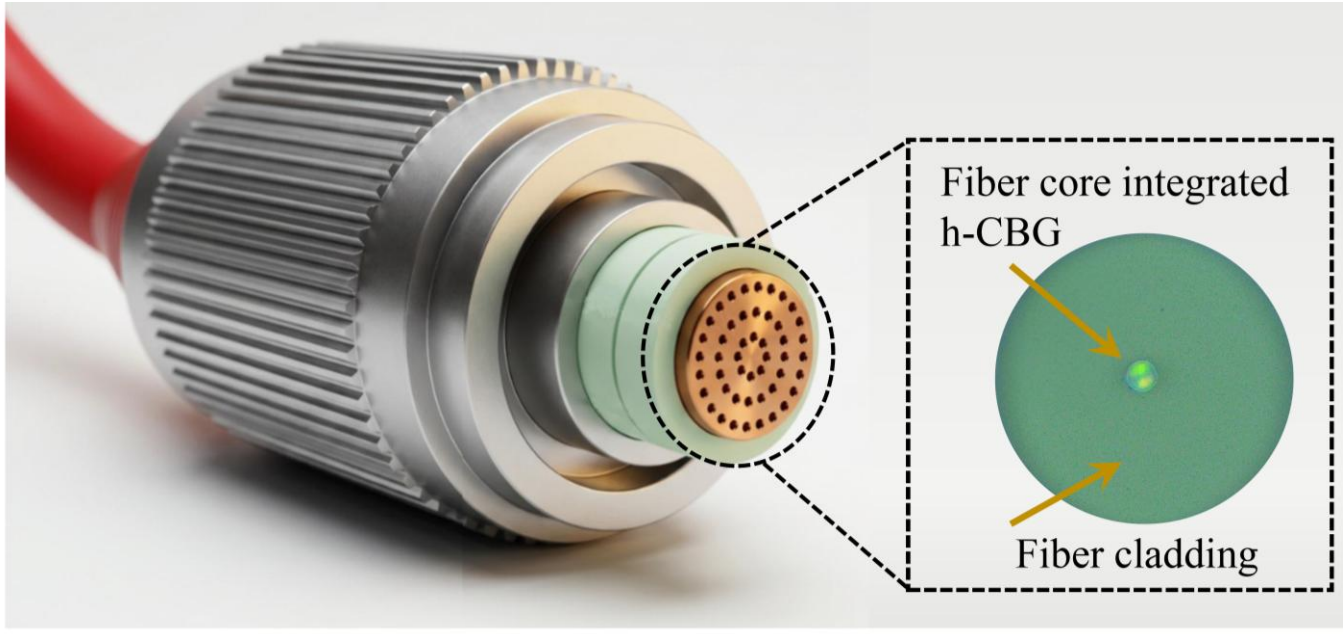


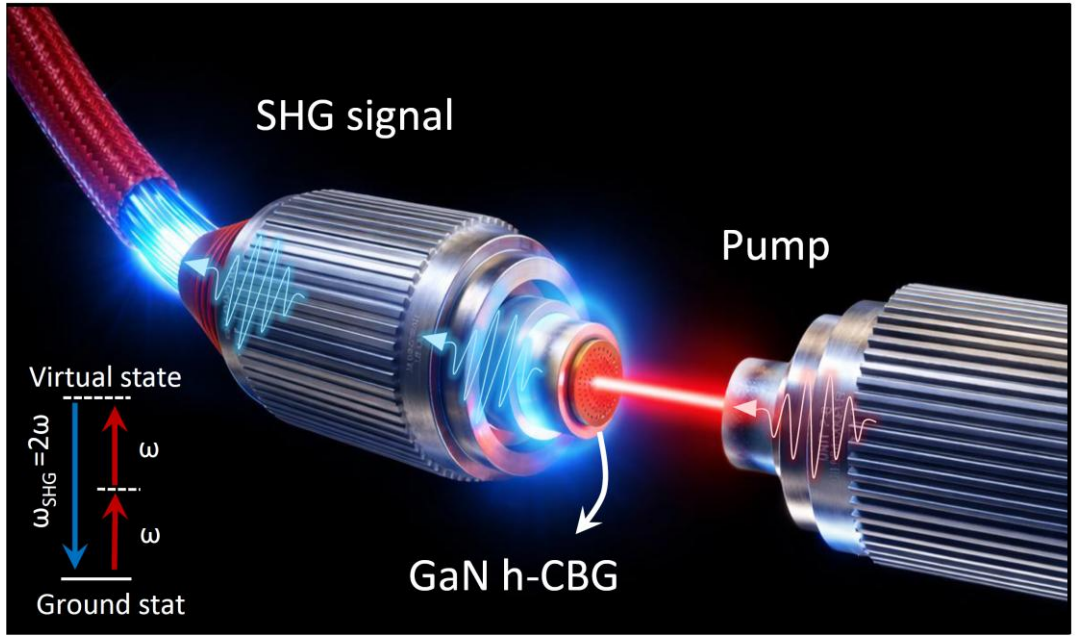


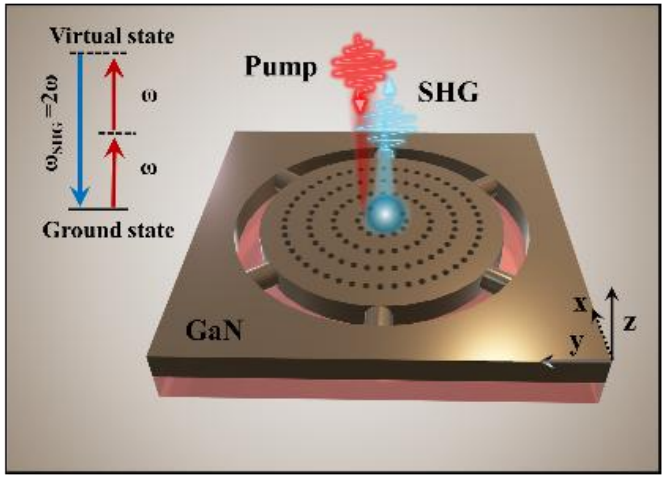


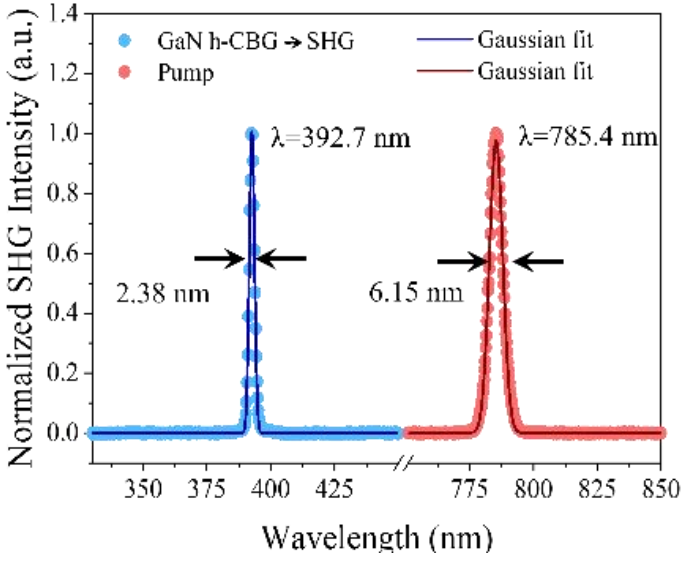


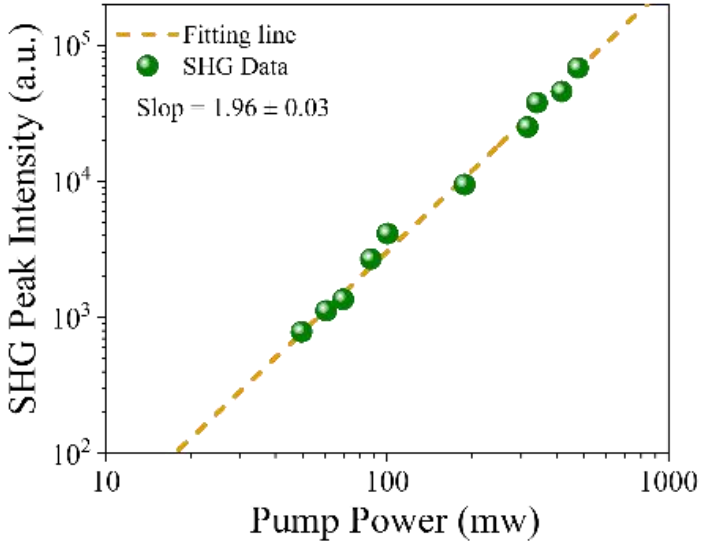
Hybrid integration of quantum emitters with an optical fiber









