

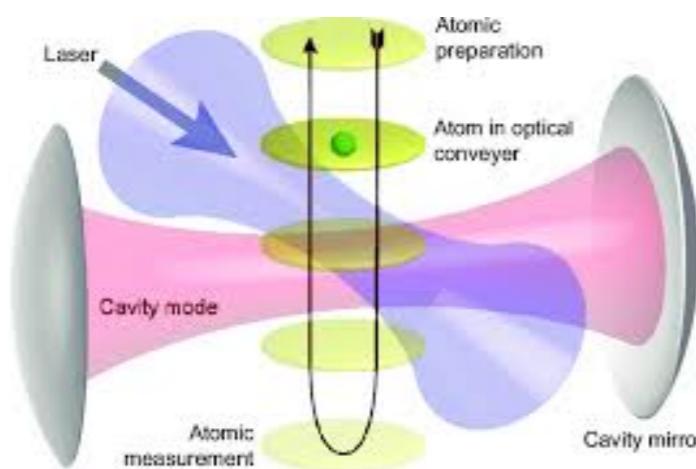
노창석 (123호)

양자 광학/정보 (quantum optics/information)

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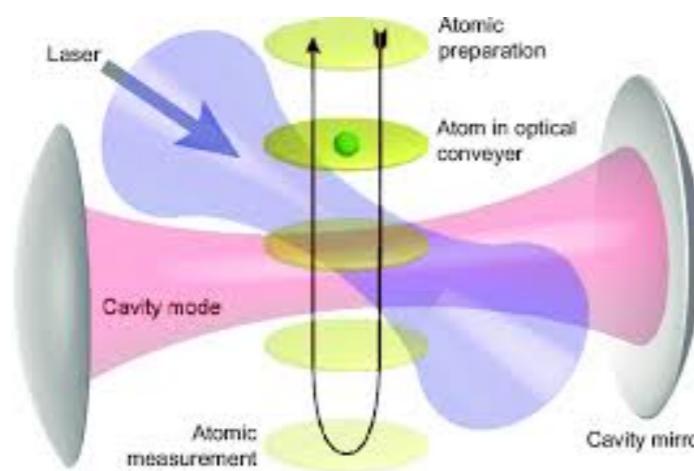
Atom-light interaction
(원자-빛 상호작용)



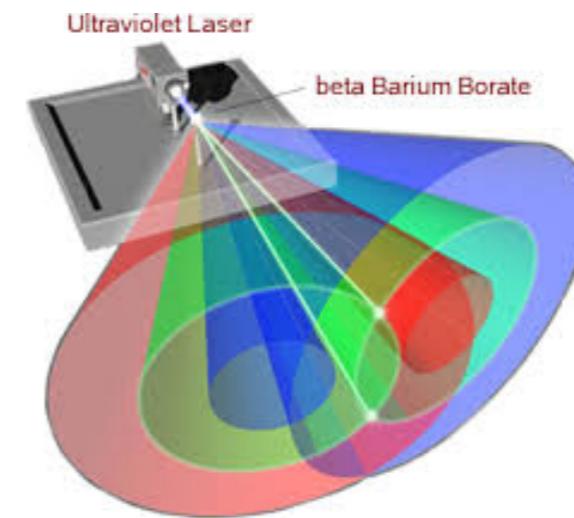
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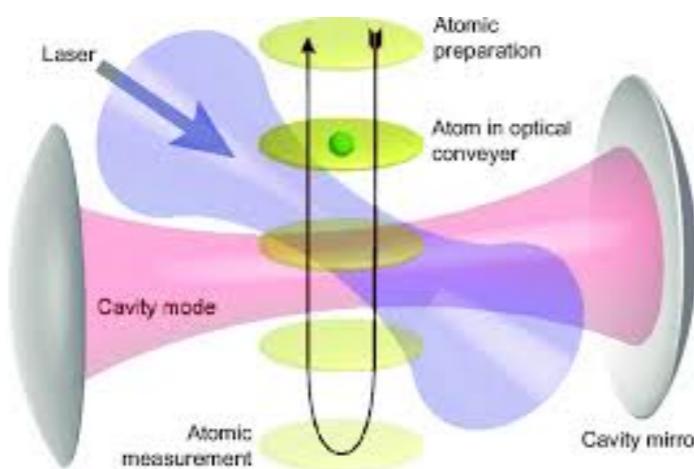
Entangled states of light
(빛의 양자얽힘 상태)



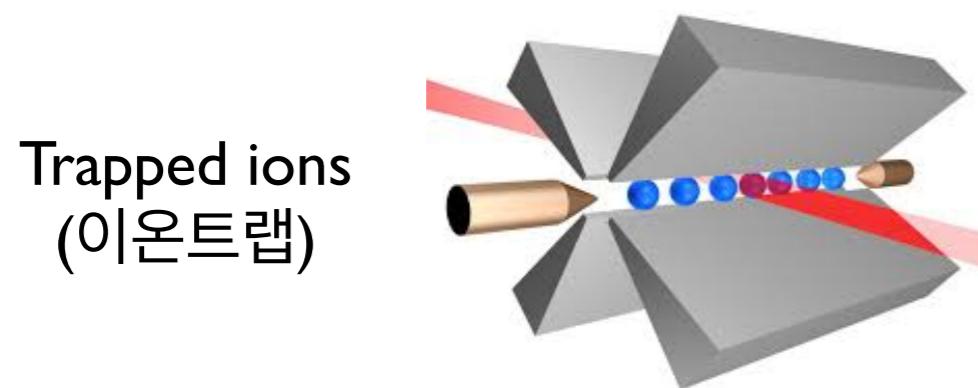
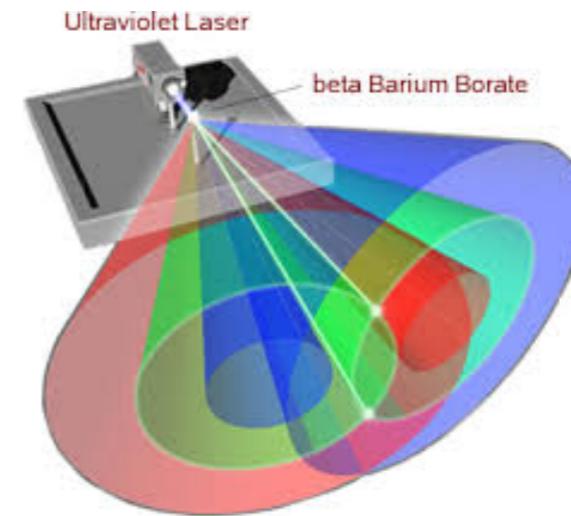
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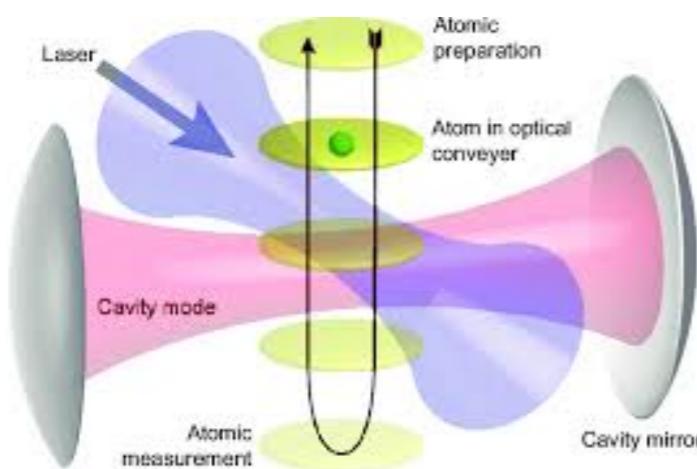
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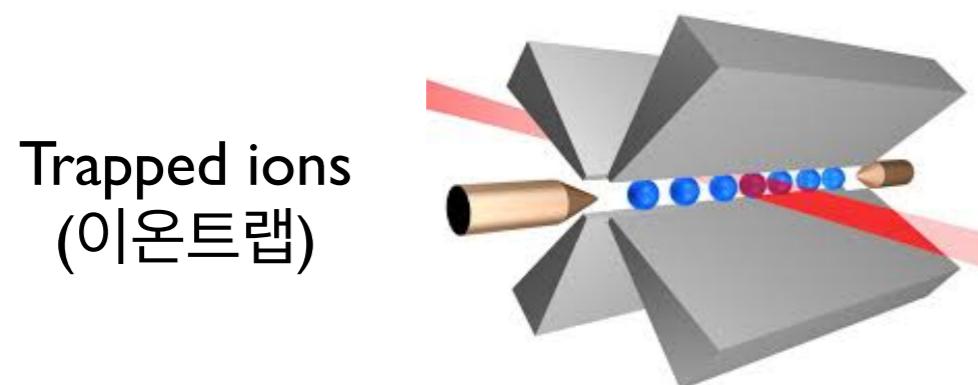
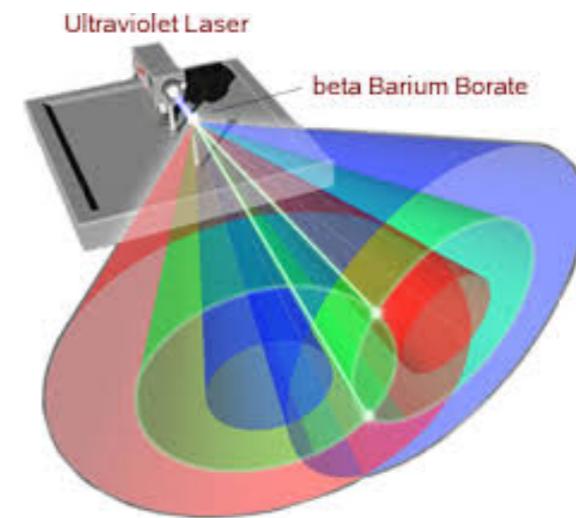
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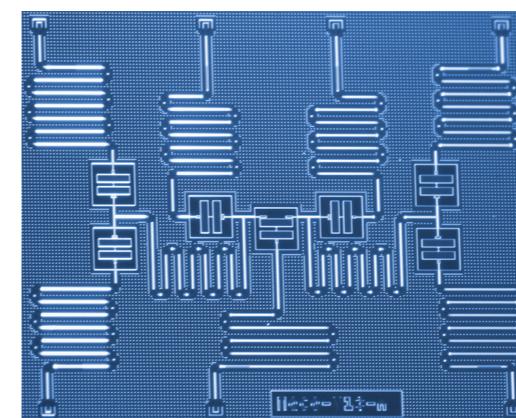
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Entangled states of light
(빛의 양자얽힘 상태)



