Quantum Taiwan

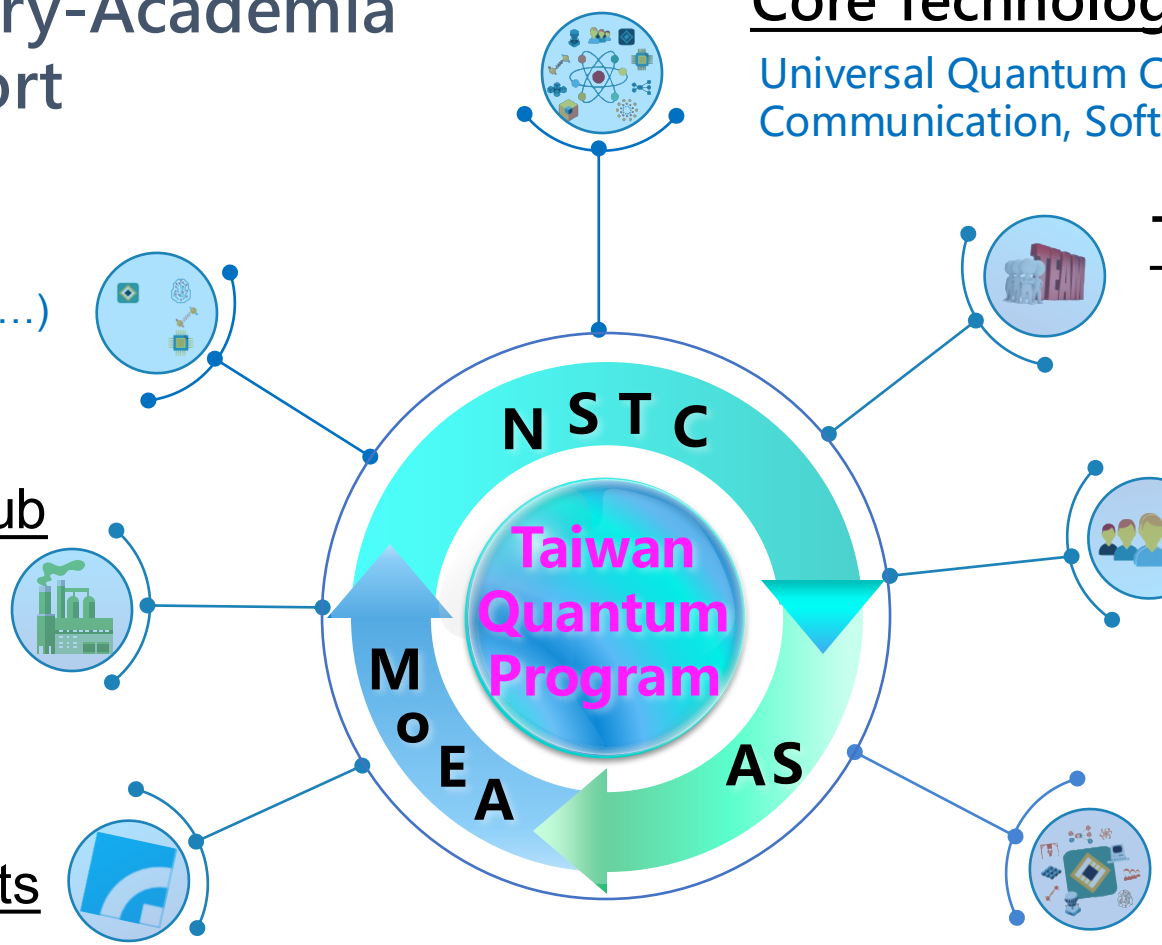
Taiwan Quantum Program
- Strategy and Plan -

Ming-Jye Wang

Chief Engineer
Taiwan Quantum Program Office

Framework of Taiwan Quantum Program

Government-Industry-Academia Joint Effort



Core Technology Development

Universal Quantum Computer, Quantum Communication, Software and Application

Talent Cultivation

High-level talent (master, PhD, and PostDoc) cultivation program

Public Outreach & Edu

Micro-courses, Social media programs, Competition events

Core Facility & Tech.

Supercon. QPU and QC,
Test platforms (QC and Q-Ph),
Advanced clean room facility

QC User platforms

QC user platforms (IBM/AWS…) for research and education

Industrial Collaboration Hub

Quantum Technology Forums

Key Components & Industry Engagements

Cryogenic control circuits and modules, bridging to industry

Ministry of Economic Affairs

ITRI Industrial Technology Research Institute

Phase I: 2022-2027
Budget: NT$ 8B (~US$ 260M)

Academia Sinica

Quantum Taiwan Program Office

Members

Convener
Shangjr (Felix) Gwo

Executive Officer
Wen-Hao Chang

Chief Engineer
Ming-Jye Wang

Project Managers
Ying-Jer Kao

Project Managers
San-Liang Lee

Project Managers
Shyh-Shyuan Sheu

Missions:

- **Integrating** efforts from government, academia, and industry
- **Coordinating** national quantum research teams
- **Strengthening** cross-project integrations
- **Engaging** international collaborations and strategic partnerships.