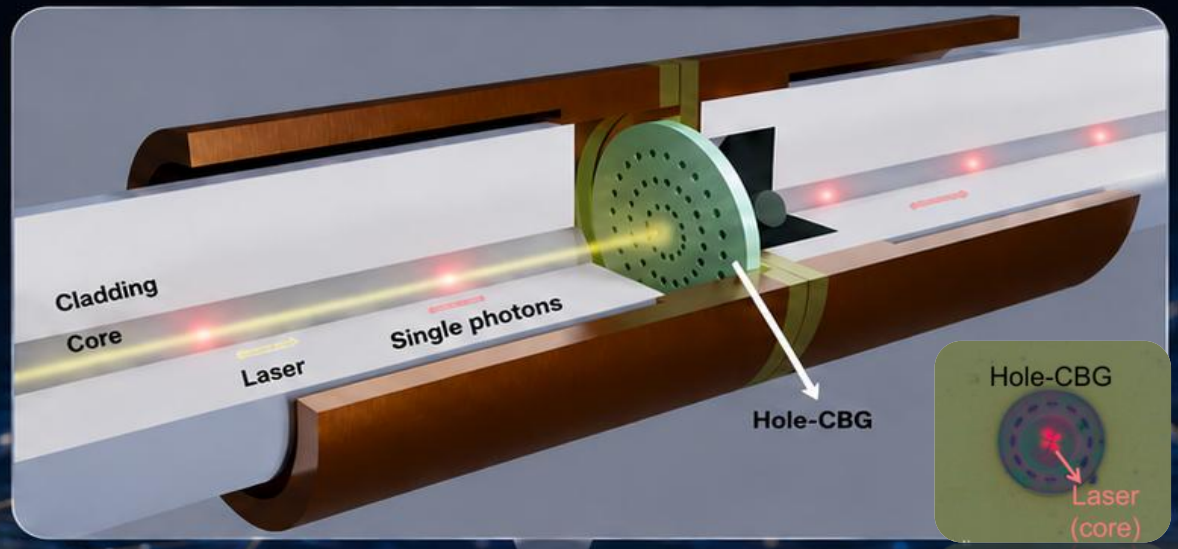


arXiv:2608.01084 (2026)

Hybrid integration of quantum emitters with an optical fiber

In-line Fiber Quantum Device

A modular device that plugs into existing optical fiber networks, instantly upgrading them to quantum fiber networks.