Trapped ions
(이온트랩)



Superconducting circuit
(초전도체 서킷)

Quick intro to Q.O.

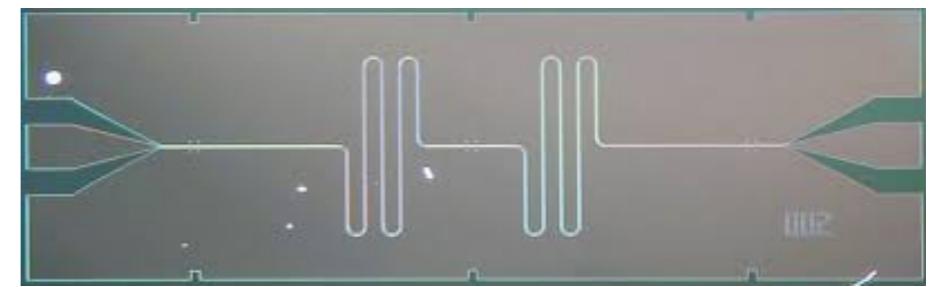
Basic ingredient I: resonator/cavity



Fabry-Perot cavity



Microtoroidal
resonator



Transmission line resonator
Superconducting circuit

Quick intro to Q.O.

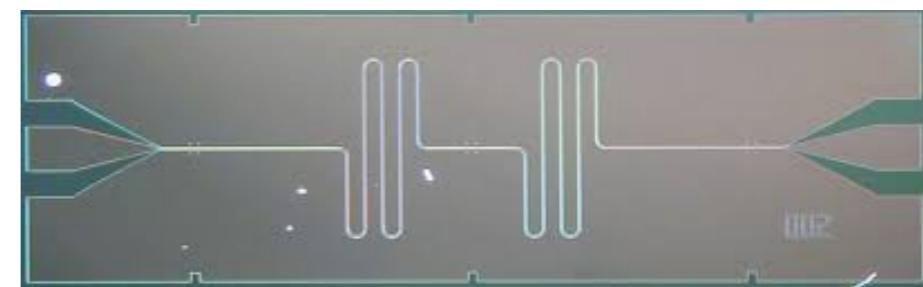
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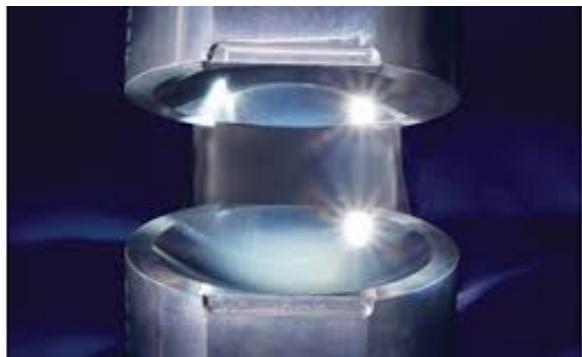
Theoretical description: harmonic oscillator

$$H = \omega_r a^\dagger a$$

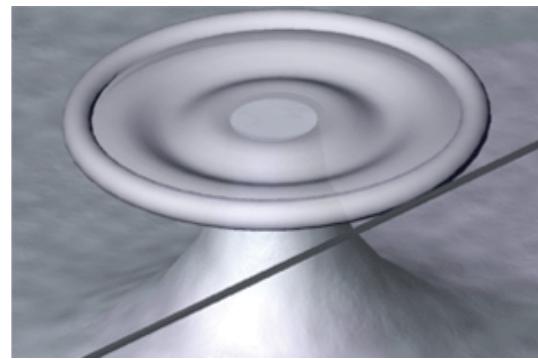
Resonator mode frequency Photon annihilation operator

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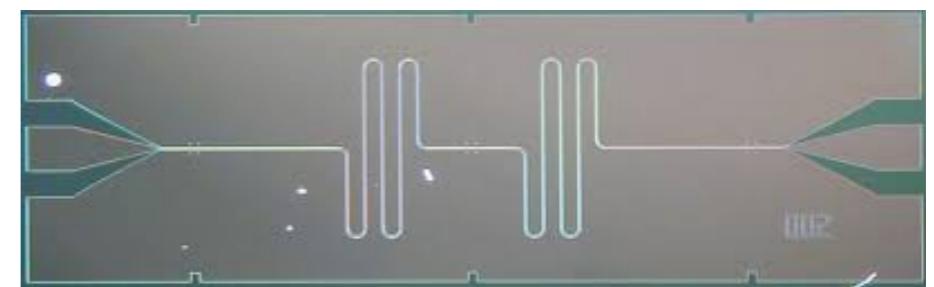
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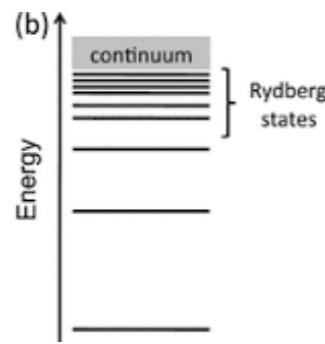
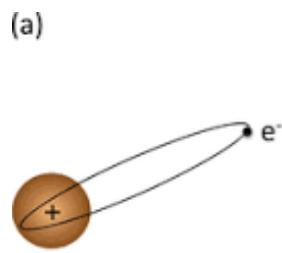
$$[a, a^\dagger] = 1$$

$$a|n\rangle = \sqrt{n-1}|n-1\rangle$$

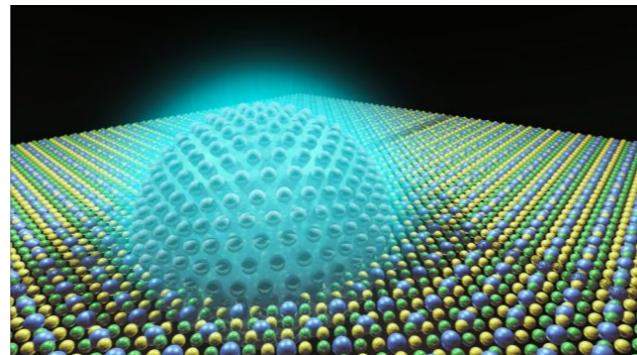
n-photon Fock state

Quick intro to Q.O.

