Key Obstacles for Quantum Supremacy

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Research Interests

- Fundamental quantum physics
  - Quantum stochastic dynamics/tomography
  - Decoherence & quantum to classical transition
  - Noise spectroscopy & feedback control
- Quantum communication (with photons)
  - Random number generators
  - Single photon generation/quantum repeaters
  - Quantum Key Distribution
- Quantum algorithms/computing
  - Quantum random walks/ with IBM's QisKit
  - Application to finance

Collaboration and Support

NIMT
SCB
NECTEC a member of NSTDA
QuTE
DIGITAL VENTURES

Tasks/Questions

- Understand behaviors of quantum systems under noise.
- How to detect/suppress/control decoherence?
- Understand coherence effects on quantum algorithms/communication channel.
- How to construct quantum network?

H-BAR: QUANTUM TECHNOLOGY CONSULTANTS
H-BAR ABOUT RESOURCES BLOG NEWS

- qubit scalability
- decoherence
- qubit control

commentary

22,458 views | Sep 4, 2019, 09:00am

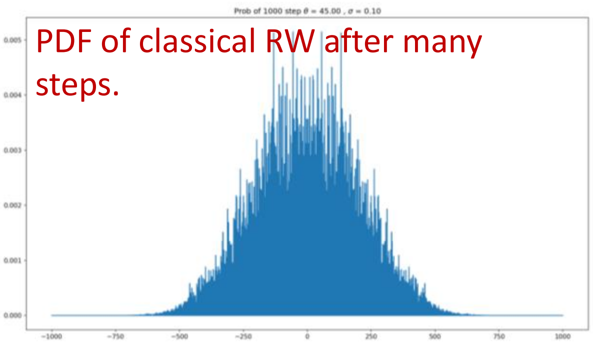
Why Quantum Computers Won't Replace Classical Computers Anytime Soon

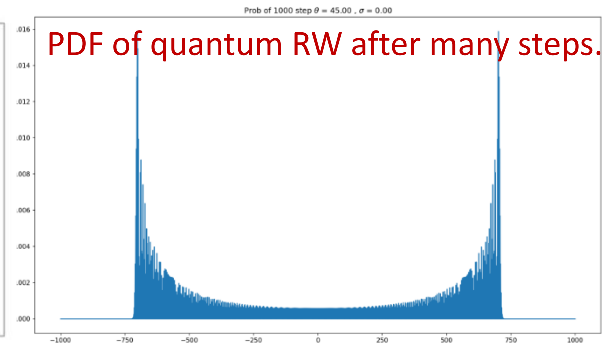
Susan Galer Brand Contributor
SAP BRANDVOICE | Paid Program
Innovation