Quantum Node
Quantum Source

Classical Network
(Control & Processing

In-line Fiber Quantum Device

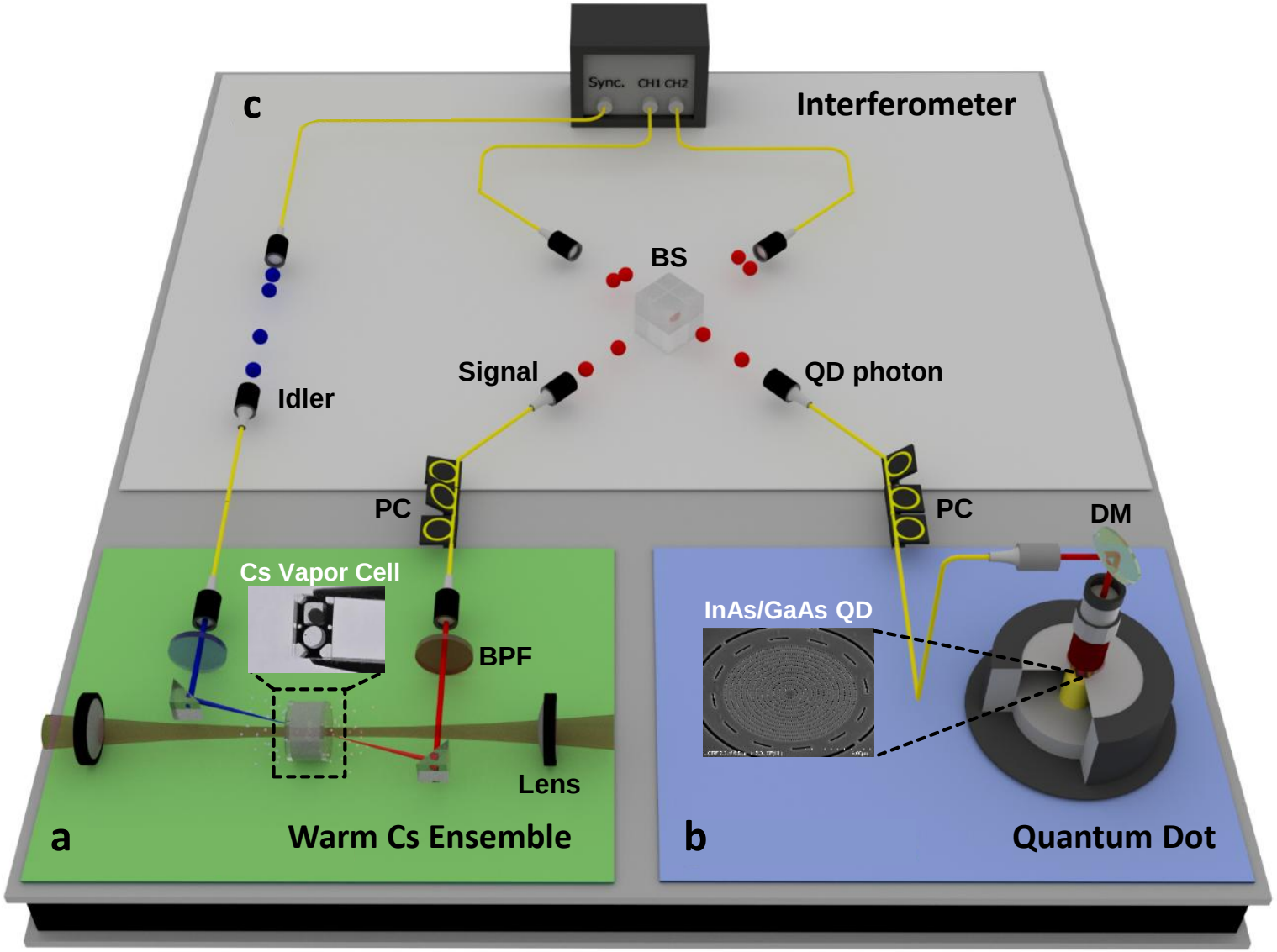
Quantum Node
Quantum Memory

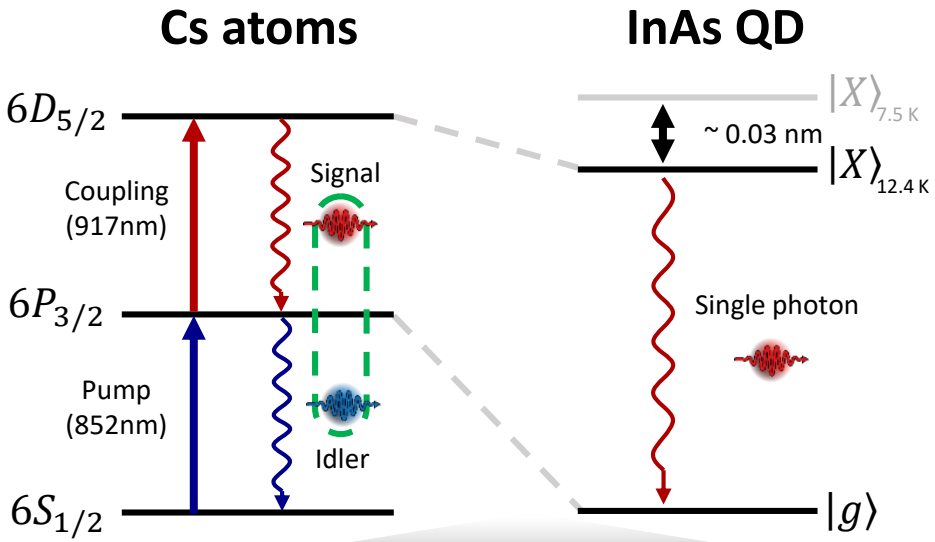
Quantum Node
Quantum Detector

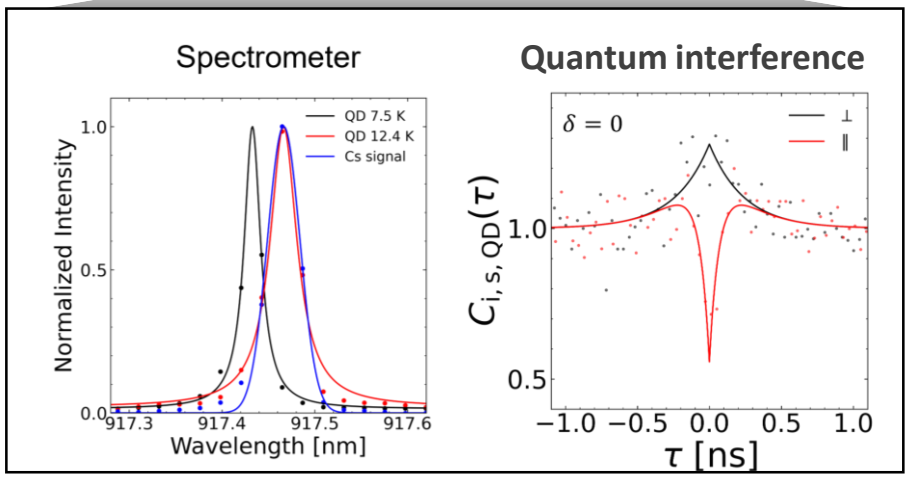
Quantum Node
Quantum Repeater

Hybrid quantum network with atom and QDs

Two-photon interference between dissimilar single-photon sources





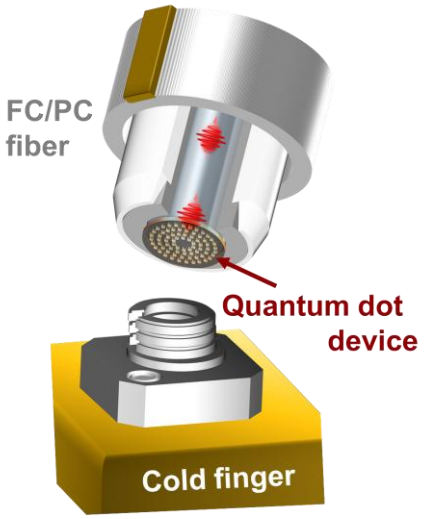


Light: Science & Applications 15, 320 (2026)