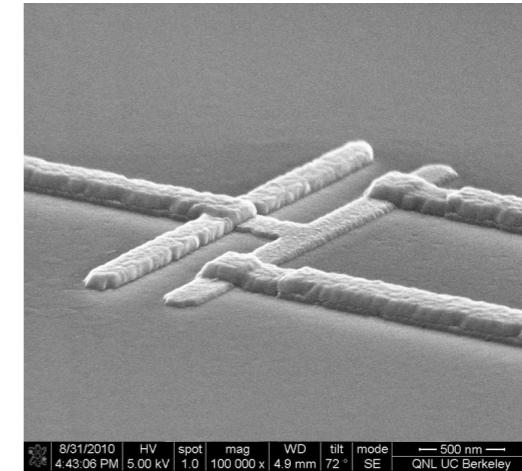
Basic ingredient 2: (artificial) 2-IV atom—qubit



Rydberg atom



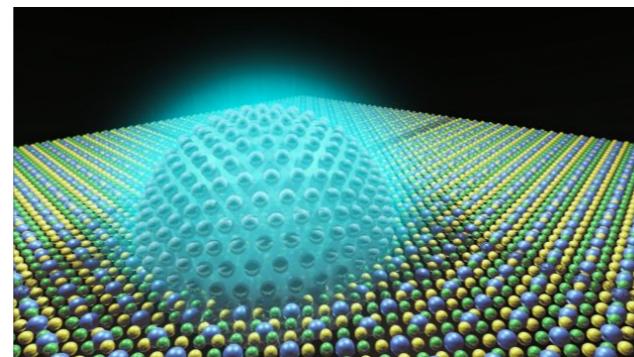
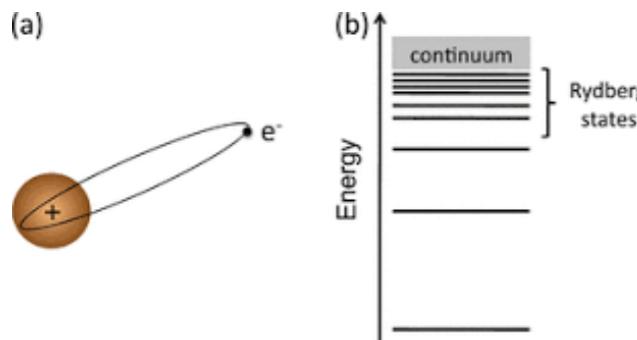
Quantum dot



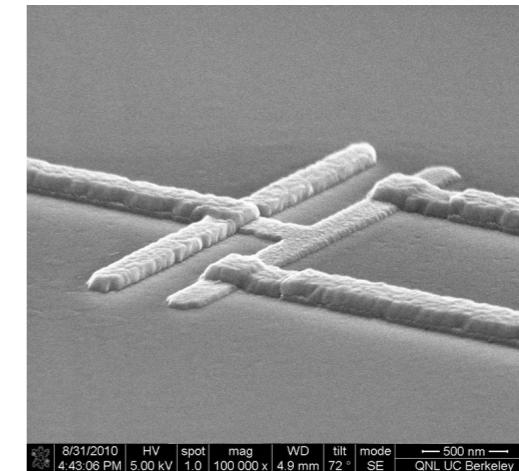
Superconducting qubit

Quick intro to Q.O.

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Rydberg atom



Quantum dot

Superconducting qubit

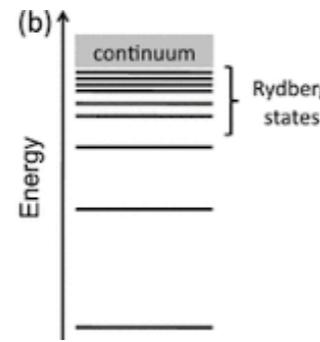
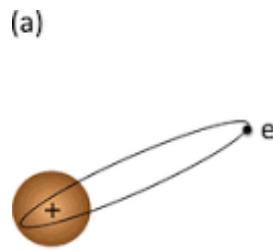
Theoretical description: spin 1/2 system

$$H = \omega_q \sigma_+ \sigma_-$$

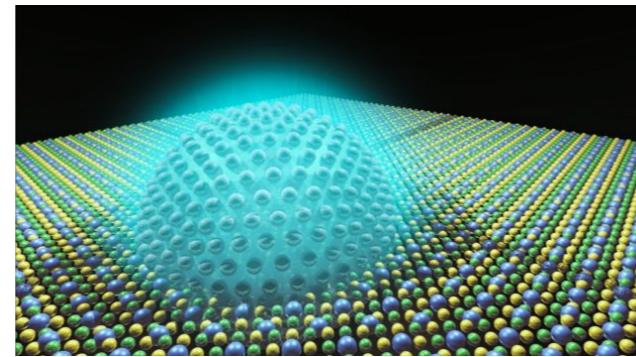
qubit frequency Qubit lowering operator

Quick intro to Q.O.

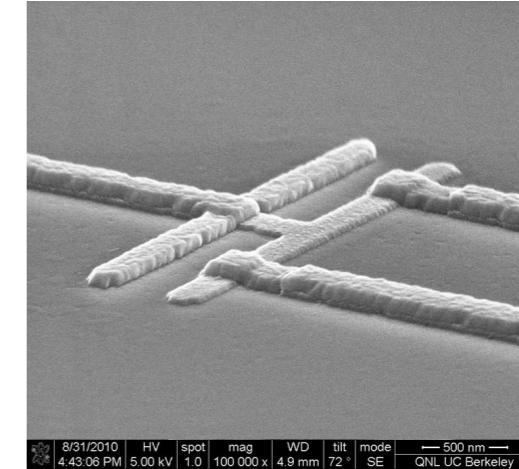
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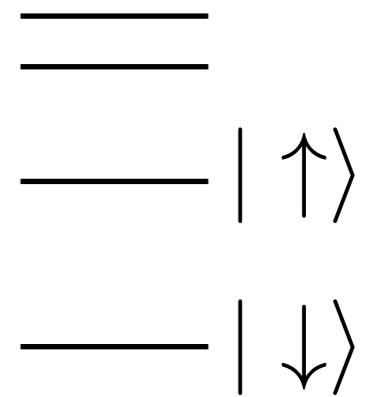
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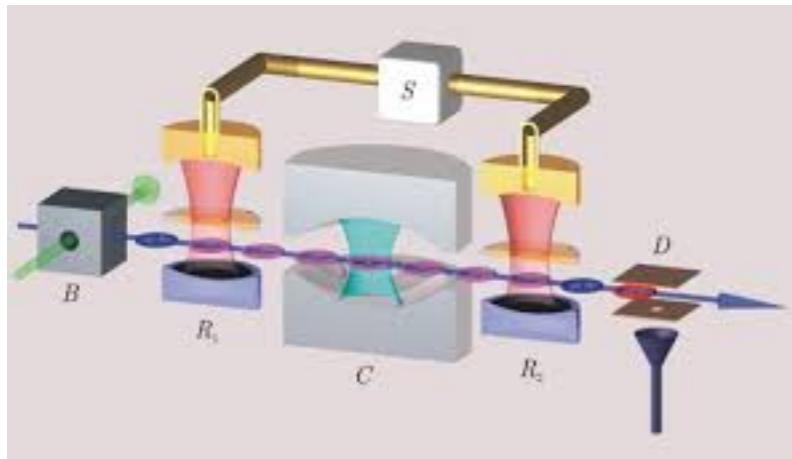
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$$\sigma_- |\uparrow\rangle = |\downarrow\rangle$$

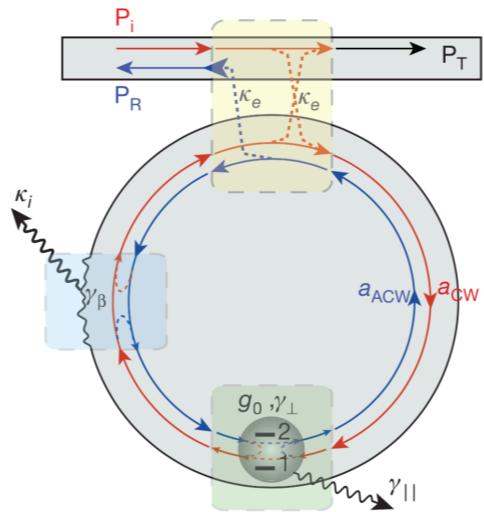


Quick intro to Q.O.