Selected Core Technologies in Phase I

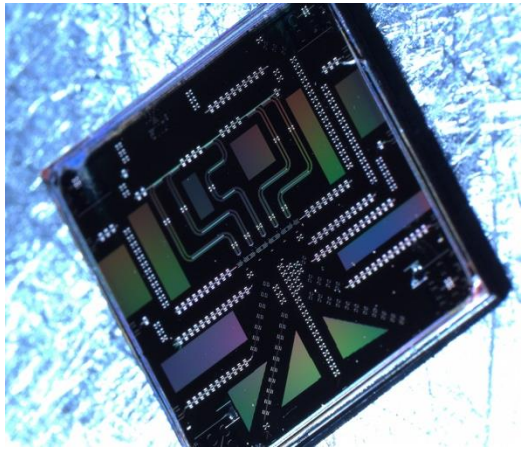
Highlights

Universal QC hardware

Superconductor Qubit/QPU and Parametric Amplifier

Transmon QPU (5Q)

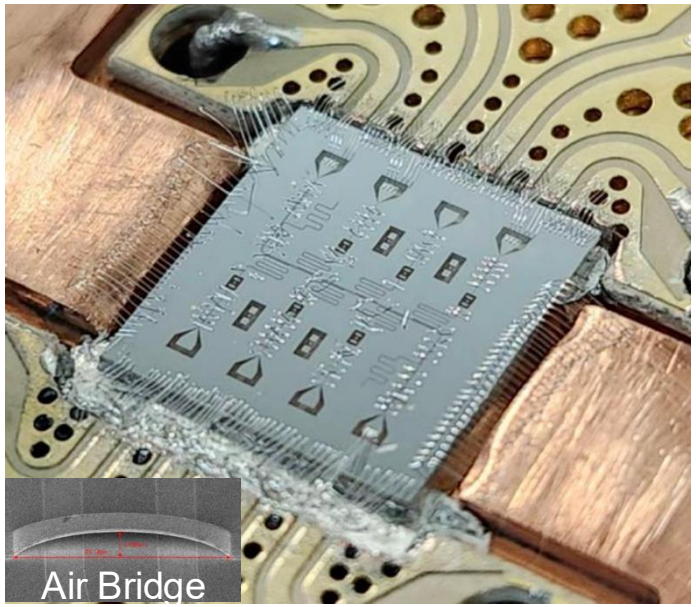
T1 >200 us



Chii-Dong Chen (Academia Sinica)

Fluxsonium Qubit (6Q)

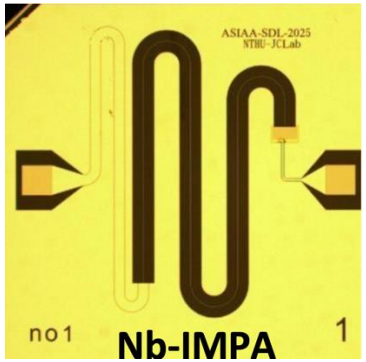
T1 ~ 1ms

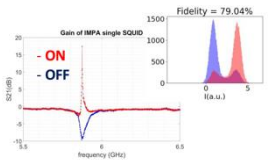


Yen-Hsiang Lin (NTHU)

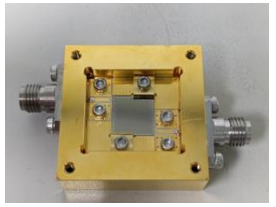
Parametric Amplifier

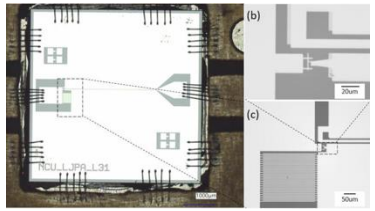
Nb-IMPA





NbTiN KITWPA Lumped JPA





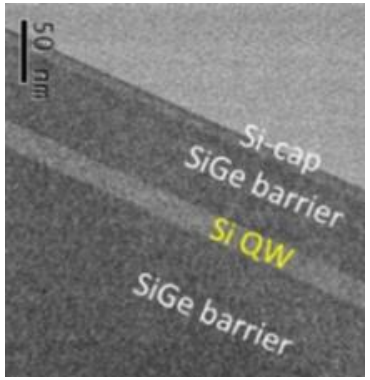
Jeng-Chung Chen (NTHU)

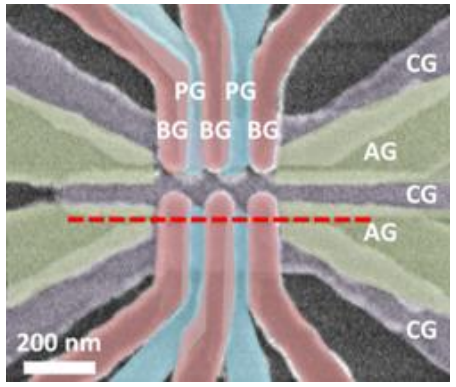
Highlights

Universal QC hardware

Semiconductor Qubits

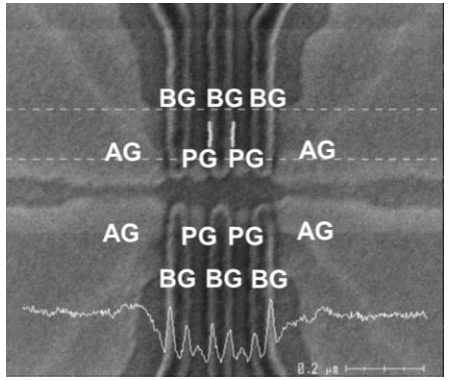
^{28}Si spin Qubit

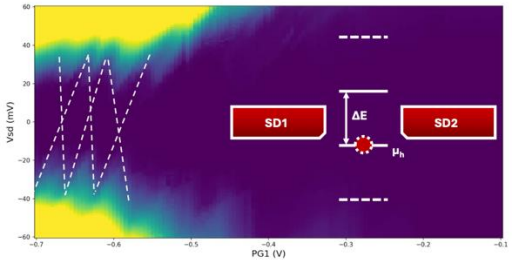




Chang-Hong Shen (TSRI)