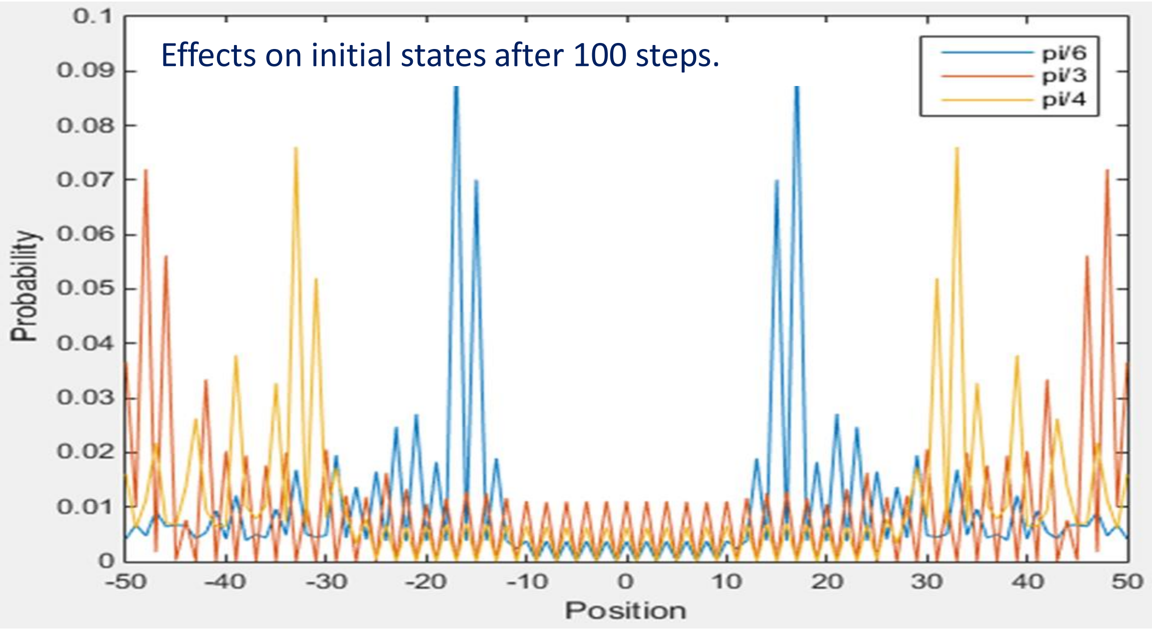
Forbes, Sept. 4, 2019

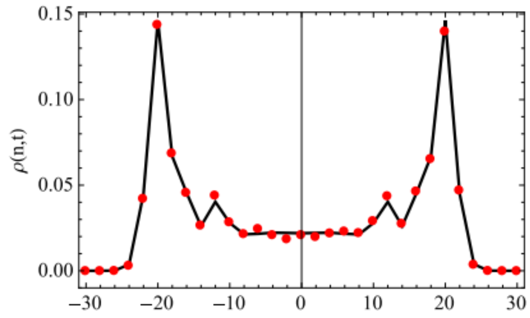
Example: Quantum Random Walks

PROBABILITY DISTRIBUTION WITHOUT FLUCTUATION IN COIN OPERATOR



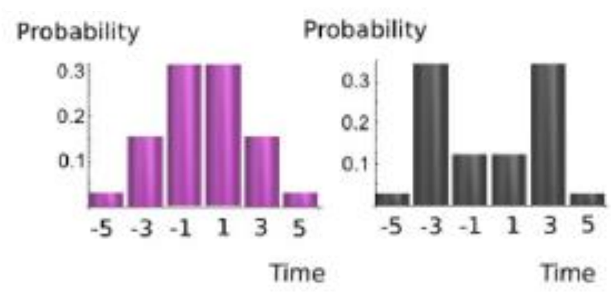






[M. Montero (2017), Phy. Rev. A **95** , 062326]

classical quantum

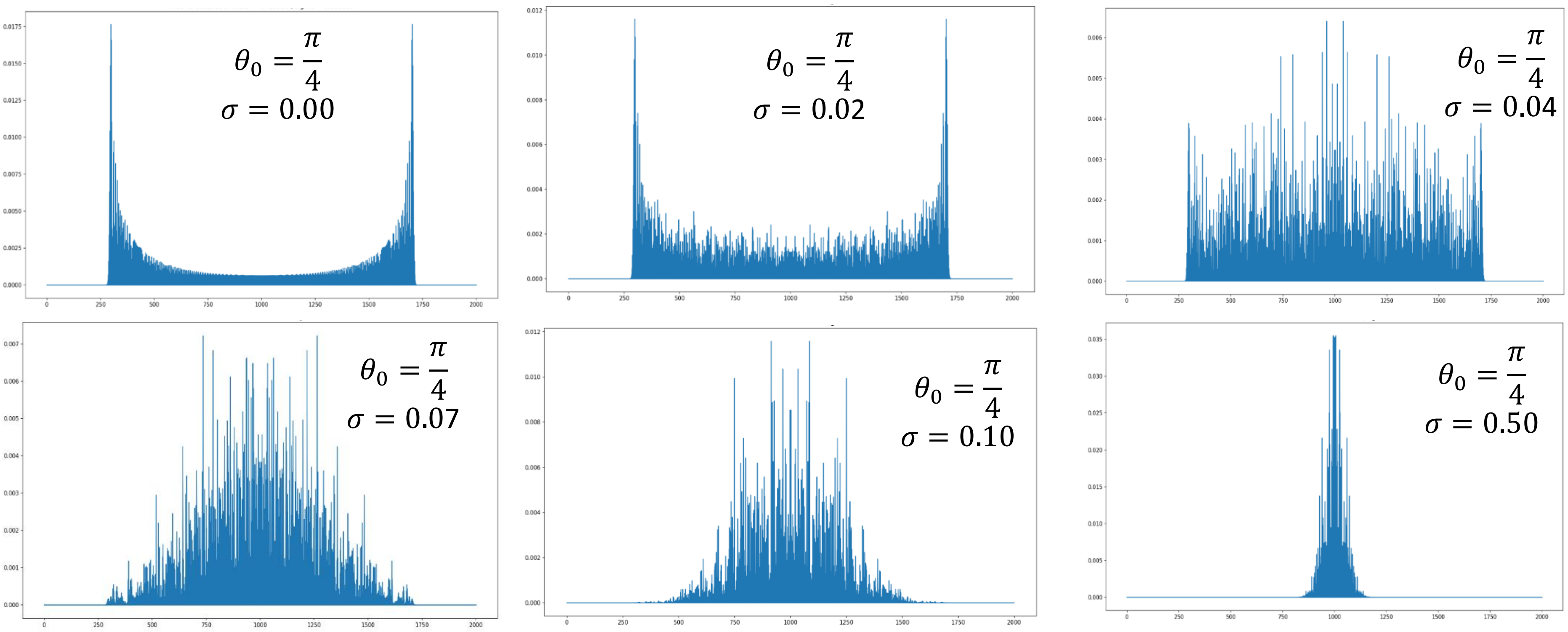


[A. Schreiber et al (2010). Phy. Rev. Lett. **104**]

