Title: PSI 2018/2019 - Quantum Information Review - Lecture 4

Speakers: Daniel Gottesman

Collection: PSI 2018/2019 - Quantum Information Review (Gottesman)

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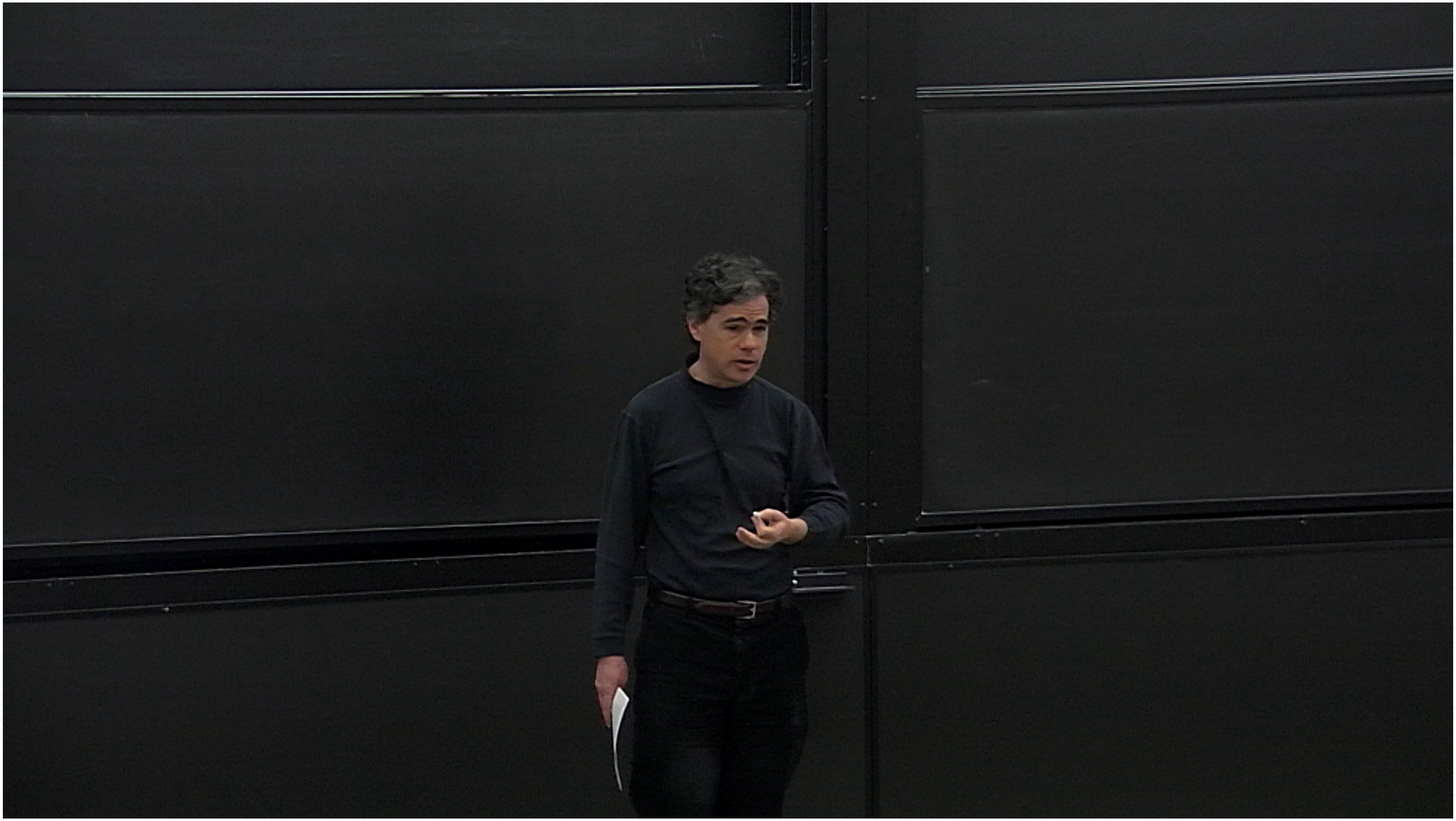

DiVincezo criteria:

1. A scalable physical system with well-characterized qubits.
2. The ability to initialize the state of the qubits to a simple fiducial state, such as $|00\rangle$.
3. Long relevant decoherence times, much longer than the gate operation time.
4. A universal set of gates.