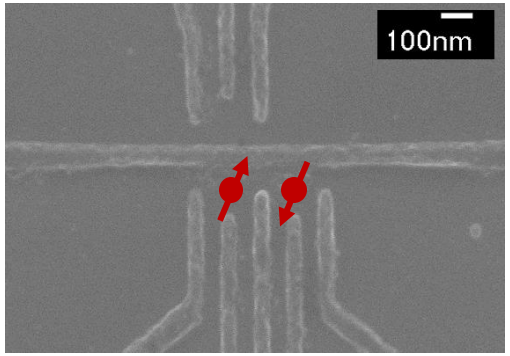
FinFET Qubits

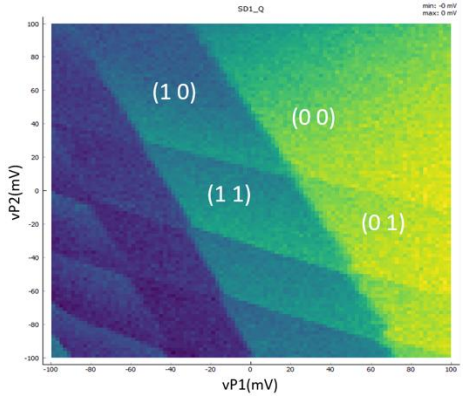




Shuo-Hung Hsu (NTHU)

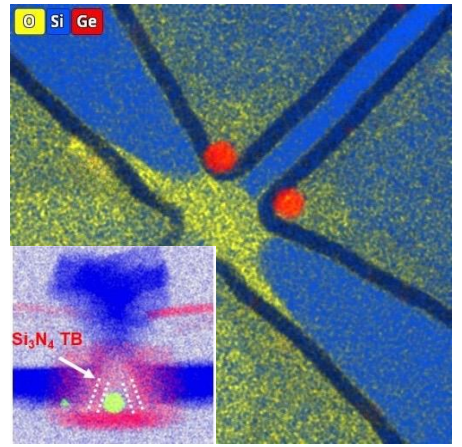
Ge/SiGe QD



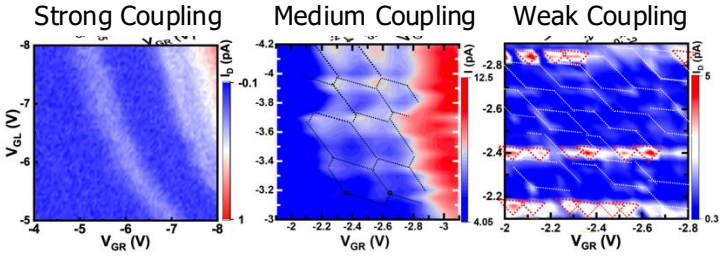


Tzu-Kan Hsiao (NTHU)

Charge Qubits (Ge QD)



SiNx as tunnel barrier



Pei-Wen Li (NYCU)

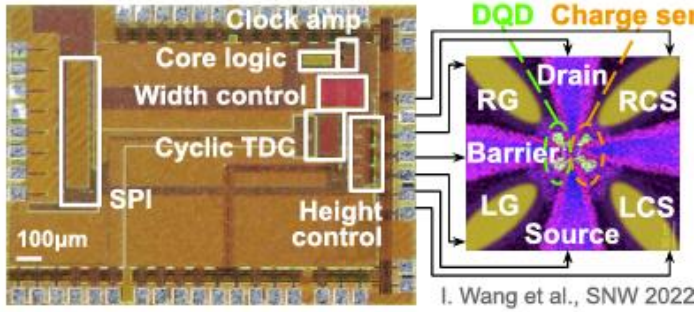
Highlights

Universal QC hardware

Cryo-CMOS control/readout modules for Semicond. Qubits

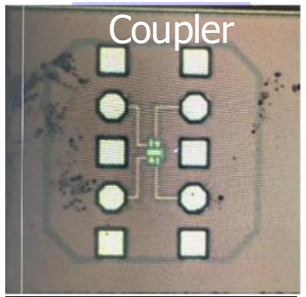
Pei-Wen Li (NYCU)

(>99.5% Fidelity Quantum state Control)