Example: Quantum Random Walks

QUANTUM RANDOM WALKS WITH FLUCTUATING COIN OPERATORS

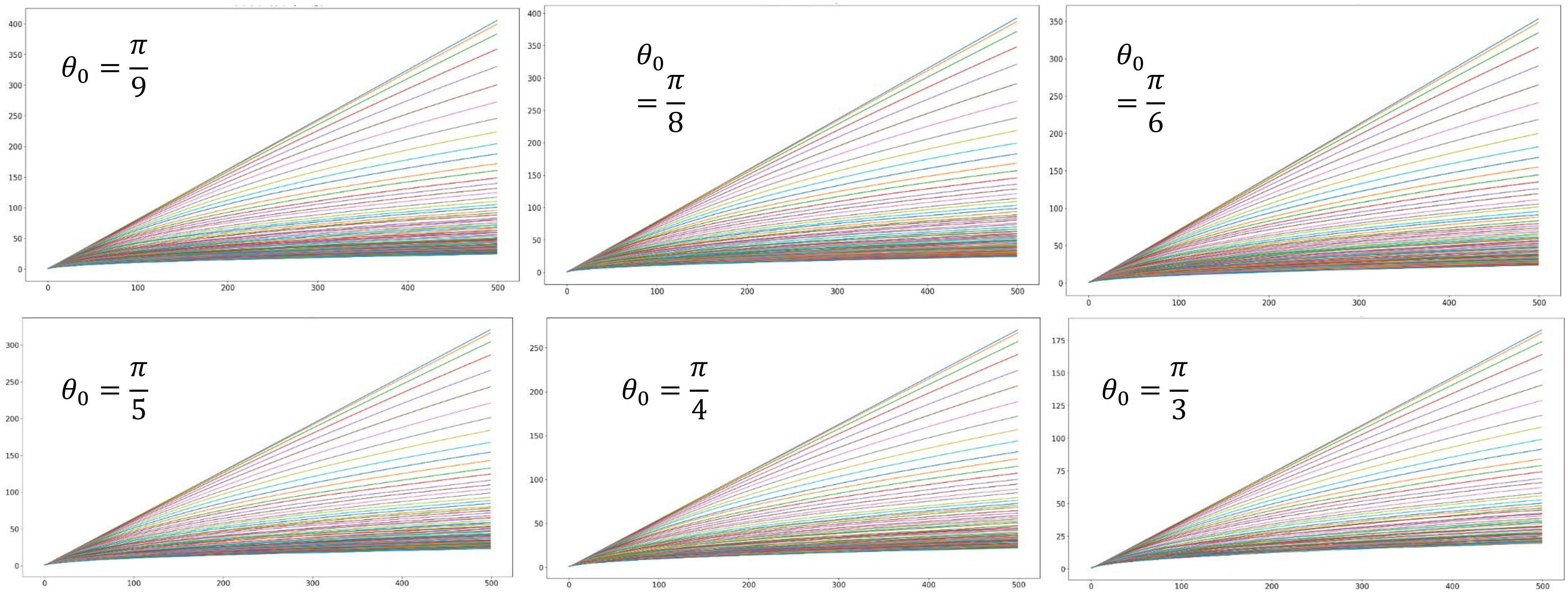
QRW Characteristics



- X axis: position after 1000 steps. Y axis: probability of occupying X after 1000 steps.
  - Common occurrence for all angle θ_0, but transition point σ_c depends on θ_0

Example: Quantum Random Walks

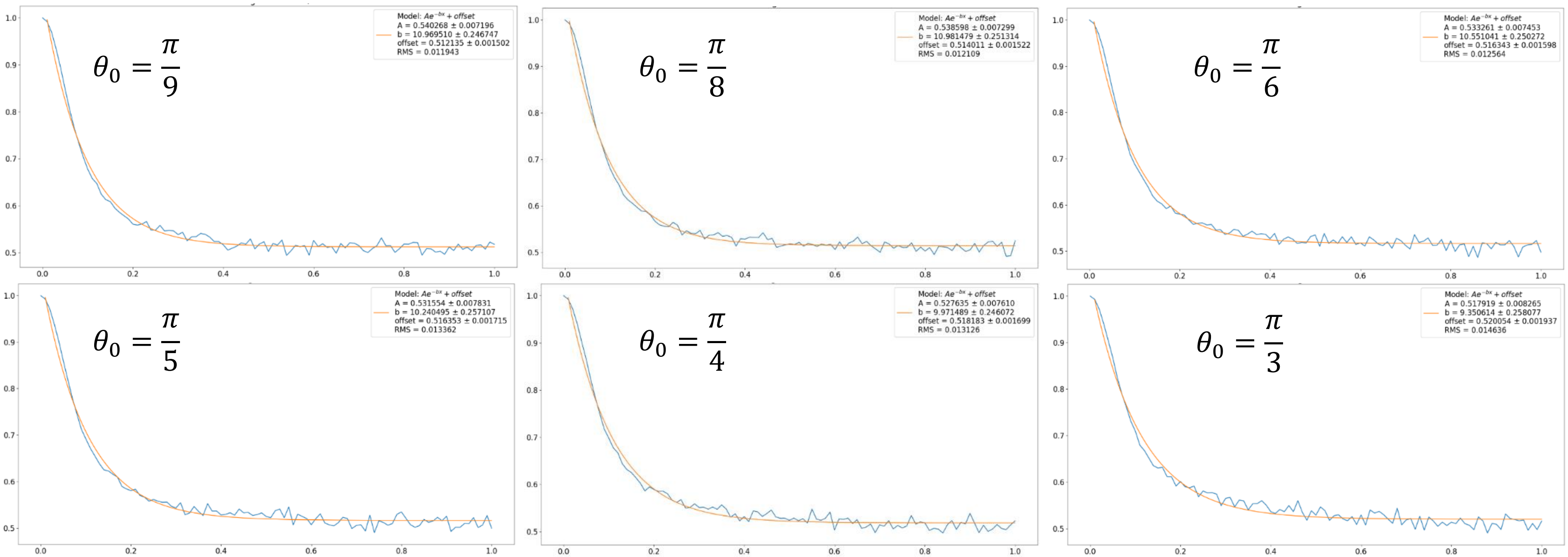
ROOT MEAN SQUARE DISTANCE AFTER 1000 STEPS



- X axis: time (1000 steps). Y axis: root mean square distance $r(t) \coloneqq \sqrt{\langle x^2 \rangle}$.
  - $\sigma = 0.00, 0.01, 0.02, \ldots, 0.99, 1.00$
  - $r(t) = At^{\beta}$ with $\frac{1}{2} \leq \beta \leq 1$, coefficients depending on θ_0 and σ