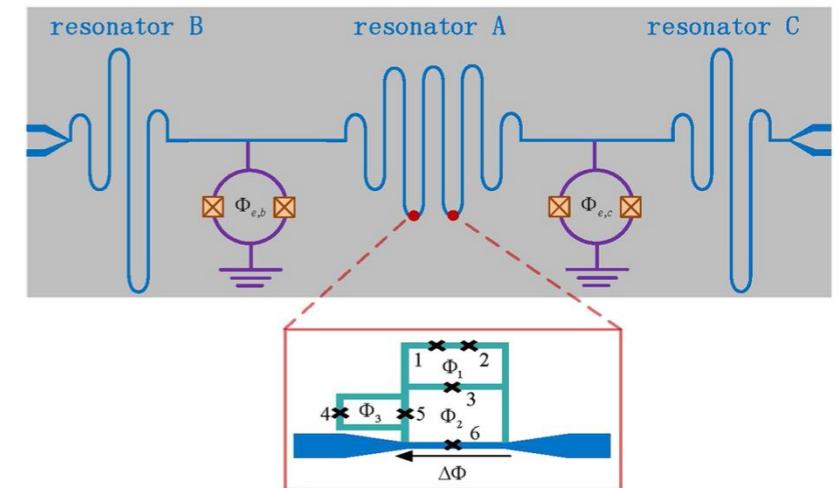
Atom-photon interaction



Rydberg atom + cavity
ENS, Paris



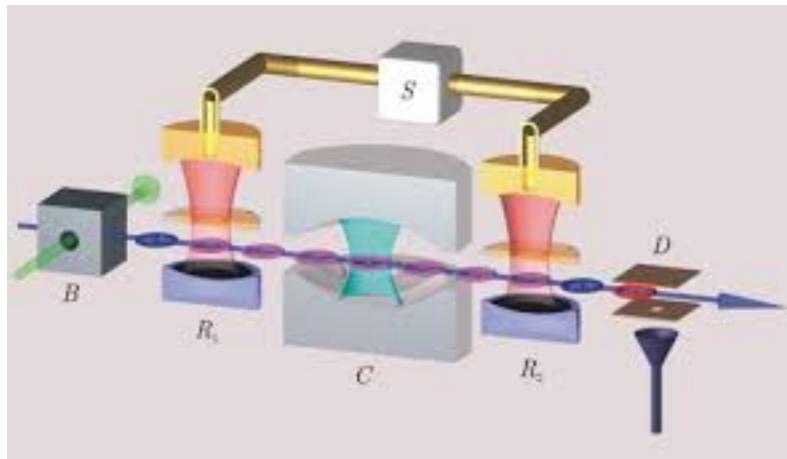
Toroidal resonator + QD
Caltech



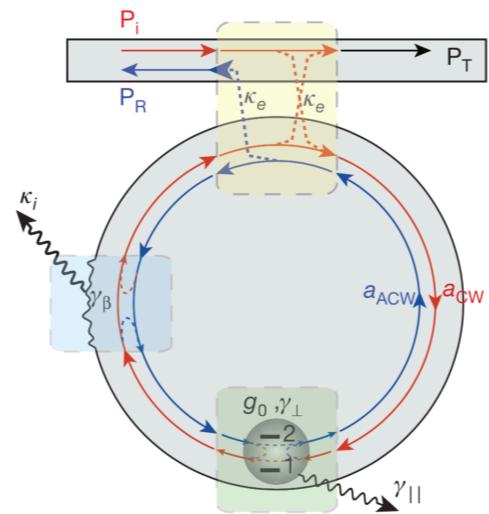
(superconducting) circuit qed
Yale, ETH, Princeton, etc..

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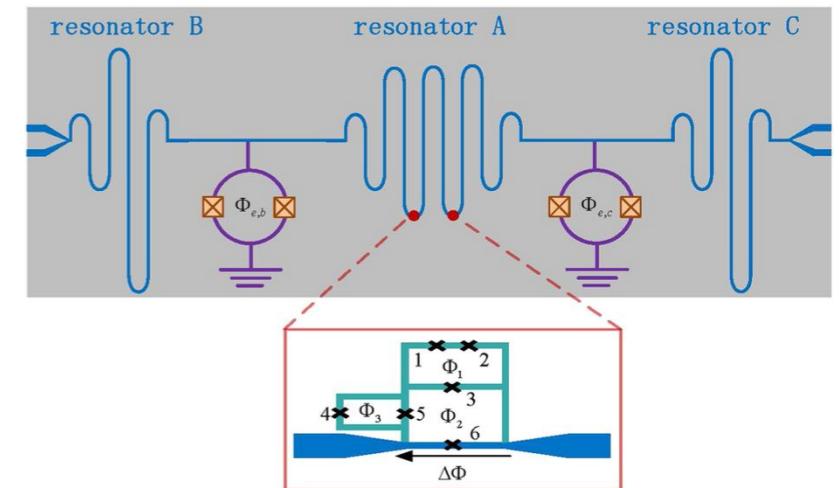
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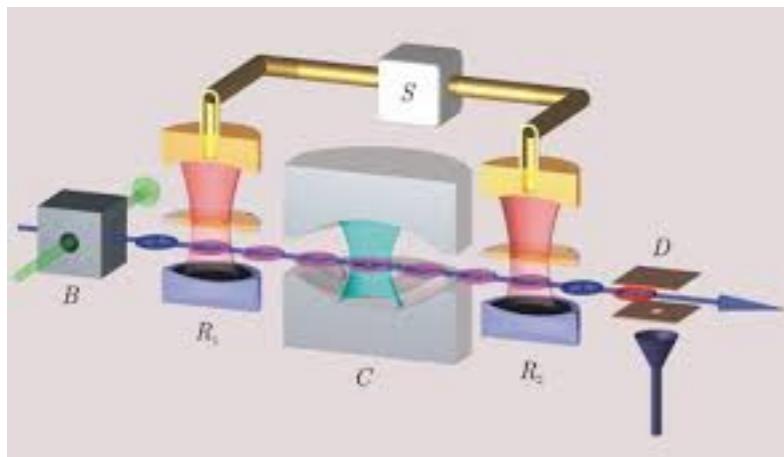
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Theoretical description: Quantum Rabi model

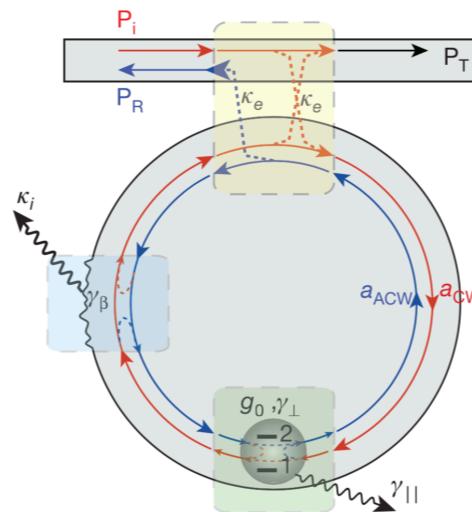
$$\begin{aligned} H = & \omega_r a^\dagger a + \omega_q \sigma_+ \sigma_- \\ & + g(a\sigma_+ + a^\dagger\sigma_-) + g(a\sigma_- + a^\dagger\sigma_+) \end{aligned}$$

Quick intro to Q.O.

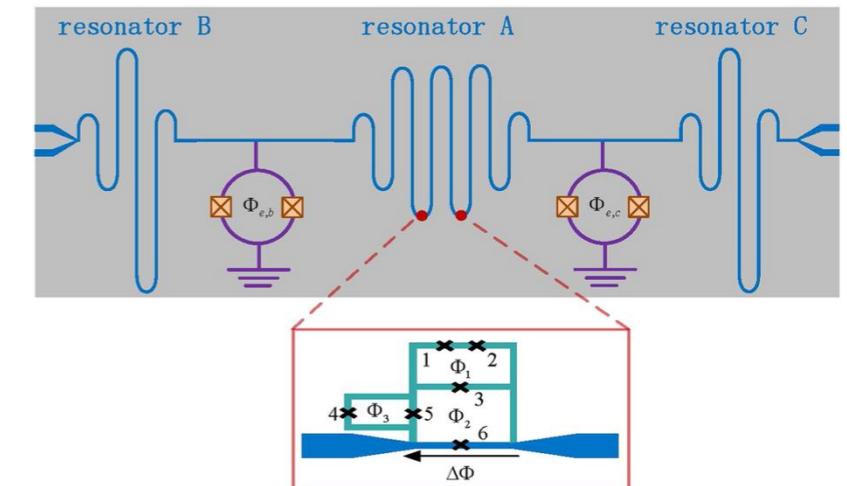
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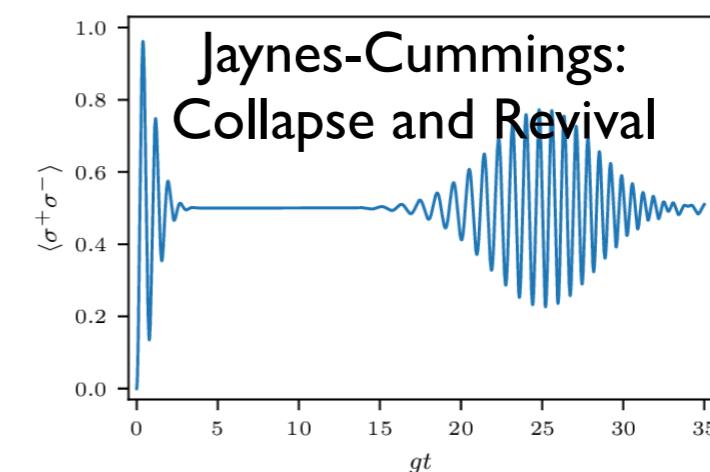