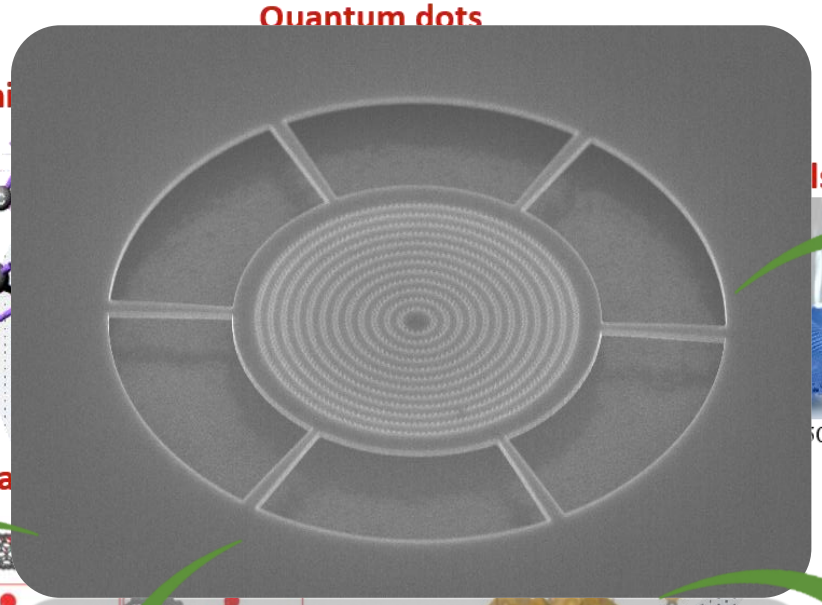
Summary

Get efficiently interfaced and interconnected

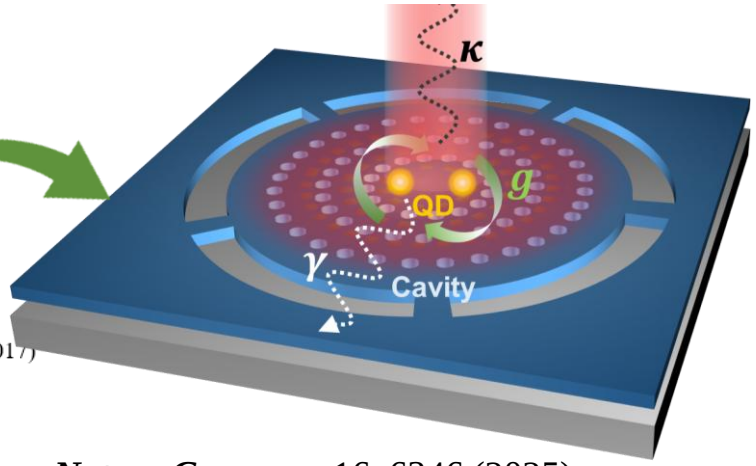
Plug & play



Adv. Quant. Tech. 2200022 (2022)

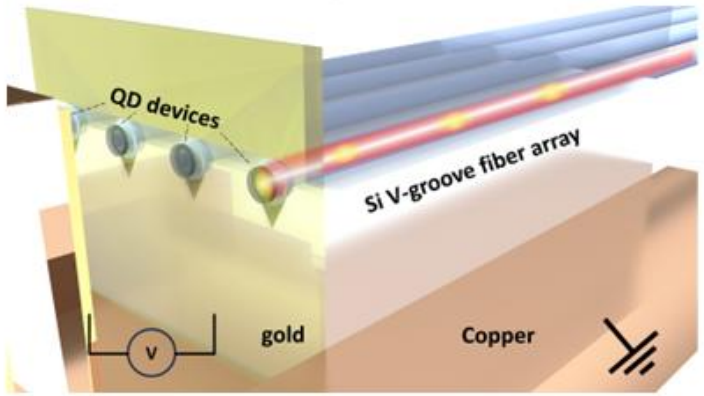


Many-body collective interaction



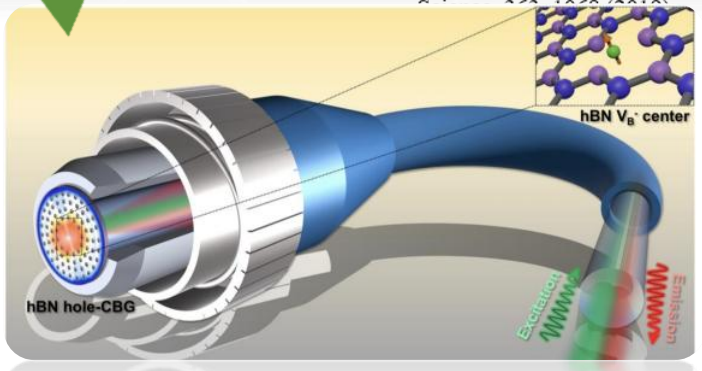
Nature Commun. 16, 6346 (2025)

Multi-channel, tunable



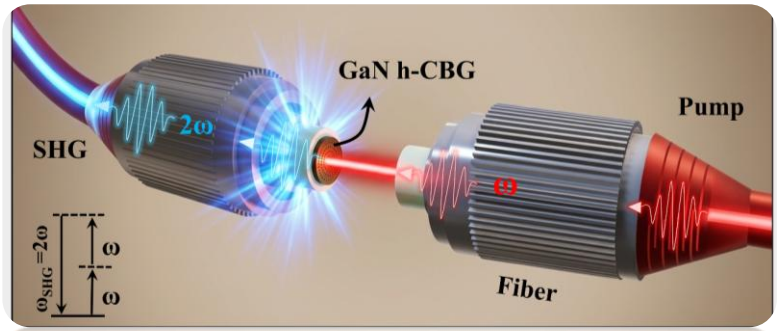
Adv. Opt. Mater. 13, e01523(2025)

Portable quantum sensor



Adv. Opt. Mater. 2401987 (2024)

In-line quantum device



*arXiv:*2608.01084 (2026)

From Semiconductor Powerhouse to Quantum Industry Hub

Quantum Fabrication Infrastructure

Korea's Strength in Semiconductor Manufacturing

- Advanced semiconductor technology and manufacturing capability
- Extensive nanofabrication infrastructure across the nation

NATIONAL QUANTUM FABS

- **KIST (Seoul)**
  National Quantum Fab
- **KAIST (Daejeon)**
  National Quantum Fab
- **UNIST (Ulsan)**
  National Quantum Fab
- **Sungkyunkwan University (Suwon)**
  National Quantum Fab