Example: Quantum Random Walks

ROOT MEAN SQUARE CRITICAL EXPONENT AFTER 1000 STEPS



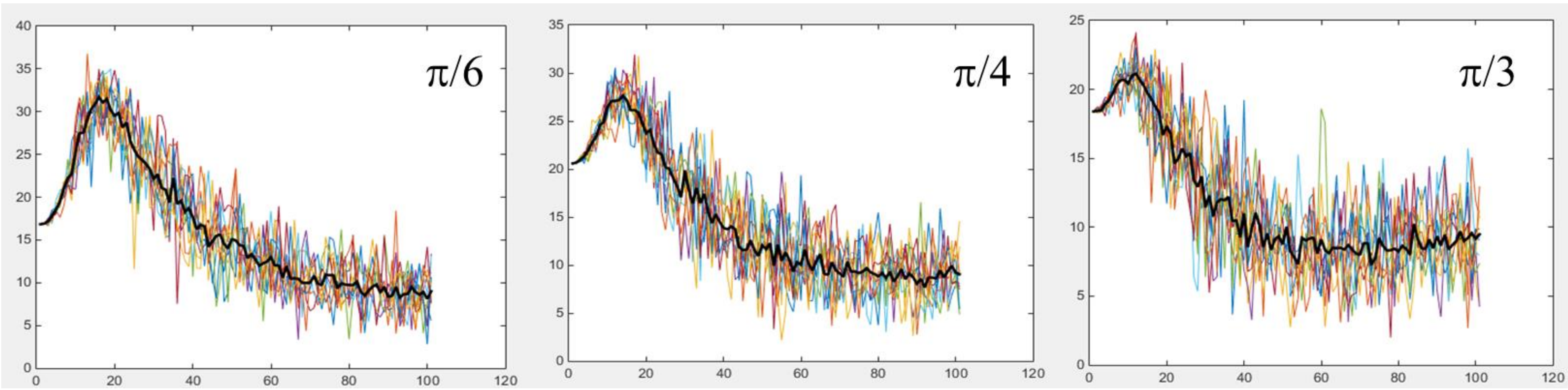
- X axis: fluctuation strength σ (%) . Y axis: β

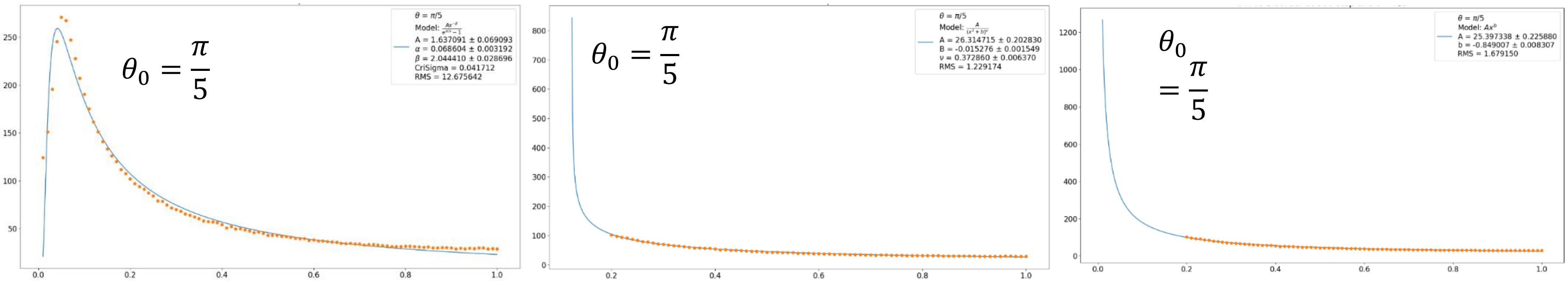
- β exponentially decays as σ increases, with asymptotic at $\beta = 0.5$
- Quantum to classical transition is continuous!