Flying qubits = ones that move

Stationary qubits = ones in computer

6. The ability to interconvert between stationary & flying qubits

7. The ability to faithfully transmit flying qubits between specified locations.

Ion traps:

Atom + charge, 1 electron in outer shell

$|g\rangle = |0\rangle$

$|e\rangle = |1\rangle$

$$H = H_{atom} + H_{laser}$$

$$H_{atom} = \epsilon |e\rangle\langle e|$$

$$H_{laser} = J\left(e^{-i\omega t}|g\rangle\langle e| + e^{i\omega t}|e\rangle\langle g|\right)$$

$\omega = \epsilon/\hbar$ frequency of laser

$$|g\rangle \longmapsto \cos(Jt/\hbar)|g\rangle + \sin(Jt/\hbar)|e\rangle$$

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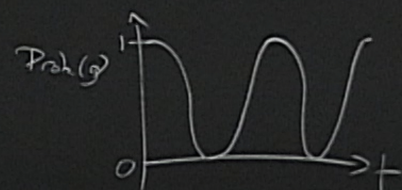
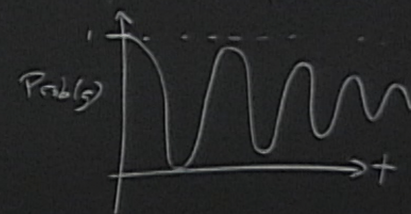


Ideal



Real

Rabi oscillations

$$H = H_{atom} + H_{laser}$$

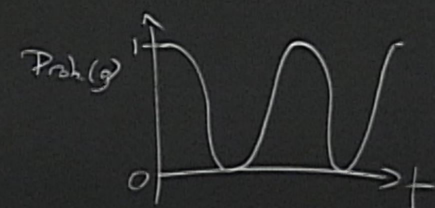
$$H_{atom} = \epsilon |e\rangle\langle e|$$

$$H_{laser} = J\left(e^{-i\omega t}|g\rangle\langle e| + e^{i\omega t}|e\rangle\langle g|\right)$$

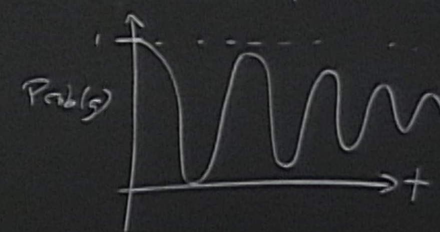
$\omega = \epsilon/\hbar$ frequency of laser

- Single-qubit X rotations by turning on laser
- Single-qubit Z rotations by waiting