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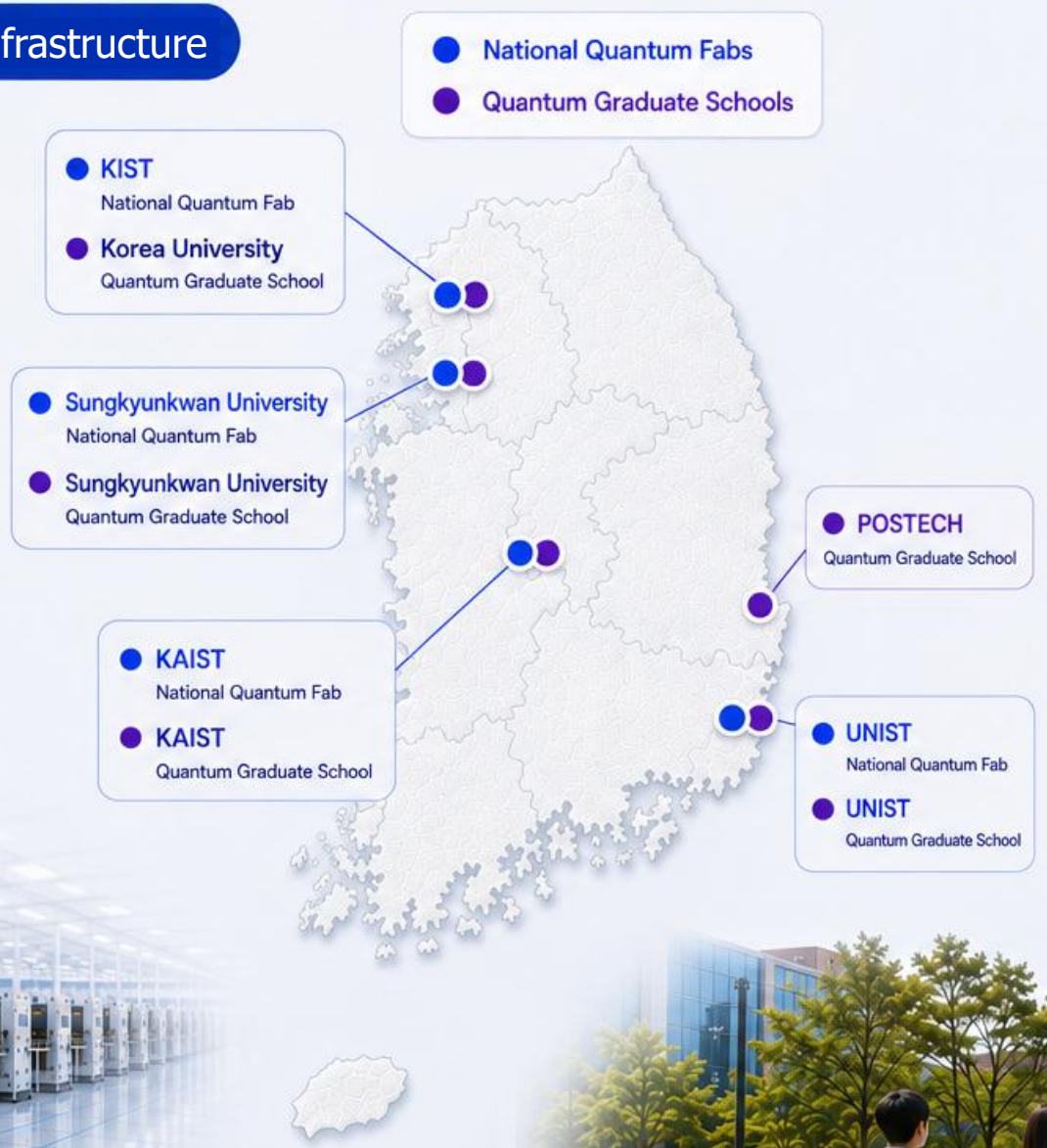

Quantum Education

Building the Quantum Leaders of Tomorrow

- World-class education and research
- Interdisciplinary curriculum
- Strong industry and global collaboration

QUANTUM GRADUATE SCHOOLS

- **Korea University** (Seoul)
- **KAIST** (Daejeon)
- **POSTECH** (Pohang)
- **UNIST** (Ulsan)
- **Sungkyunkwan University** (Suwon)

PHYSICS | MATERIALS | DEVICES | ENGINEERING | QUANTUM SYSTEMS

KOREA LAUNCHES ‘QUANTUM CLUSTERS’

Driving the quantum industry through regional collaboration
across research, innovation, and industrialization

SEOUL

Quantum Computing Cluster

- Quantum R&D
- Industry Innovation
- Investment & Finance

GWANGJU

Quantum Communication Cluster

- Quantum Networks
- Testbed & Verification
- Talent Development

SOUTHEAST REGION

Quantum Sensing Cluster

- Quantum Sensing
- Industry Applications
- Industrial Support

FROM RESEARCH TO INDUSTRIAL IMPACT

Research & Development → Industry Collaboration → Technology Commercialization → Global Market Expansion

uPiD
Quantum Photonic Integrated Device

UNIST

Group members


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Dr. Mahsa Moghadam


Kirlie Michal


Byung Guk Ahn


Dong Hyun Park


Sang Woo Lee


Sijin Sung


Minjae Joo


Haemin Lee


Junhee Lee

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Prof. Hee Deuk Shin (POSTECH)

Prof. Changhyoup Lee (Hanyang Univ.)

Prof. Edo Waks (Univ. of Maryland)

Prof. Mohamed Benyoucef (Univ. of Kassel)

Prof. Shuo Sun (CU Boulder, JILA)

Prof. Han Seb Moon (Pusan National Univ.)

Prof. Igor Aharonovich (Univ. of Technology Sydney)

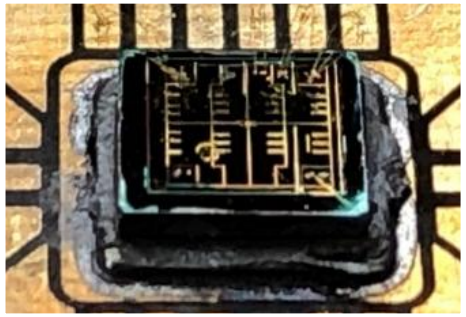
QUPID group

uPiD
Quantum Photonic Integrated Device

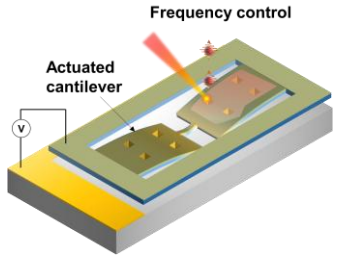
Comprehensive researches in **engineering, integrating**, and **characterizing** solid-state qubits as well as studying their **quantum interactions**

Quantum engineering

Quantum lights on Si MEMS
(Deterministic controlled emitters)