Example: Quantum Random Walks

QUANTUM RANDOM WALKS WITH FLUCTUATING COIN OPERATORS

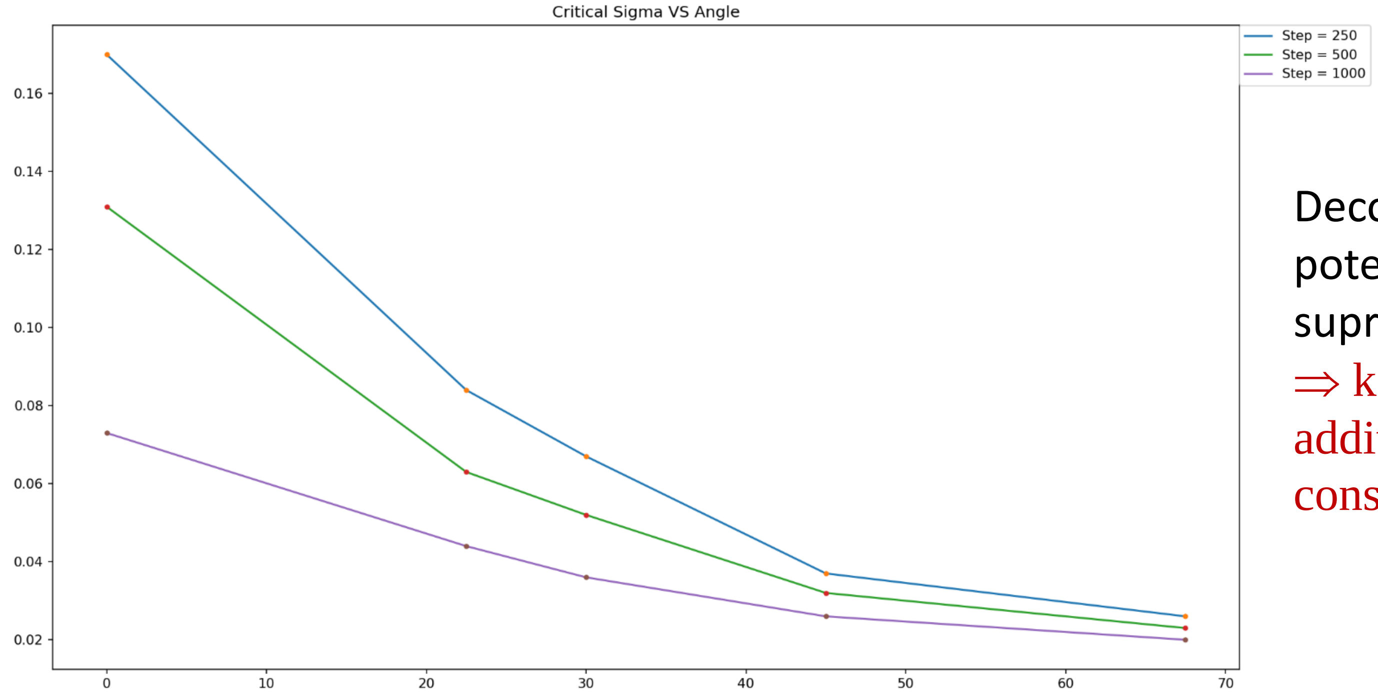
Localization of PDF profiles as seen from inverse participation ratio (IPR).





- IPR shows localization as σ increases, but weaker than Anderson localization.

Example: Quantum Random Walks



Decoherence destroys potential quantum supremacy.
⇒ key obstacles, in addition to hardware construction

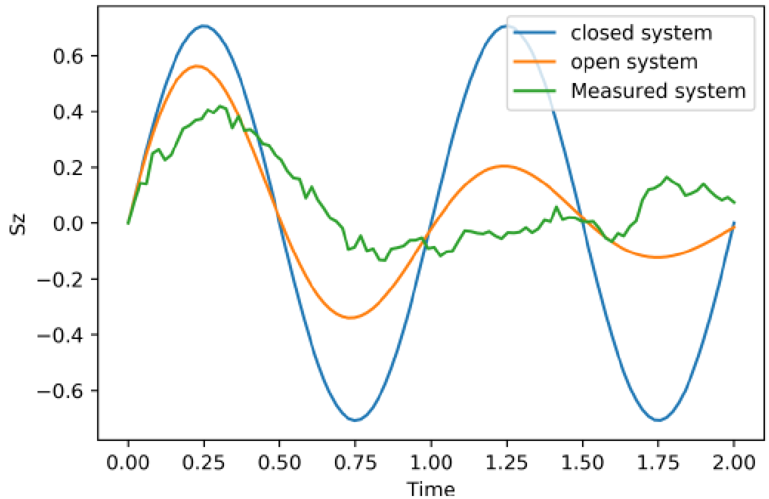
Interpretation of results

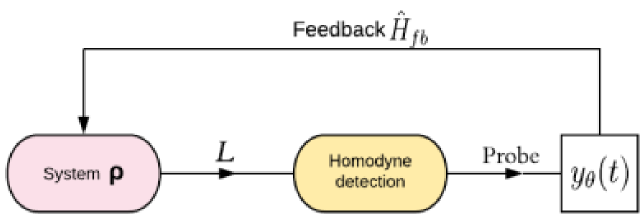
- Tails fit well with power law $A\sigma^{-\nu}$ or polynomial decay $\frac{A}{(a\sigma+b)^{\xi}}$ ⇒ fluctuation around 10% yields quantum to classical transition.
- Number of operations exponentially decrease with high disorder
- Quantum state loose its quantumness exponentially quick with high disorder and number of operations (walks).