$$|g\rangle \longmapsto \cos(Jt/\hbar)|g\rangle + \sin(Jt/\hbar)|e\rangle$$

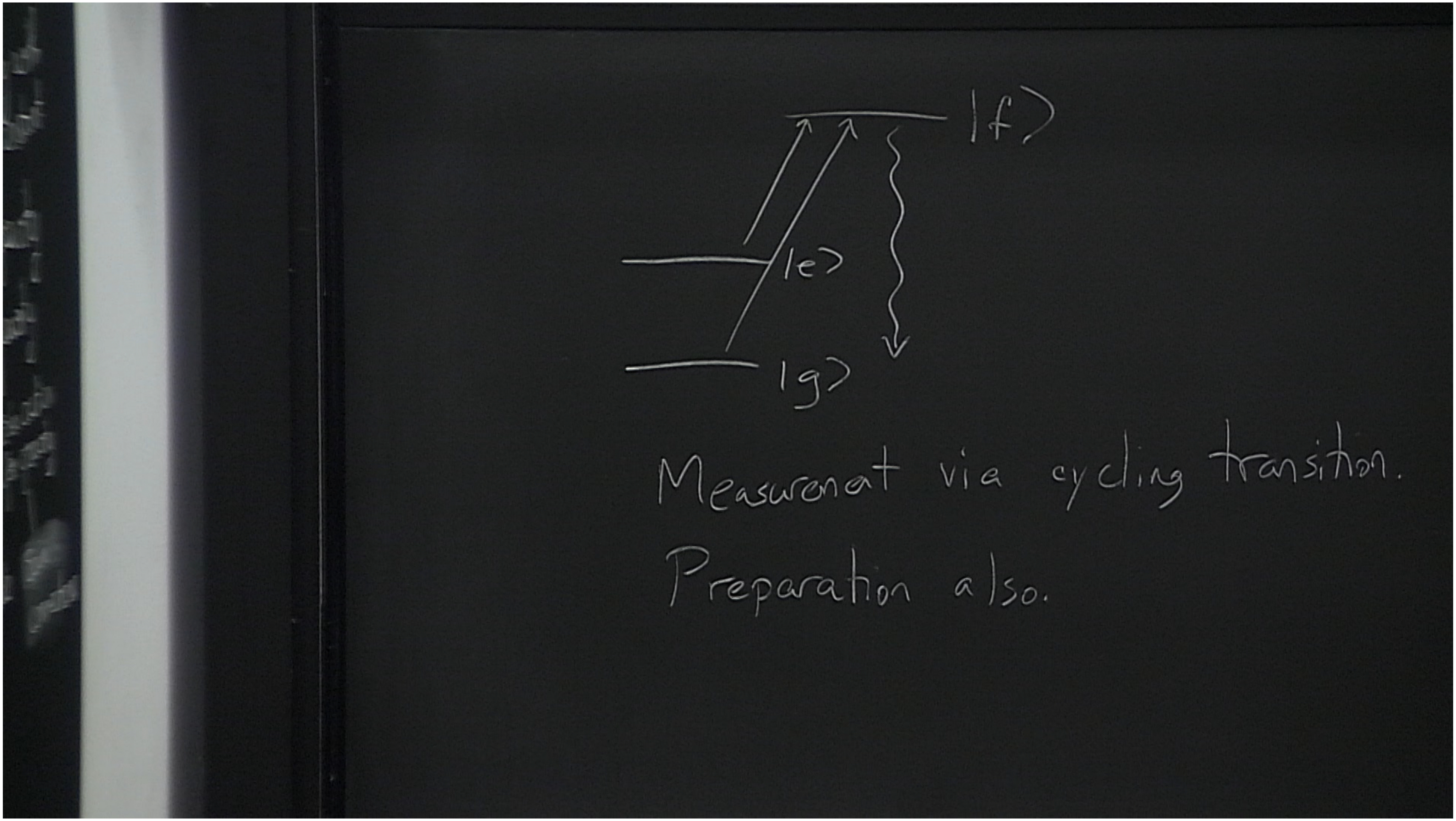


Ideal



Real

Rabi oscillations


|f⟩
|e⟩
|g⟩
Measurement via cycling transition.
Preparation also.

Single-qubit Z rotations by waiting

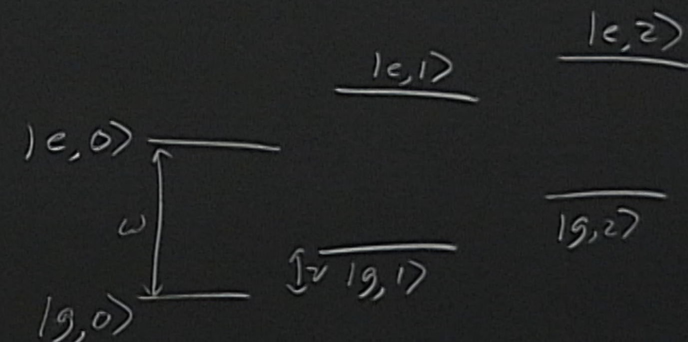
transition.

Two-qubit gates:

(←●→ ●)

Phonon modes

$H_{phonon} = \hbar \nu a^\dagger a$



$\omega = \epsilon/\hbar$ frequency of laser

- Single-qubit X rotations by turning on laser
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Rabi oscillations

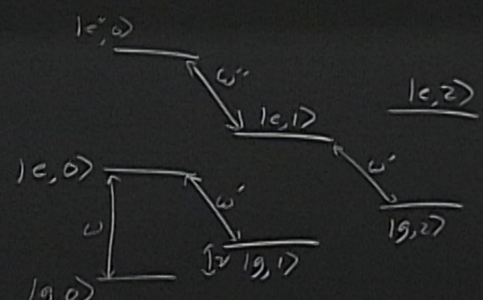
ransition.

Two-qubit gates:

$(\leftrightarrow \quad \bullet)$

Phonon modes

$H_{phonon} = \hbar \nu a^\dagger a$



$\hbar\omega' = \epsilon - \hbar\nu$

$|e''\rangle$ w/ energy ϵ''

$\omega'' = (\epsilon'' - \epsilon)/\hbar - \nu$

Cirac-Zoller gate

1. $\pi/2$ pulse on atom 1 w/ frequency ω'
2. π pulse on atom 2 w/ frequency ω''

1. $|e\rangle_1 |0\rangle_p \longrightarrow |g\rangle_1 |1\rangle_p$

$|g\rangle_1 |0\rangle_p \longrightarrow |g\rangle_1 |0\rangle_p$

2. $|g\rangle_2 |0\rangle_p \longrightarrow |g\rangle_2 |0\rangle_p$

$|e\rangle_2 |0\rangle_p \longrightarrow |e\rangle_2 |0\rangle_p$

$|g\rangle_2 |1\rangle_p \longrightarrow |g\rangle_2 |1\rangle_p$

$|e\rangle_2 |1\rangle_p \longrightarrow -|e\rangle_2 |1\rangle_p$