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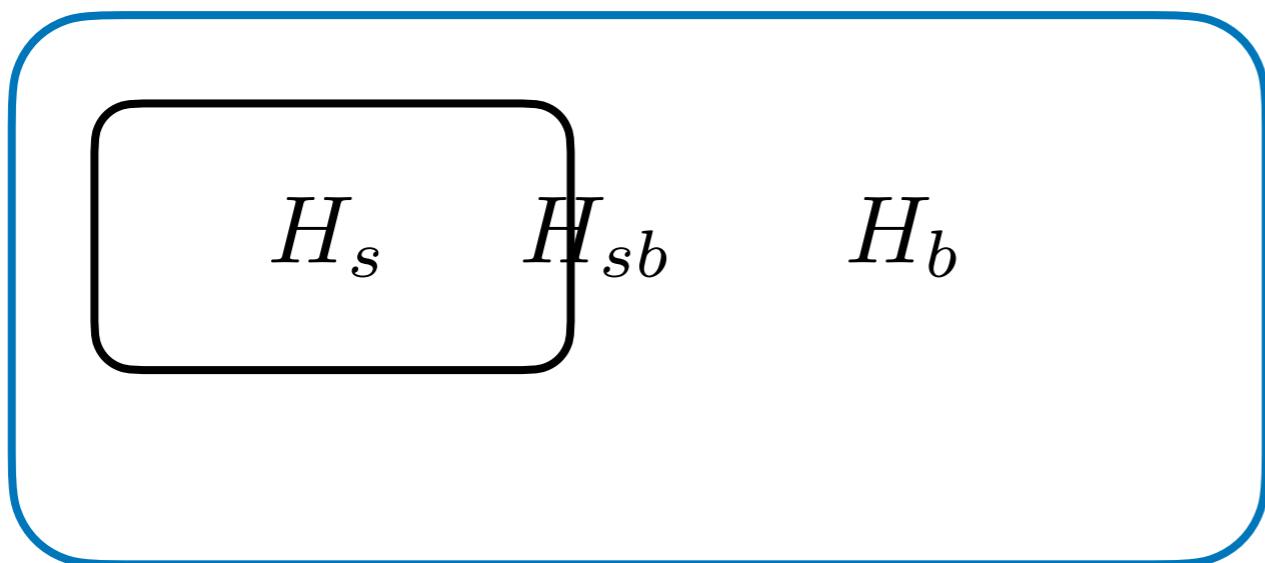
$$H = \omega_r a^\dagger a + \omega_q \sigma_+ \sigma_- + g(a\sigma_+ + a^\dagger \sigma_-) + g(a\sigma_- + a^\dagger \sigma_+)$$

$$g \ll \omega_r \approx \omega_q$$



Quick intro to Q.O.

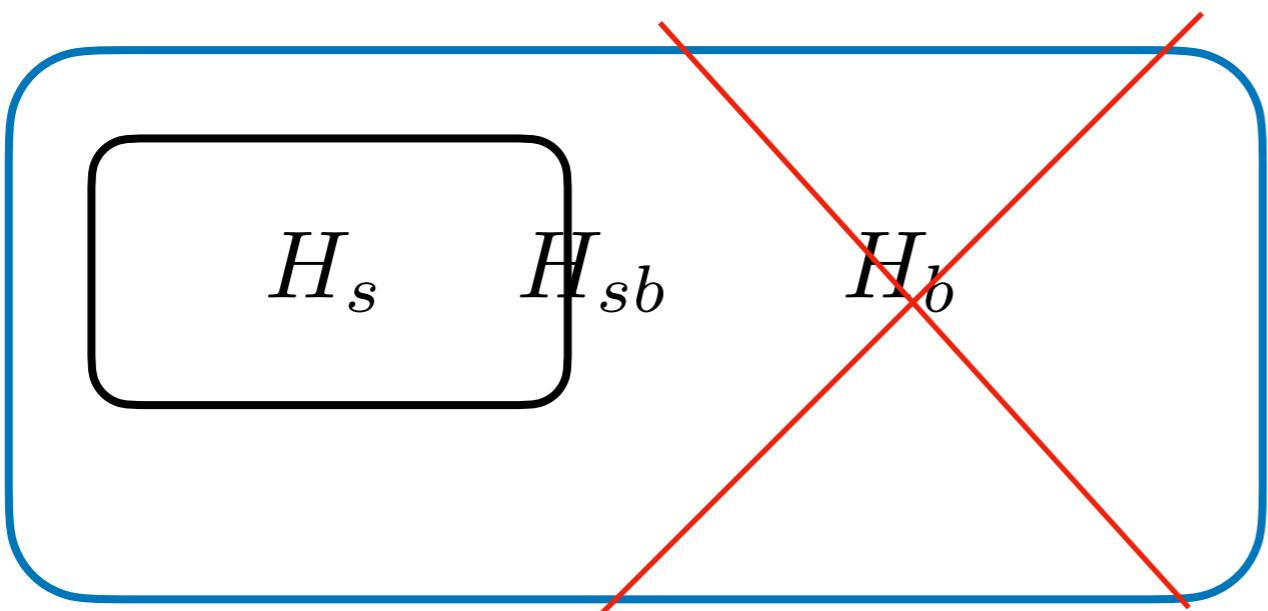
Open system dynamics



$\chi(t)$

Quick intro to Q.O.

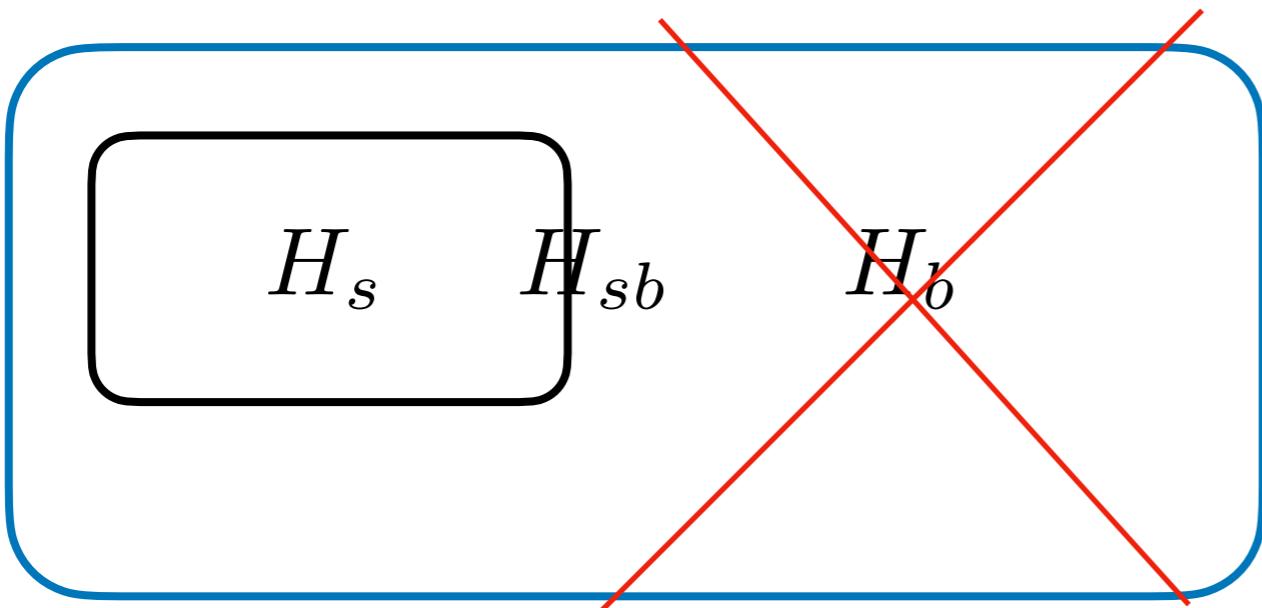
Open system dynamics



$$\rho_s(t) = \text{tr}_b [\chi(t)]$$

Quick intro to Q.O.

Open system dynamics



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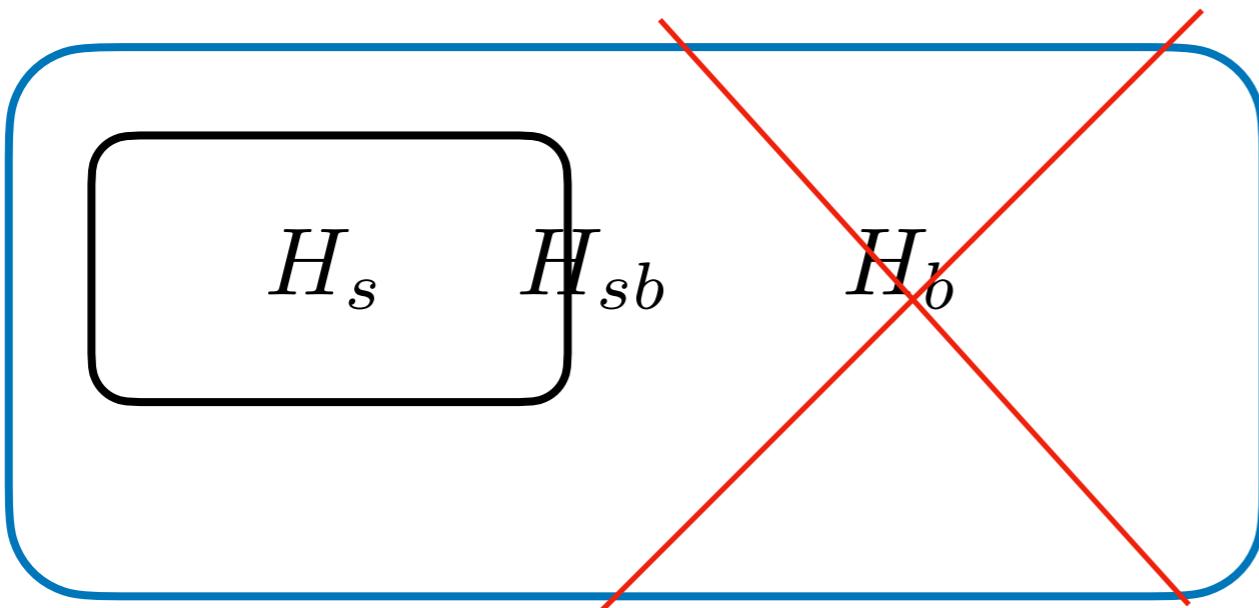
**Weak
system-bath interaction**

Born-Markov approximation

$$\chi(t) = \rho_s(t) \otimes \rho_b \quad \dot{\rho}_s(t) = \mathcal{K}[\rho_s(t)]$$

Quick intro to Q.O.