Example: Quantum Feedback Control

$$d\rho_f(t) = dt(-i[\hat{H}, \rho(t)] + dt\mathcal{D}[\hat{L}]\rho(t)) + dW(t)\mathcal{H}[\hat{L}]\rho(t)$$

$$\mathbb{E}[\dot{\rho}_f] = \dot{\rho} = -i[\hat{H}, \rho] + \mathcal{D}[\hat{L}]\rho.$$





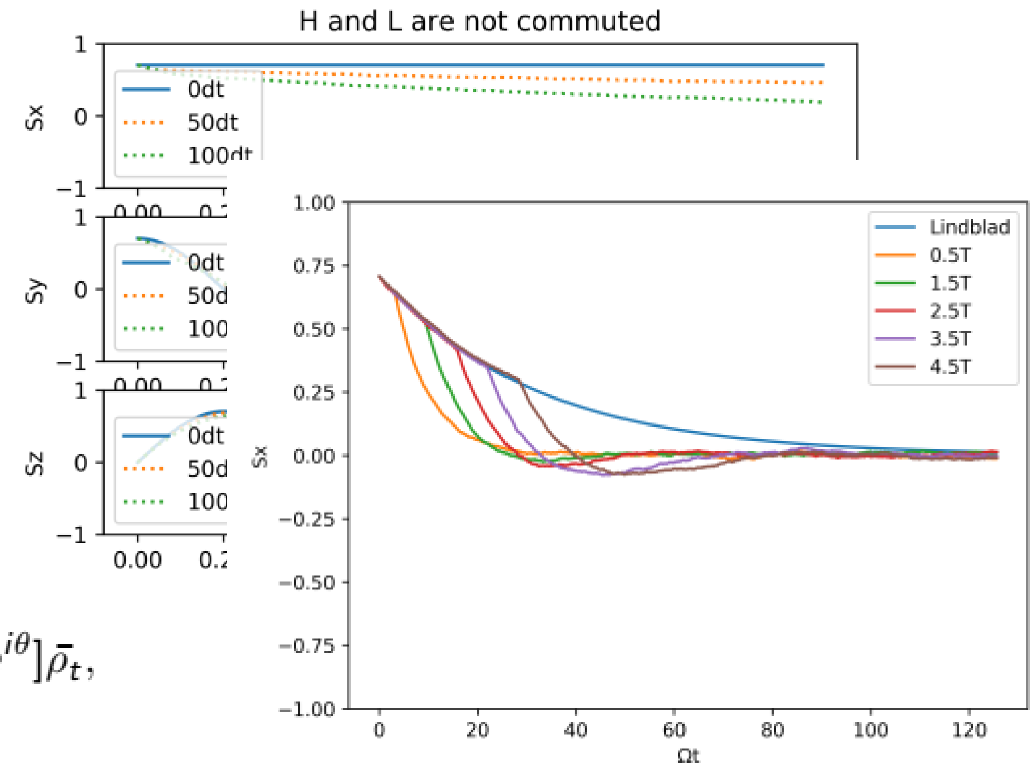
$$\partial_t \bar{\rho}_t = \mathcal{L}\bar{\rho}_t + \sqrt{\eta}\mathcal{A}[\hat{L}e^{i\theta}]\bar{\rho}_t y_\theta(t) - \frac{\eta}{2}\mathcal{A}^2[\hat{L}e^{i\theta}]\bar{\rho}_t,$$

$$y_\theta(t) = \sqrt{\eta}\langle \hat{L}e^{i\theta} + \hat{L}^\dagger e^{-i\theta}\rangle + \xi(t).$$

S. Szigeti, A. Carvalho, J. Morley, and M. Hush *PRL.* **113** (2014):020407

No-Knowledge Measurement with Hermitian Operator

$$\Rightarrow \quad \partial_t \bar{\rho}_t = -i[\hat{H} - \hat{L}y_{\pi/2}(t), \bar{\rho}_t].$$



J. Saiphet, B.Sc.Thesis, Dep. Physics. Mahidol University (2019)

Key Obstacles for Quantum Supremacy

Quantum Science and Technology

Technology that exploits "quantum properties" or "quantum states" of light and matter to perform calculation, evaluation, communication, restoration or presentation of data with the goals to understand, control, process and manipulate quantum systems to yield ability beyond the limit of classical world.

- **Key properties** such as superposition, entanglement, teleportation, no cloning
- Many platforms using light, spins, paths, fundamental particles