Tunable quantum emitters

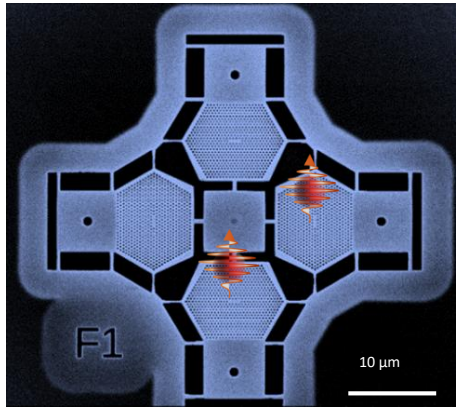


Position & frequency controlled quantum device

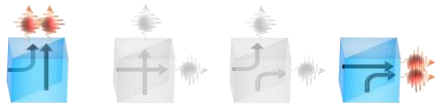
Nano Letters 19, 7534 (2019)

Quantum interference

Two-photon interference
(Photon-Photon interaction)



Indistinguishable photons

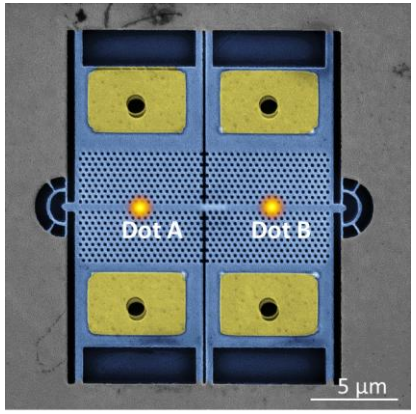


Multiple photonic qubits

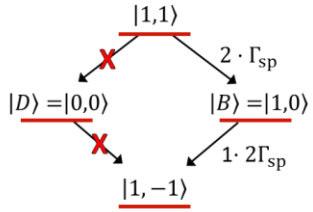
Nano Letters, 16, 7061 (2016)

Quantum interaction

Super-radiant Dicke state
(Emitter-Emitter interaction)



Identical emitters

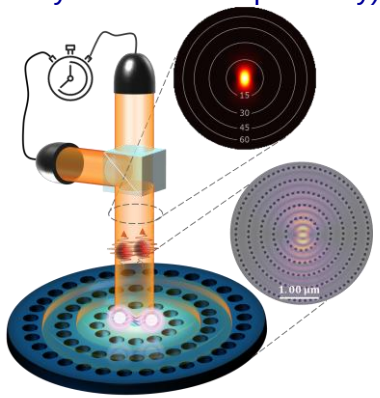


Multiple stationary qubits

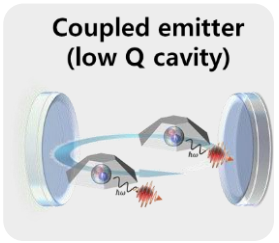
Nano Letters, 18, 4734 (2018)

Quantum correlation

Long-lived subradiance
(cavity-mediated cooperativity)



Steady-state subradiance

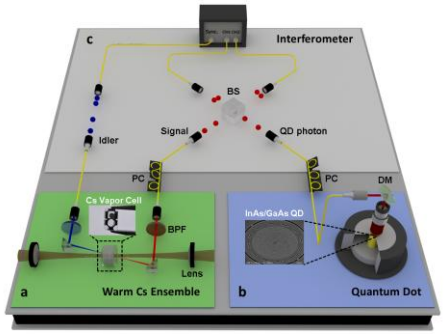


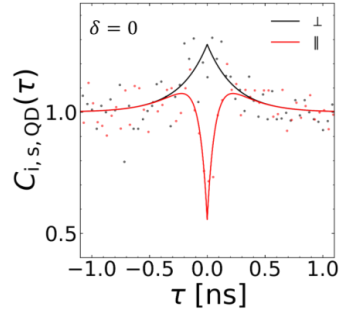
Collective interaction between emitters

Nature Commun. 16, 6346 (2025)

Hybrid quantum system

Atom-QD Hybrid system
(Leverage distinct advantages)





Quantum interference across Hybrid quantum nodes

Light:Science & Application

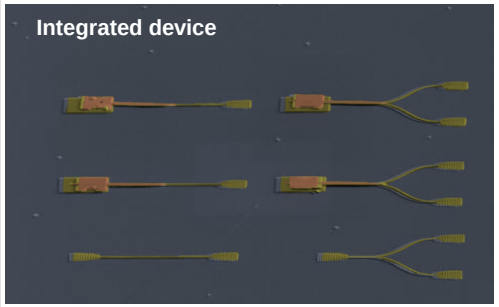
QUPID group

uPiD
Quantum Photonic Integrated Device

Toward Quantum Photonic Integrated Devices

On-chip integration

On-chip hybrid Integration

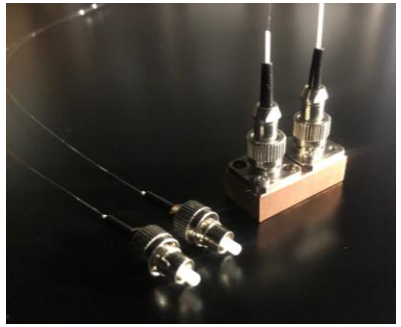


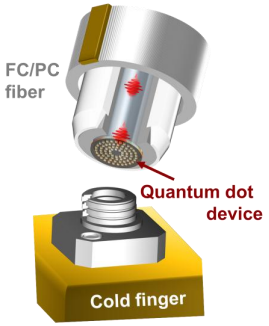
Quantum photonics on a hybrid chip

Nano Letters 7, 7394 (2017)

Quantum light device

Fiber-integrated Quantum light sources



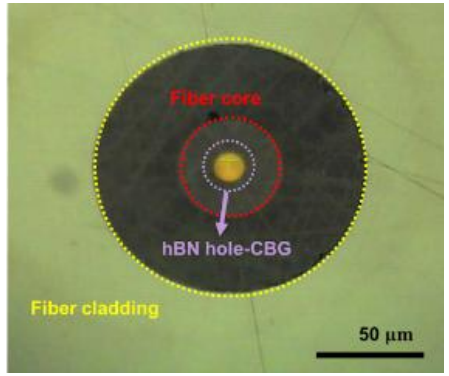


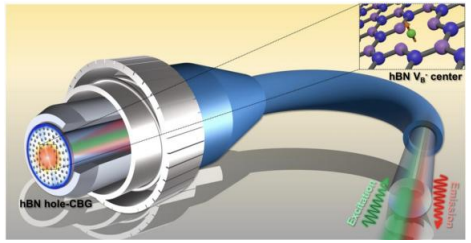
Plug & Play quantum light sources

Adv. Quantum. Tech.2200022 (2022)