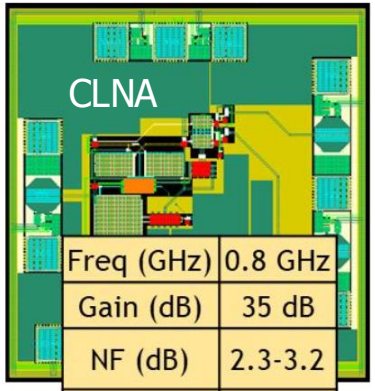


I. Wang et al., SNW 2022

Reflectometry readout



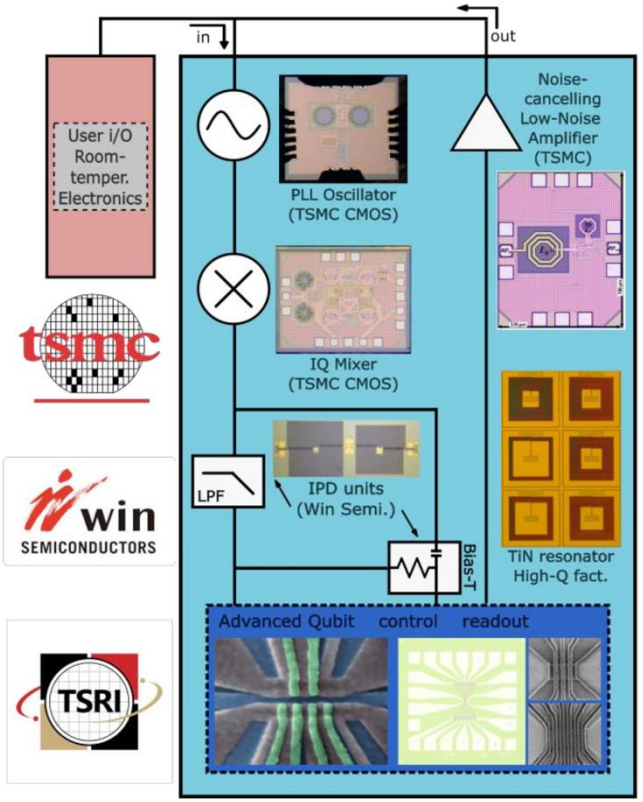
Freq (GHz)	0-3 GHz
Directivity (dB)	33.8 dB



Freq (GHz)	0.8 GHz
Gain (dB)	35 dB
NF (dB)	2.3-3.2
P_{DC} (mW)	24

Shuo-Hung Hsu (NTHU)

Control and readout scheme
and developed chips



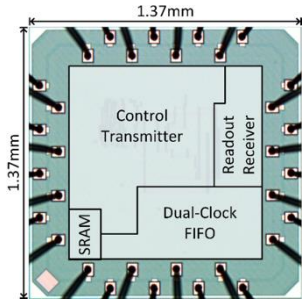
Highlights

Universal QC hardware

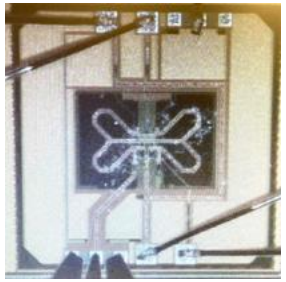
Cryo-CMOS control/readout modules for Supercond. Qubits

Jiun-Yun Li (NTU)

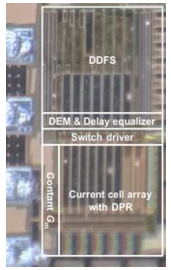
Qubit control



Digital control

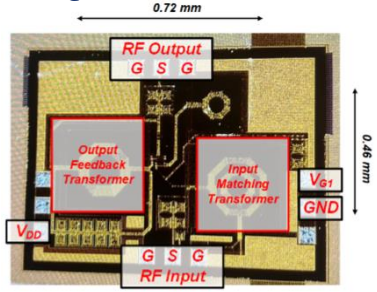


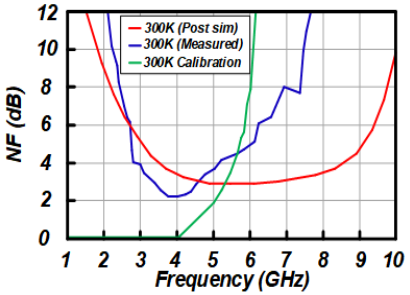
RF generator



DAC

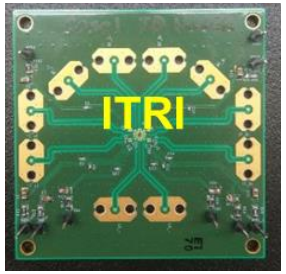
Qubit readout





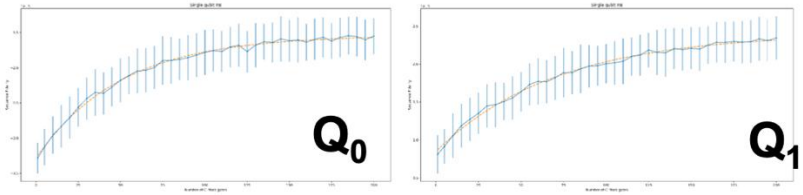
CMOS LNA Gain: 14 dB

Shyh-Shyuan Sheu (ITRI)

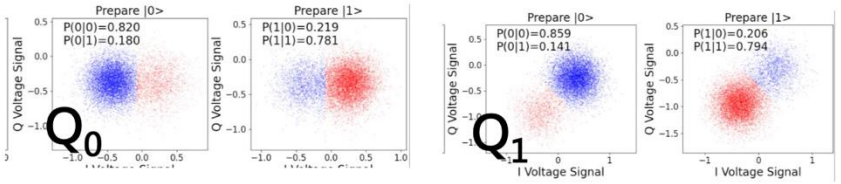


- 2-Q control module
- 2-Q readout module
- tested with Qubits

2-Q control fidelity, 99.47% (Q_0) and 99.62% (Q_1)