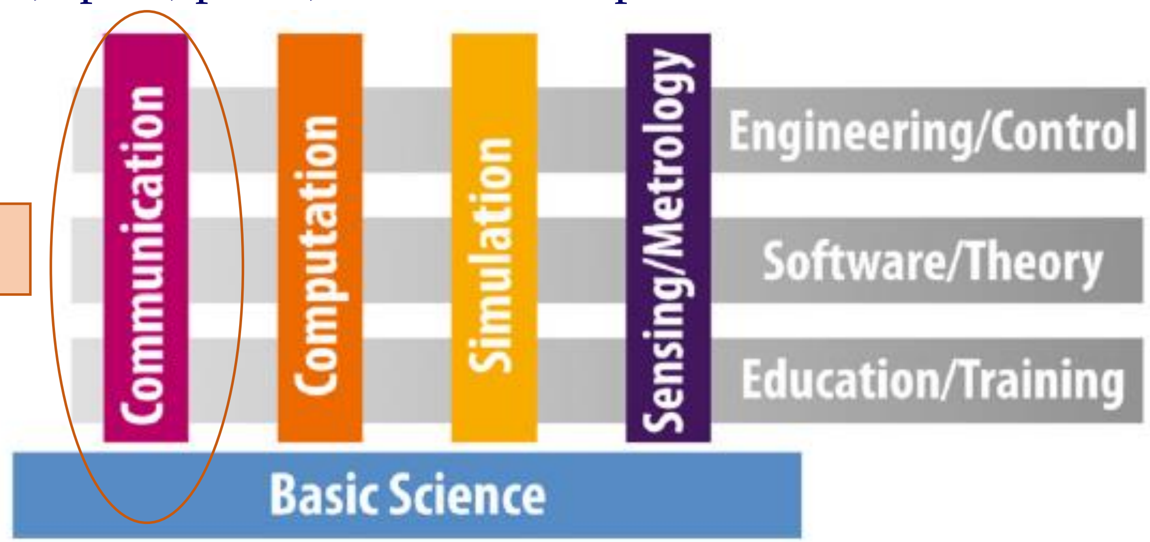
quantum communication

QRNG

quantum teleportation

quantum cryptography

quantum error correction

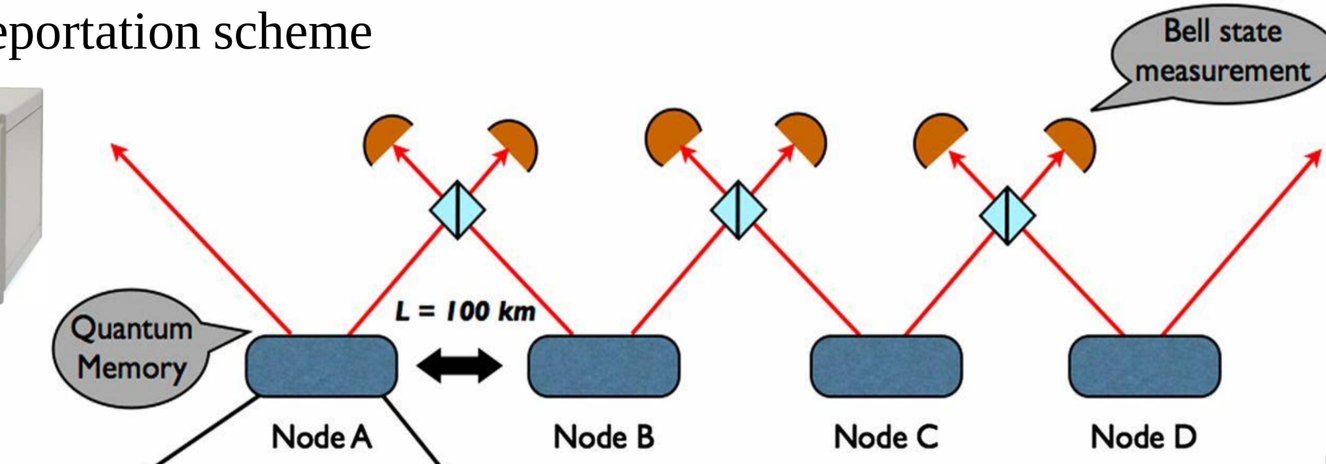


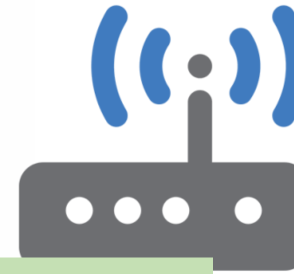
[A. Acin et al 2018 *New J. Phys.* **20** 080201]

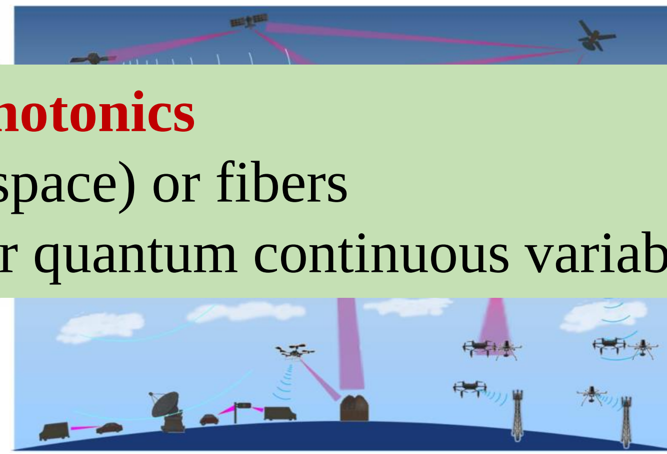
Quantum Communication “Scheme”

quantum teleportation scheme

QRNG







Physical platforms: **photonics**

- Media: air (free space) or fibers
- Single photons or quantum continuous variables (QCV)