Quantum sensing device

Fiber-integrated Quantum sensor



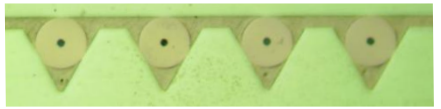


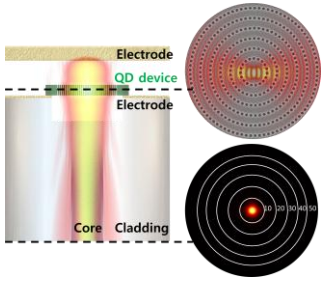
Quantum sensors on a fiber-integrated platform

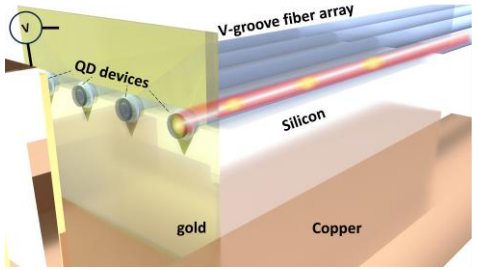
Adv. Opt. Mater. 2401987 (2024)

Multi-channel devices

Multi-channel, functional Quantum devices







Multi-channel, tunable Fiber Quantum platforms

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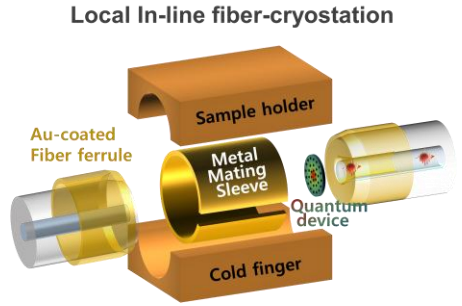
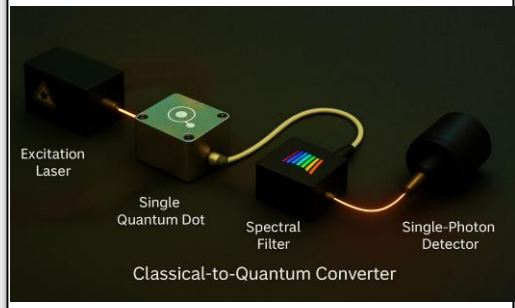
Quantum converter

In-line fiber-integrated Quantum devices





Classical-to-quantum converter on Fiber platforms

In preparation

Toward Scalable and Integrated quantum photonics

Advanced Quantum resources

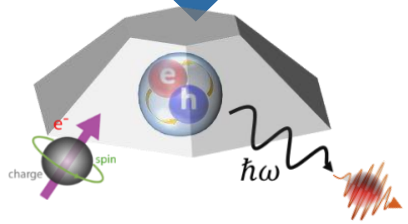
- Bright single-photon sources
- Spin-photon entanglement
- Quantum illumination
  (NOON states, entangled photon pairs)
- Photonic cluster states

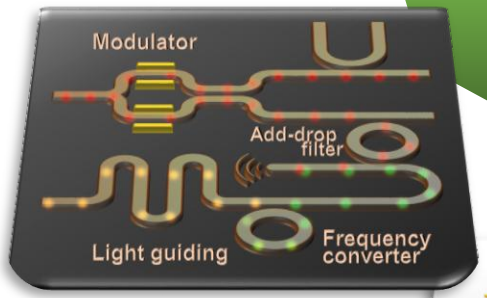
Quantum lab-on-chip(fiber)

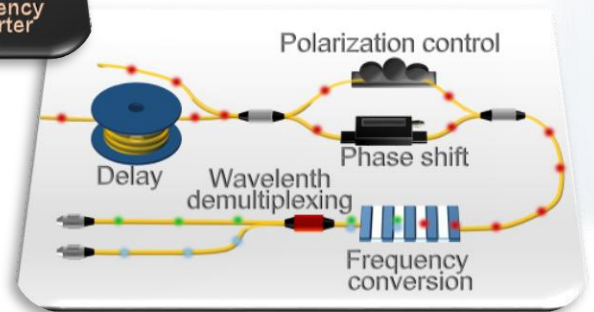
- Hybrid integration
- Efficient interfacing
- Reliable manipulation

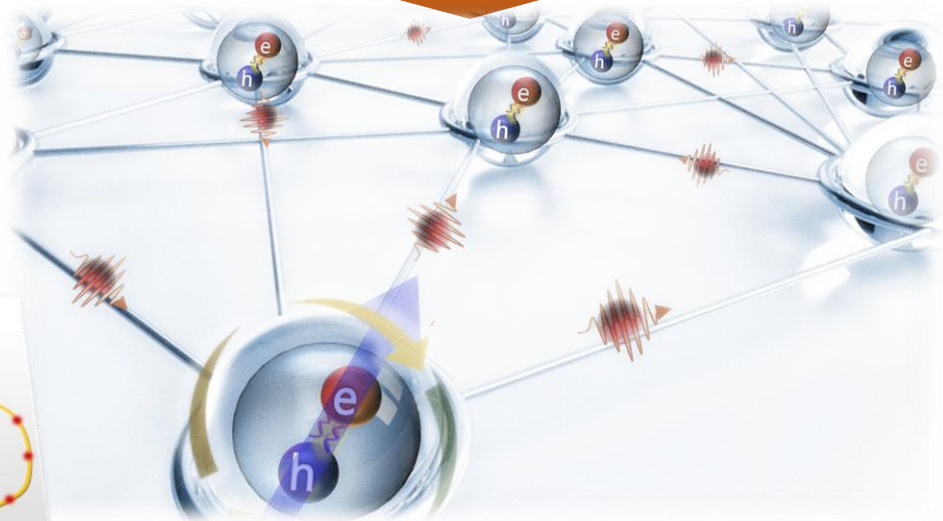
Practical Quantum applications

- Photonic quantum computing
  (Deterministic quantum gates)
- Quantum metrology
  (Chip & Fiber-integrated quantum sensors)
- Quantum network
  (Quantum lights and memories in fiber network)