2-Q readout fidelity > 80%

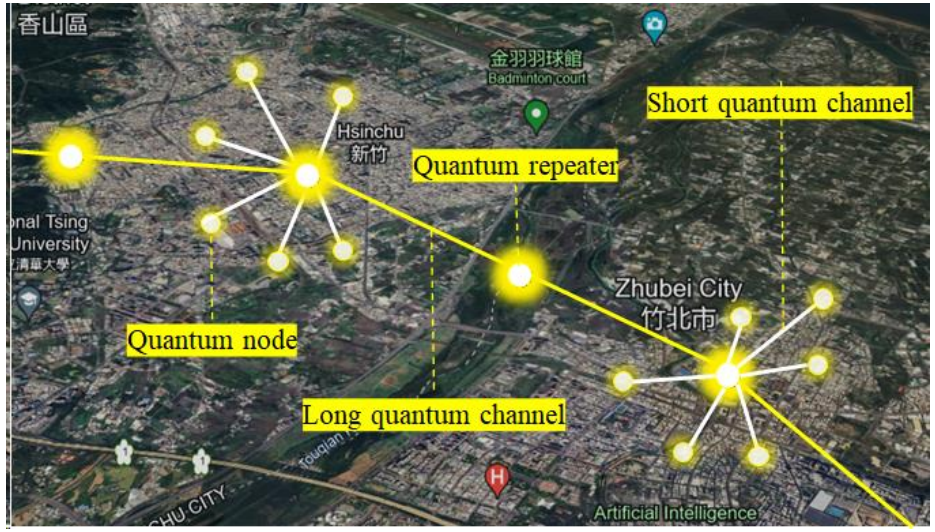


Highlights

Photonic Quantum Technology

Quantum Communication
Intercity Quantum Network

Intercity (~20 km) QKD link with commercial fibers
(70 km link with dark fibers)

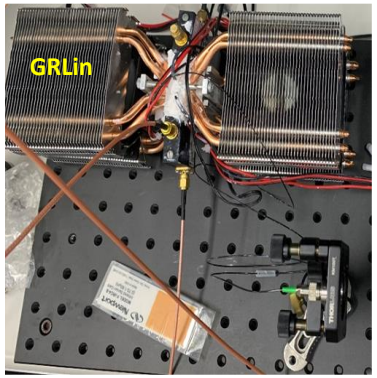


Chih-Sung Chuu (NTHU)

QKD Components and System
Devices/modules/hardware/software

- >1 Gbps QKD
- 1.3/1.55 μm CWDM/DWDM p-to-p network
- Over 25-100 km (fiber in lab) SMF link toward QBER<0.5%

-40 °C SPAD



2D-Decoy QKD Tx

QKD Tx/Rx module

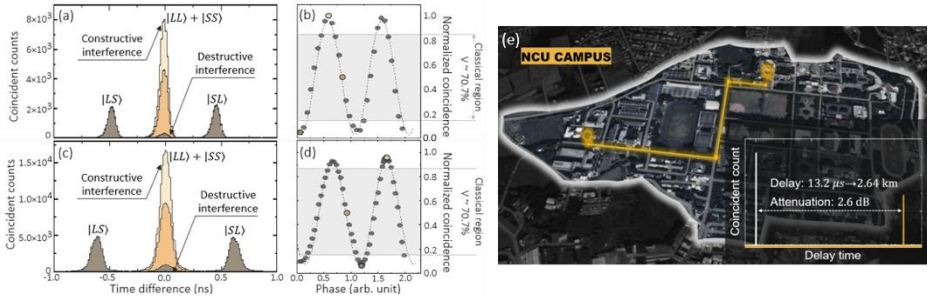
Gong-Ru Lin (NTU)

Quantum Taiwan

Highlights

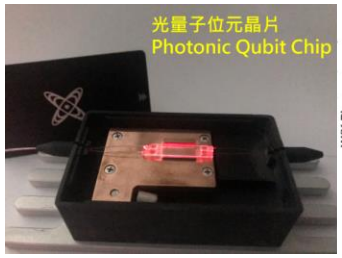
Photonic Quantum Technology

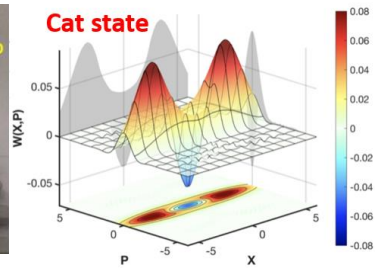
Fiber-network
quantum entanglement distribution



Long-distance quantum entanglement distribution through the NCU campus fiber network

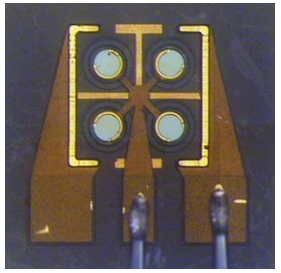
Quantum photonic
source chips

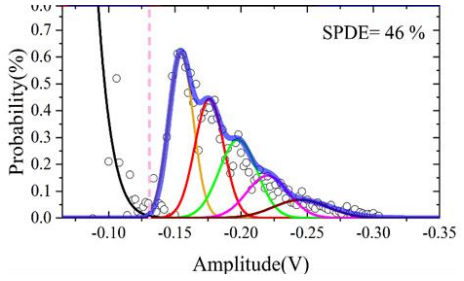




Integrated Heralded single photon, Entangled (Bell) state, Squeezed vacuum state, Cat state chip sources

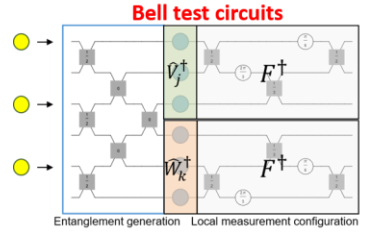
Single Photon detectors
photon number resolving