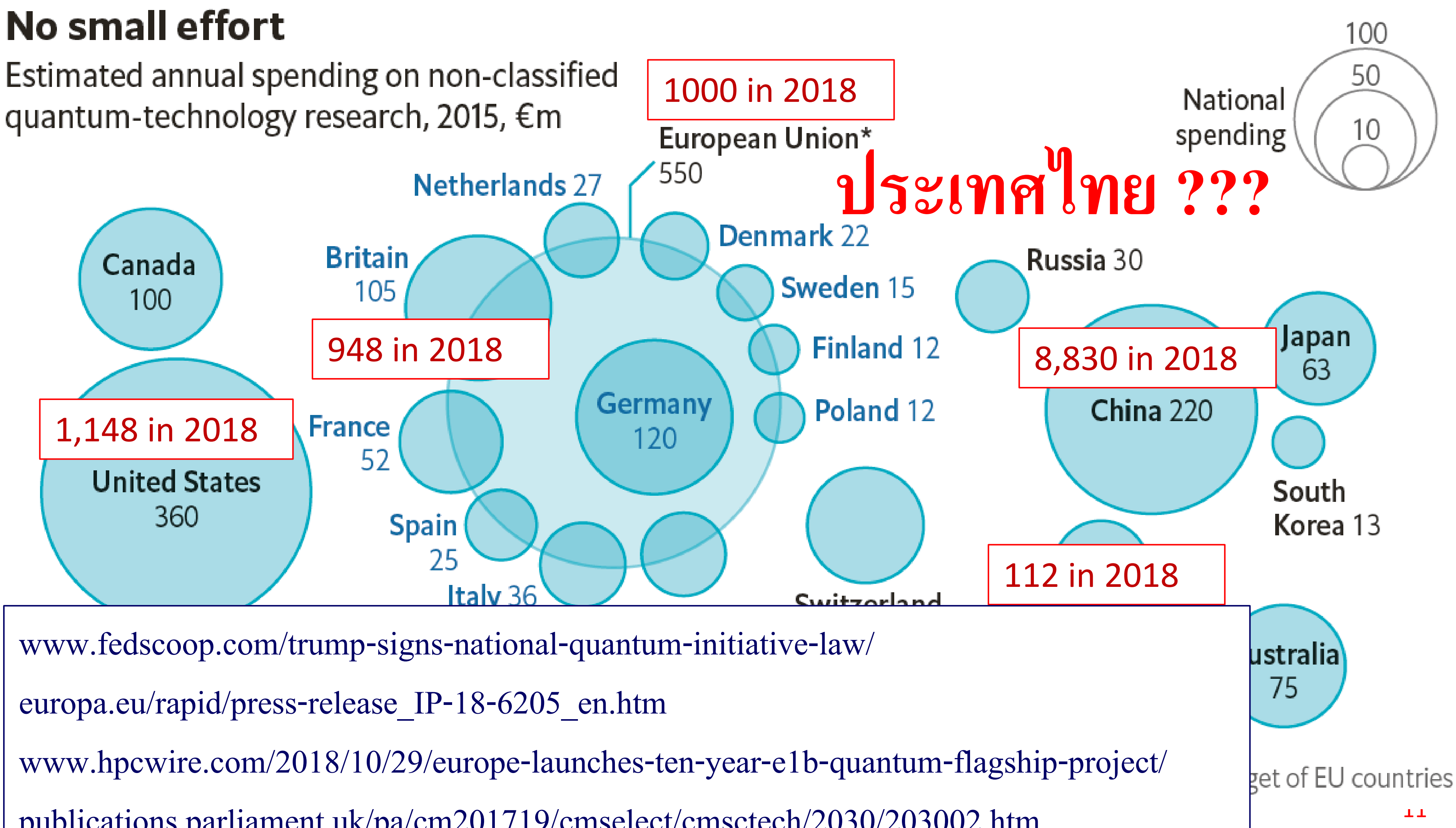
No-clone Theorem
quantum repeaters
quantum memories
trusted nodes
photon-matter interface

HAPS
satellite
drone-like

detectors
QEC
photon-matter interface
storage

[M. Sasaki Quantum Sci. Technol. (2017) **2,** 020501]

Key Obstacles for Quantum Supremacy



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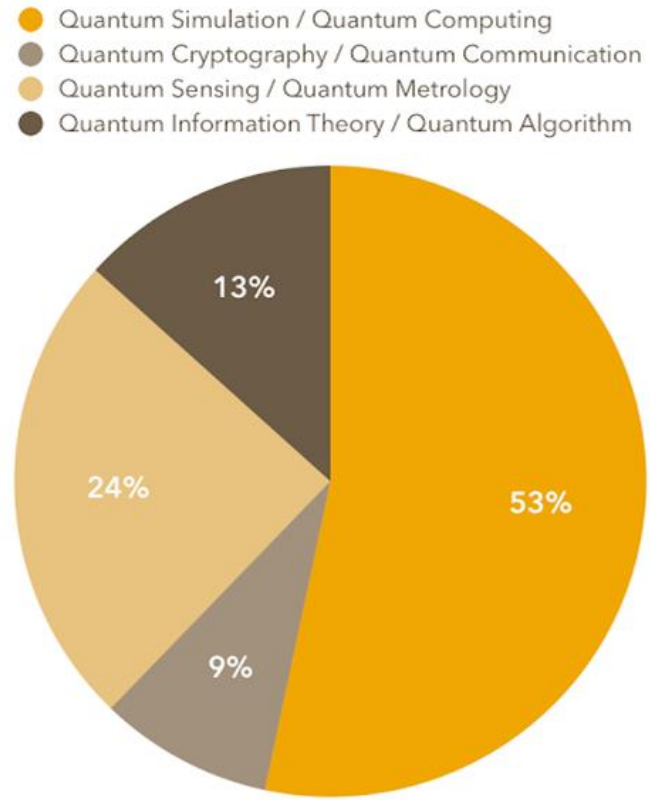
Is Thailand Ready?

Quantum Computing
(Experiment)

Quantum Sensing

Quantum Metrology/Sensing
Quantum Communication
Quantum Computing (Software and Algorithms)

Quantum Communication



Researchers ~ 40
Ph.D. students/postdoc ~ 30