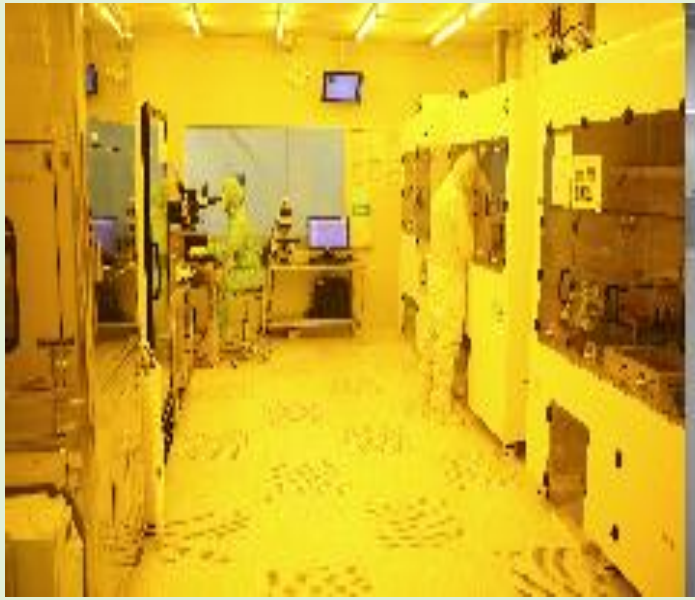






Organizations and Qualifications of the group

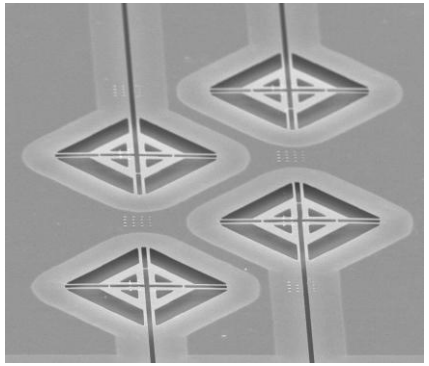
Nano Fabrication (UNIST Central Research Facilities for fabrication)

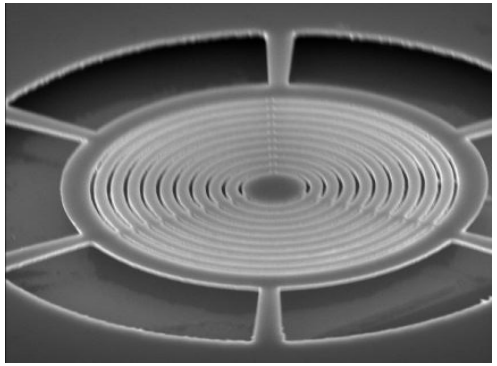


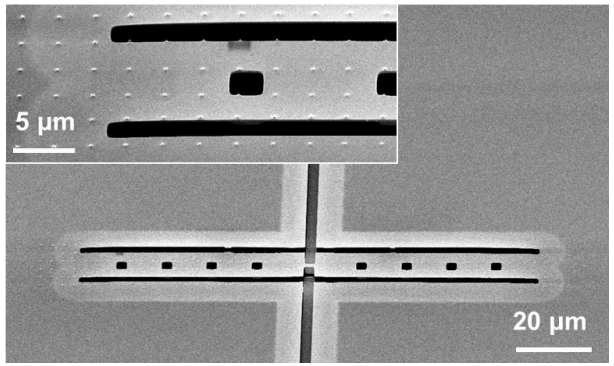
Ebeam/Photolithgoraphy

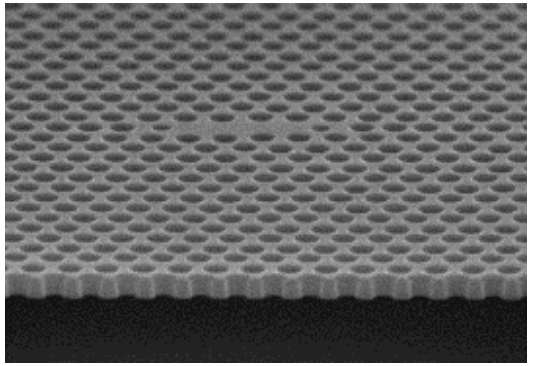
Thin-film deposition

Dry etching and developing





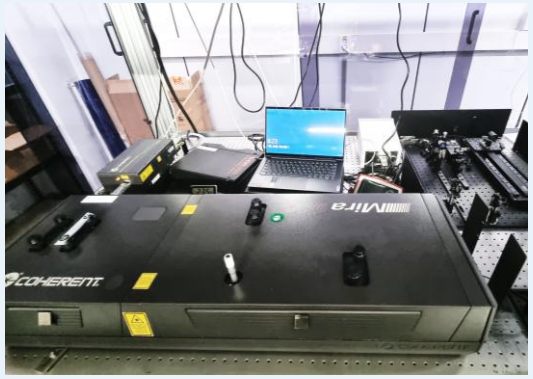




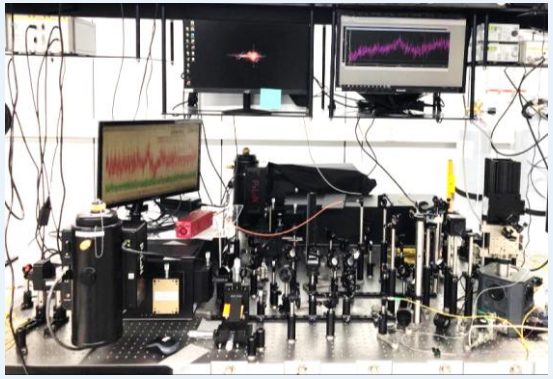
Organizations and Qualifications of the group

Facility in the Lab.

High-resolution/high sensitivity spectroscopy system for solid-state qubits



Picosecond pulse laser

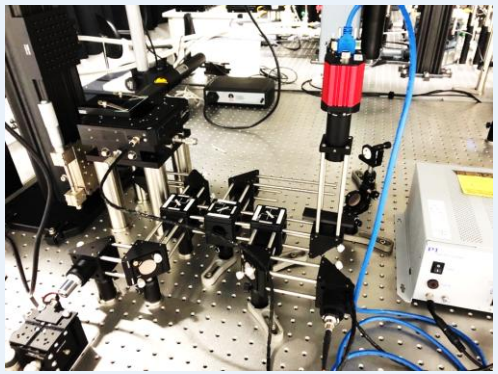

Spectroscopy system


Single-photon characterization

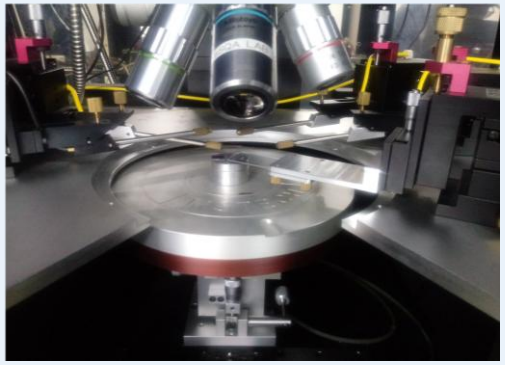
Low T experiment


Multi-functional cryostation
(4K, RF/DC/ gas injection/ fiber)

Spin characterization


ODMR system based on
home-built confocal microscope

Pattern transfer


Pattern transfer for hybrid
integration of nanodevices