SAPD with photon number resolving detection efficiency at near room temperature

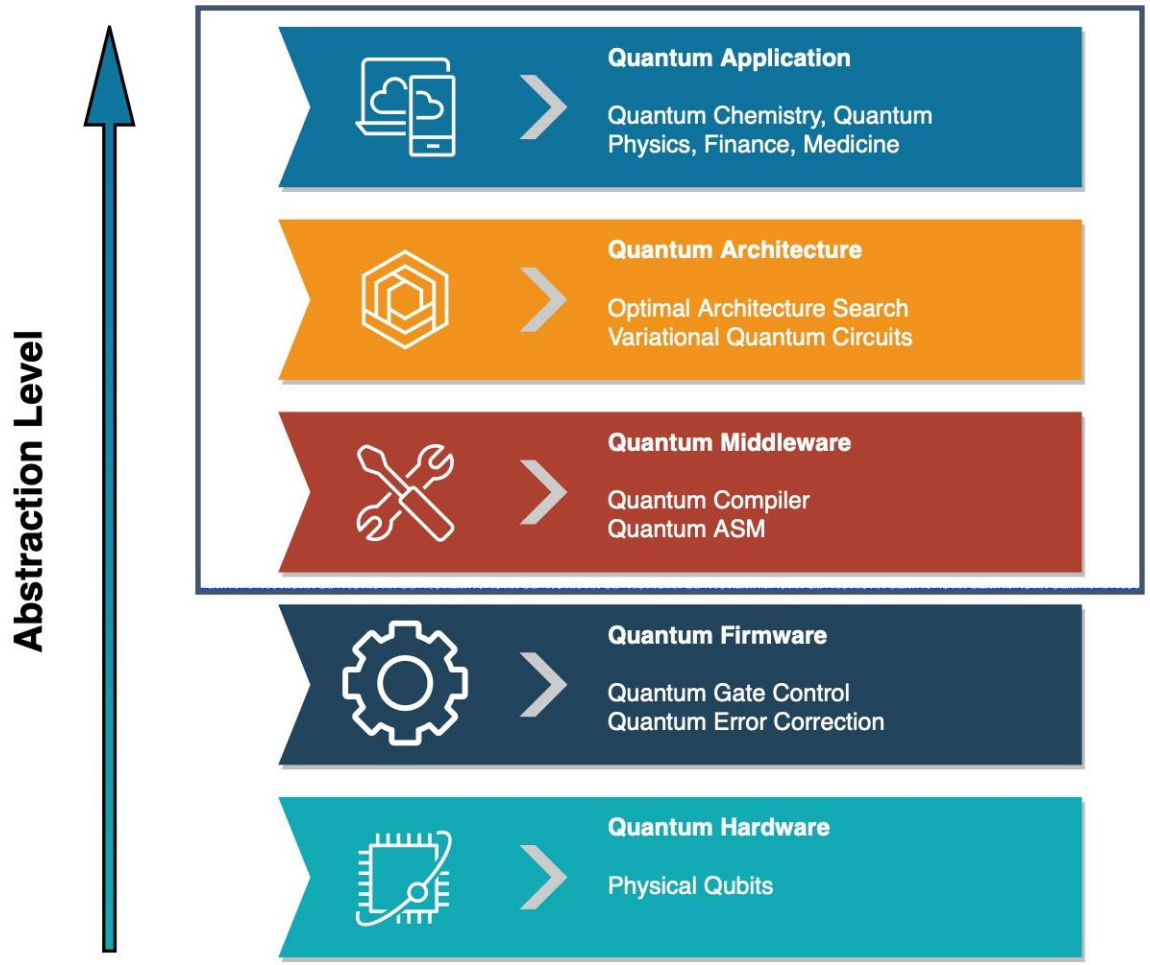
Si-photonics
reconfigurable photonic chips



Si-based reconfigurable quantum circuit chips for Shor's algorithm, Gaussian Boson sampling, and Bell test

Software Technology & Applications

- Theoretical development in quantum Computer Science
- Quantum virtual machine
- Quantum program verification and transformation
- Enabling efficient quantum simulation of chemical systems through characterization and utilization of device noises
- Quantum error correction for near-term quantum computing technologies
- Applications of quantum computing in optimization and finances

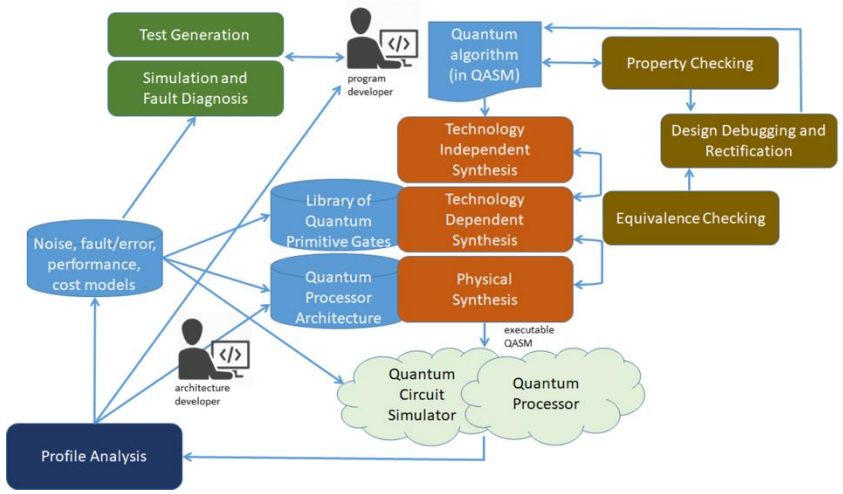


Highlights

Software Technology & Applications

Quantum Program

Compilation Systems



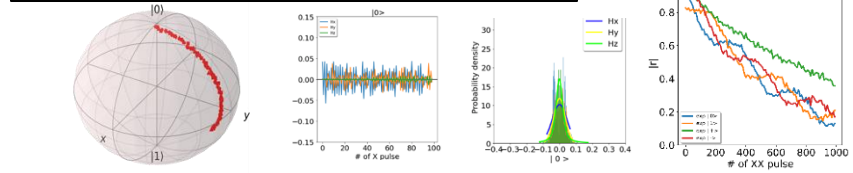
Jie-Hong Jiang (NTU)