Open system dynamics



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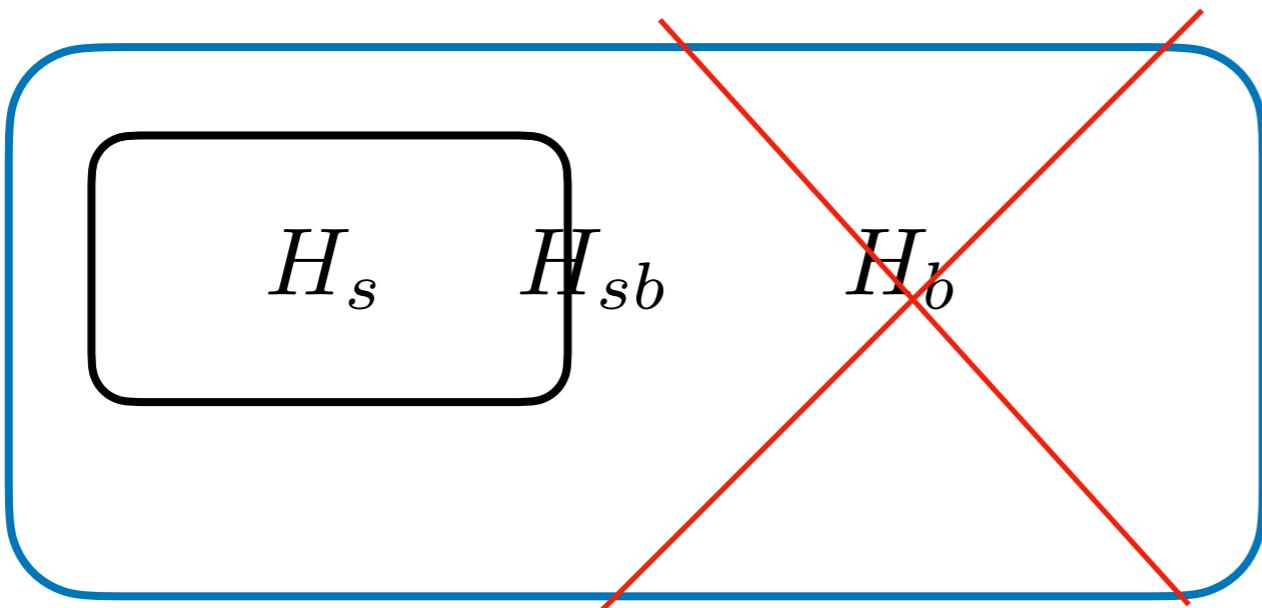
$$\chi(t) = \rho_s(t) \otimes \rho_b \quad \dot{\rho}_s(t) = \mathcal{K}[\rho_s(t)]$$

$$\dot{\rho}_s = -i [H_s, \rho_s] + \sum_j \mathcal{D}[c_j] \rho_s$$

**Dissipation and decoherence
of the system**

Quick intro to Q.O.

Open system dynamics



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**Dissipation and decoherence
of the system**

e.g. harmonic oscillator
dissipation

$$\mathcal{D}[a]\rho = a\rho a^\dagger - \frac{1}{2}a^\dagger a \rho - \frac{1}{2}\rho a^\dagger a$$

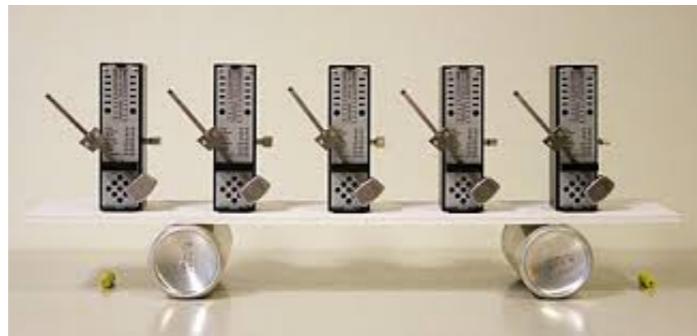
Quantum synchronization (양자 동기화)

동기화 (위상)

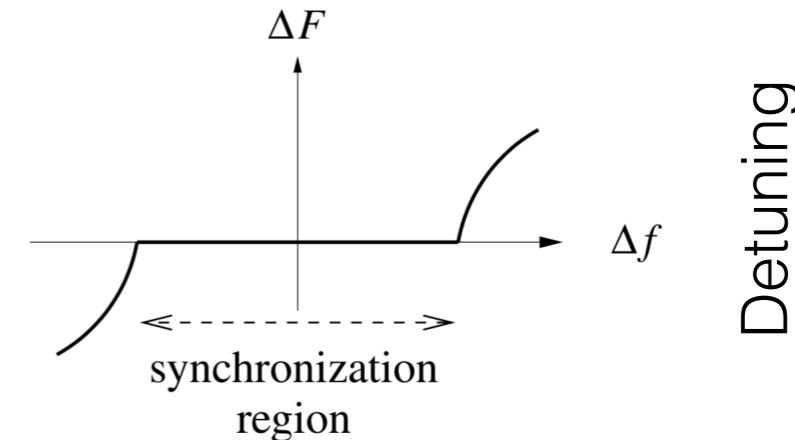


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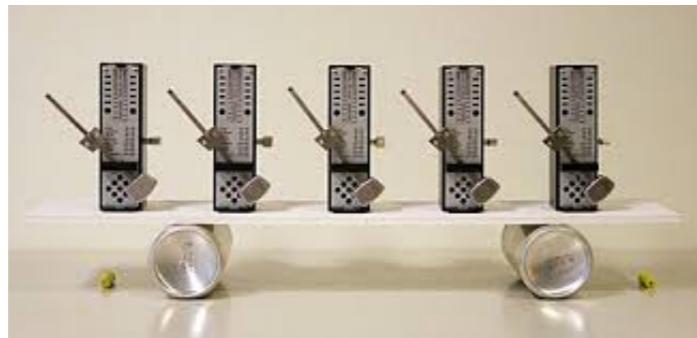


Frequency difference
(진동수 차이)

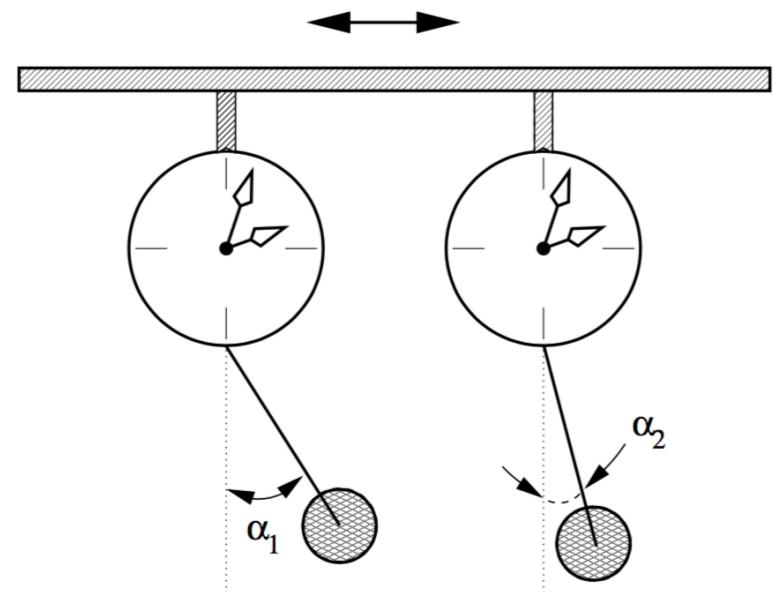
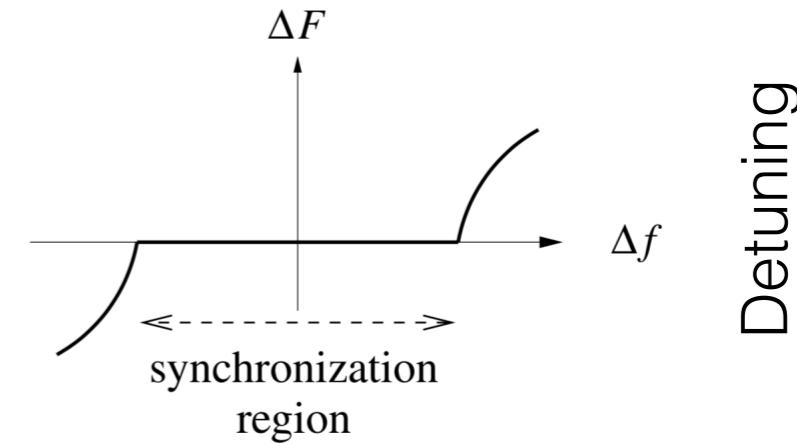