- **Synthesis**
  - Qsyn: An open-source quantum ckt synthesis tool
- **Simulation**
  - SliQSim: First exact quantum ckt simulator using binary decision diagrams
  - Non-volatile memories (NVMe) + remote direct memory access (RDMA) based low-cost simulation
- **Verification**
  - SliQEC: A symbolic, exact quantum ckt checker for both full and partial equivalences
  - Runtime assertion methodology for reliability enhancement in quantum experiments
  - Quantum exponential speed-up in Boolean matching reversible logic circuits under negation equivalence
- **Testing**
  - Fault diagnosis methods
  - Error detection and mitigation methods

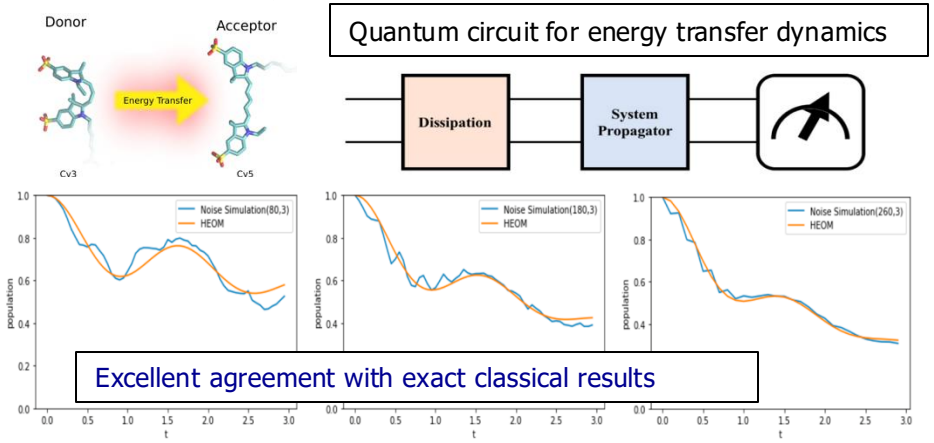
Highlights

Software Technology & Applications

Gate errors via stochastic Liouville equation



Quantum circuit for energy transfer dynamics



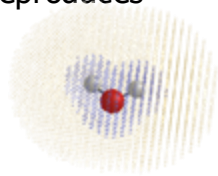
Excellent agreement with exact classical results

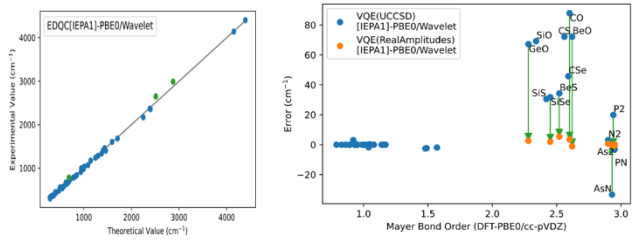
Characterization and utilization of IBM-Q device noises for open quantum system simulation

Efficient Quantum Simulation

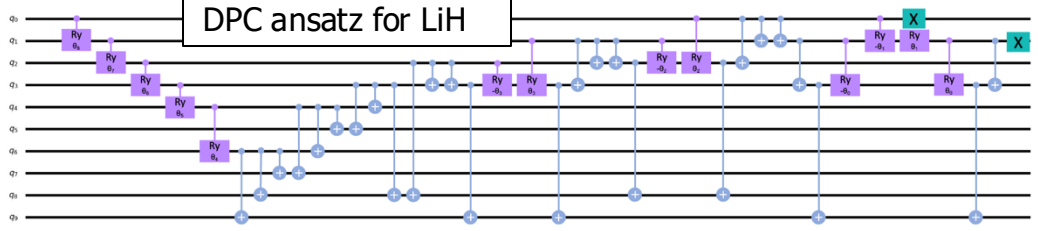
for Chemical Systems

Quantum simulation using wavelet basis reproduces experimental vibrational frequencies with minimal quantum resources.