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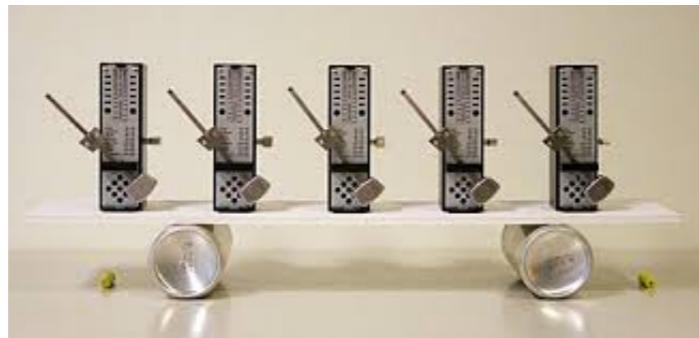


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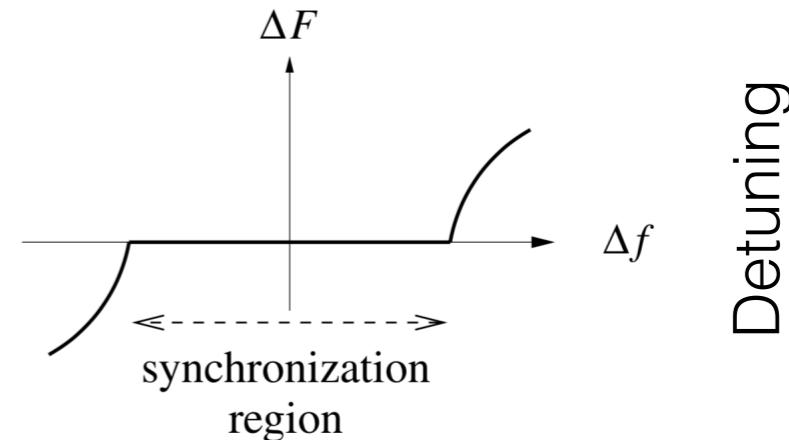


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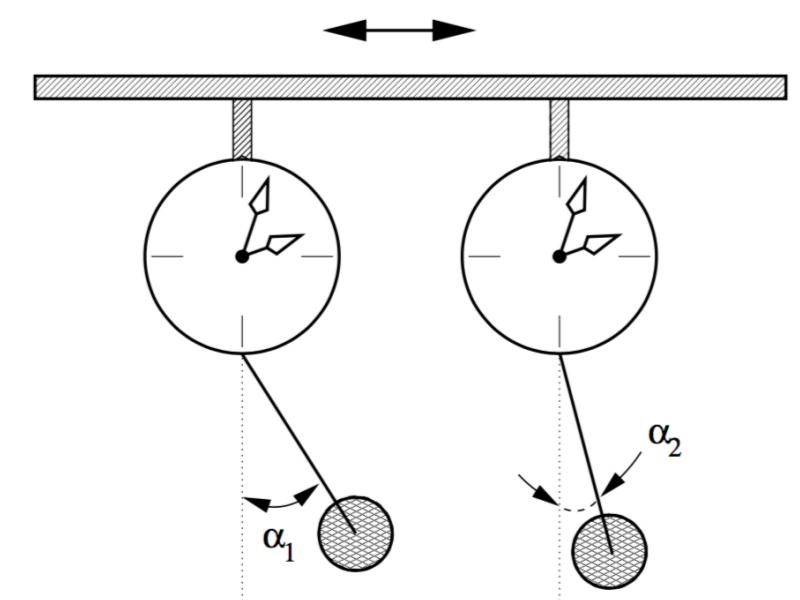


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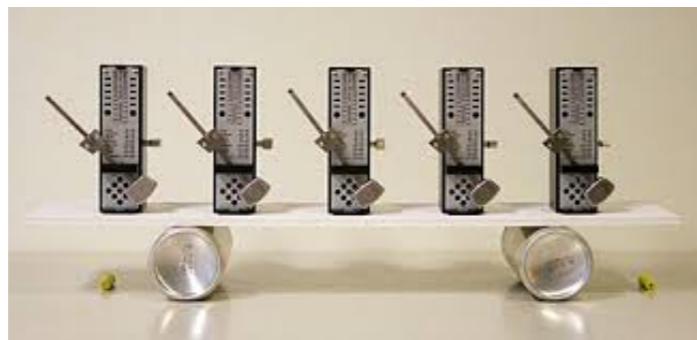
$$\dot{\rho} = -i[\omega_0 a^\dagger a, \rho] + \mathcal{D}[\sqrt{\kappa_1} a^\dagger] \rho + \mathcal{D}[\sqrt{\kappa_2} a^2] \rho$$

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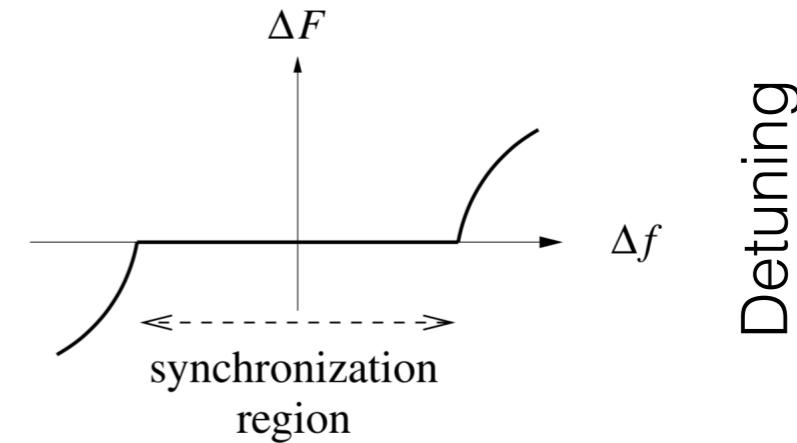


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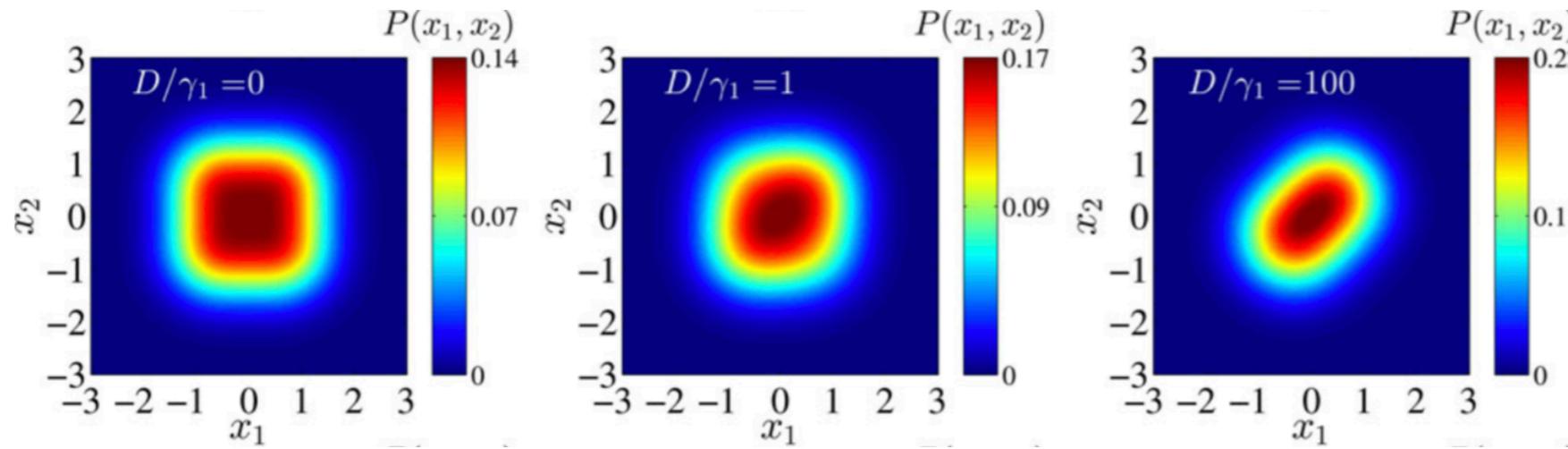


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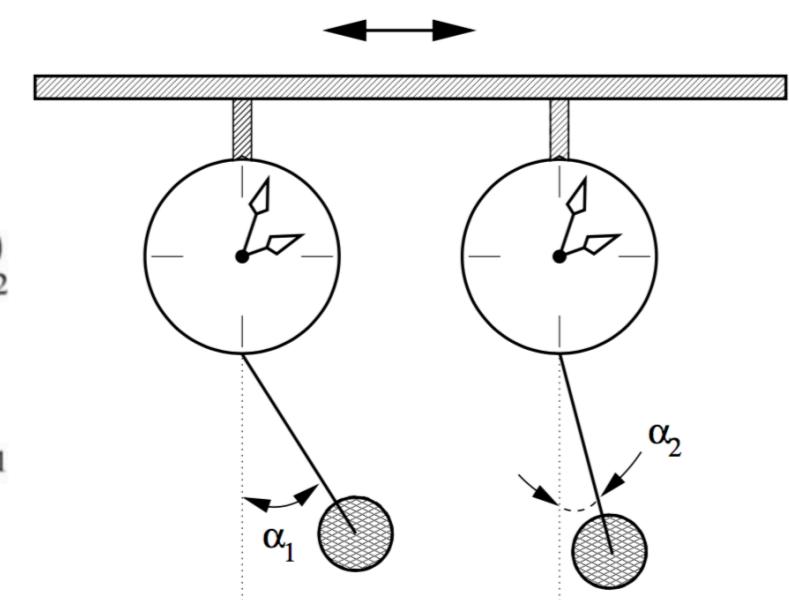


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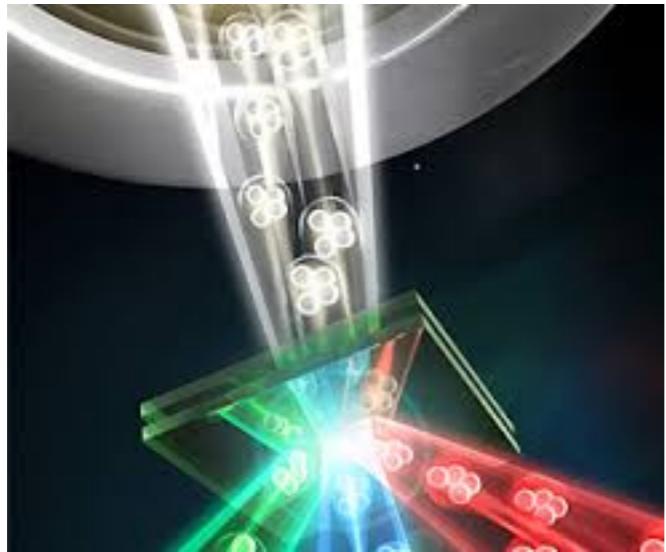


Coupling strength



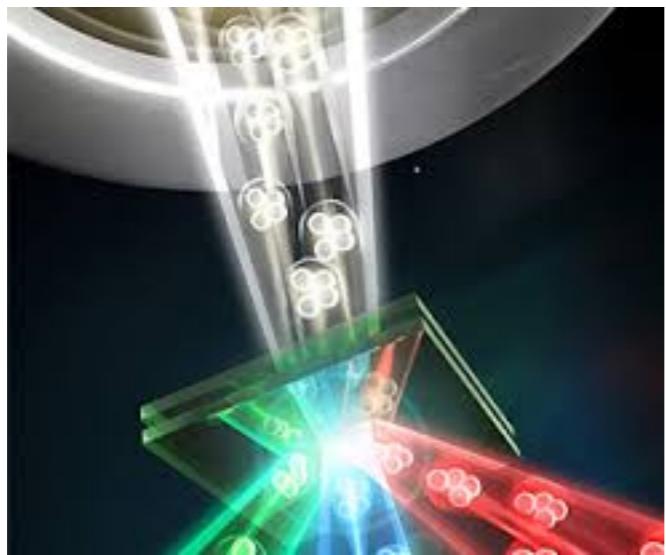
그 외 관심분야 (other areas of interest)

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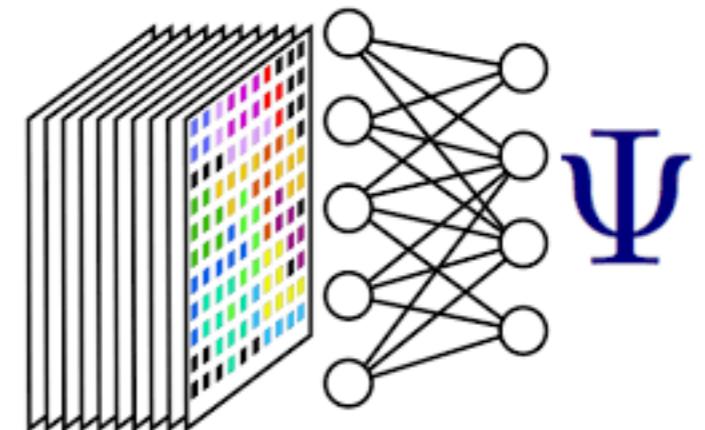
Quantum metrology and sensing
(양자 계측과 센싱)

그 외 관심분야 (other areas of interest)

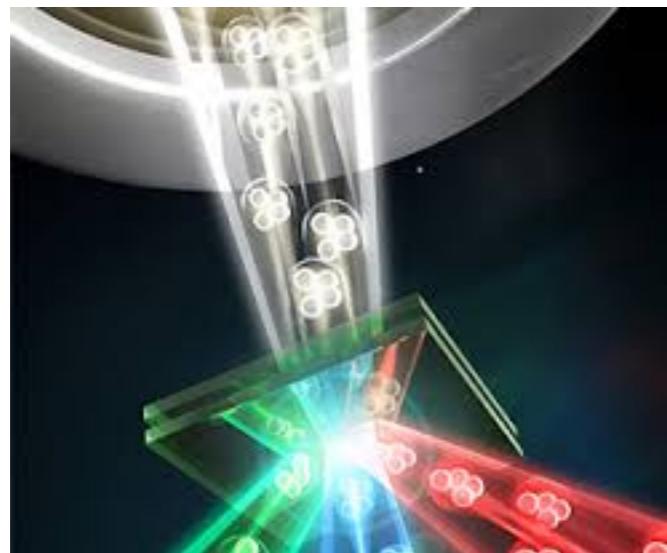


Quantum metrology and sensing
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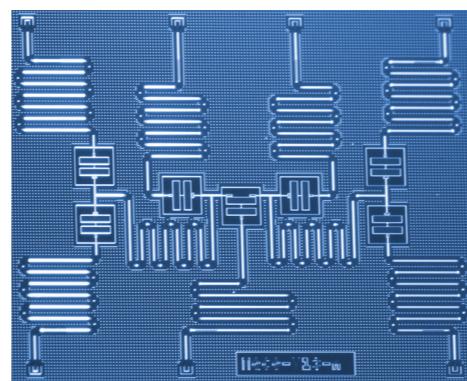
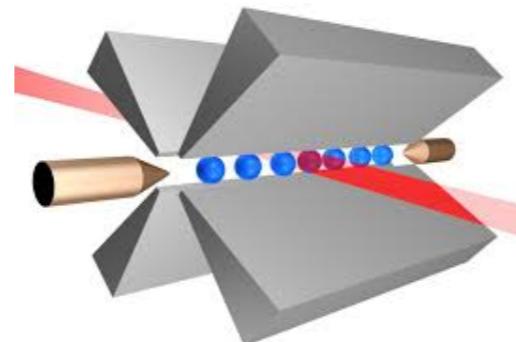
Quantum machine learning
(양자 기계 학습)



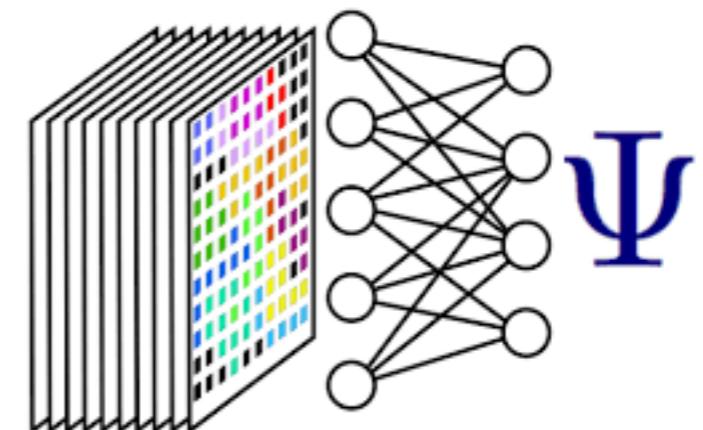
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Quantum metrology and sending
(양자 계측과 센싱)



Quantum machine learning
(양자 기계 학습)



Quantum computing/simulation

- Speed-up, avoiding decoherence, error-correcting etc.