DPC ansatz for LiH



LiH (10 qubits)	# of parameter	circuit depth	# of gates	# of iterations	Energy from VQE	Energy from exact diagonalization	Energy error
DPC ansatz	10	41	42	103	-7.882537778	-7.882537780	0.000000002
real amplitude ansatz (10 layers)	110	101	200	33989	-7.878519537	-7.882537780	0.004018242

Algorithms for NISQ era quantum simulation of chemistry

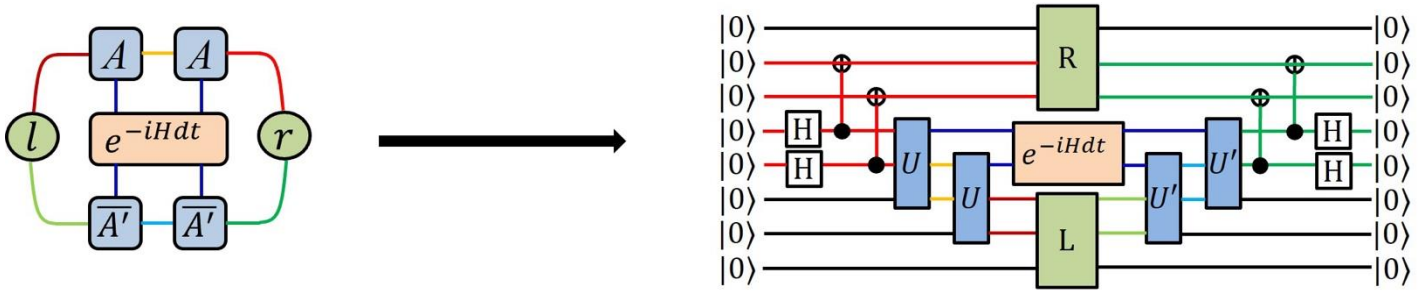
Yuan-Chung Cheng (NTU)

Highlights

Software Technology & Applications

High-Level Software Packages

- **Qurry** (https://github.com/harui2019/qurry)
  - Quantum experiment manager for Qiskit
  - Randomized Sampling toolkit for measurement of Renyi entropy, overlap, and more
  - Importance sampling algorithms to scale to large systems
- **Cytnx** (https://github.com/Cytnx-dev/Cytnx)
  - Tensor Network library for quantum manybody physics simulations



Pochung Chen (NTHU)

Talent Cultivation

Lecture Scholar
Associated to research team

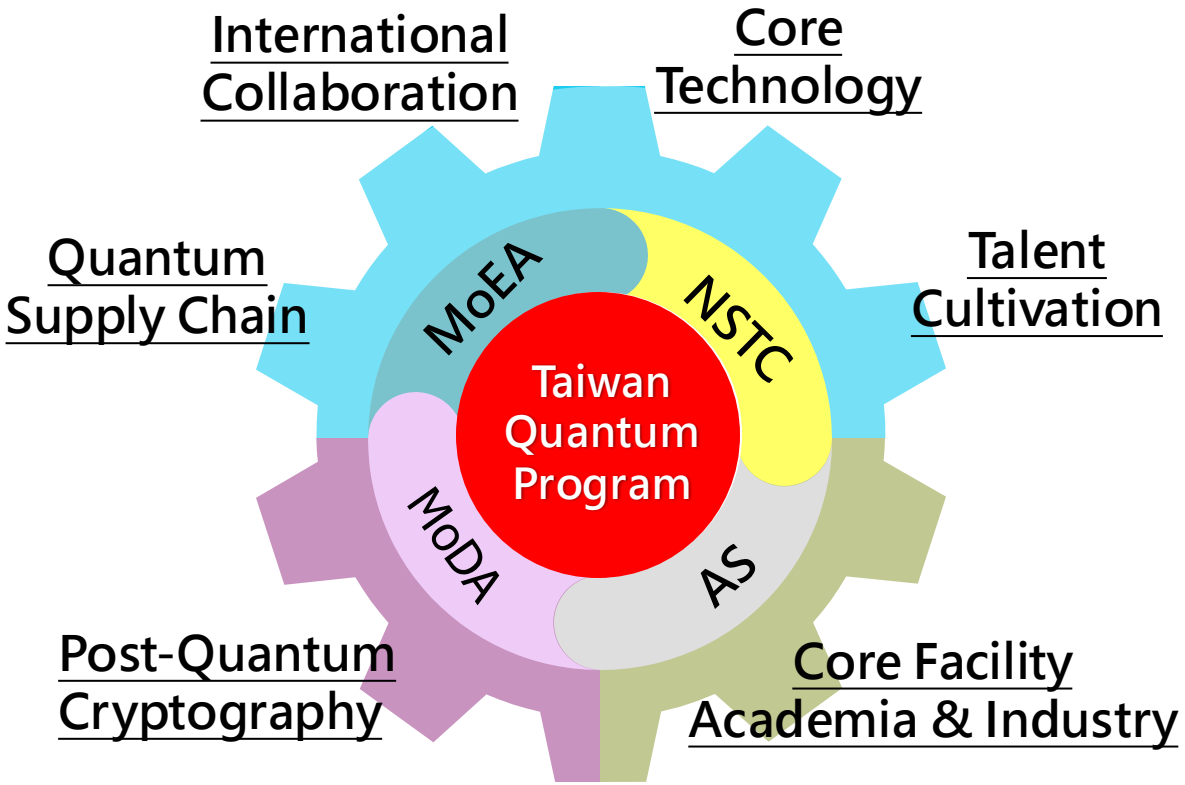
Postdoc
Research team

Taiwan Quantum Program

PhD student
Research team

Postdoc/PhD student
International collaboration

Strategic Priorities in the second Phase



Priorities of the next 5 years

- **Quantum chips**
  QPUs, Control/readout chips, Si-photonic chips
- **Quantum cybersecurity**
  Quantum network deployment, QKD chips, Post-Quantum Cryptography chip
- **Quantum computation**
  Quantum AI, Quantum simulator, QC-HPC hybrid computation

Missing Fragment – Quantum Sensing?

Quantum Taiwan

Thank you

謝謝

Taiwan

can be a key enabler
in the coming Quantum Era