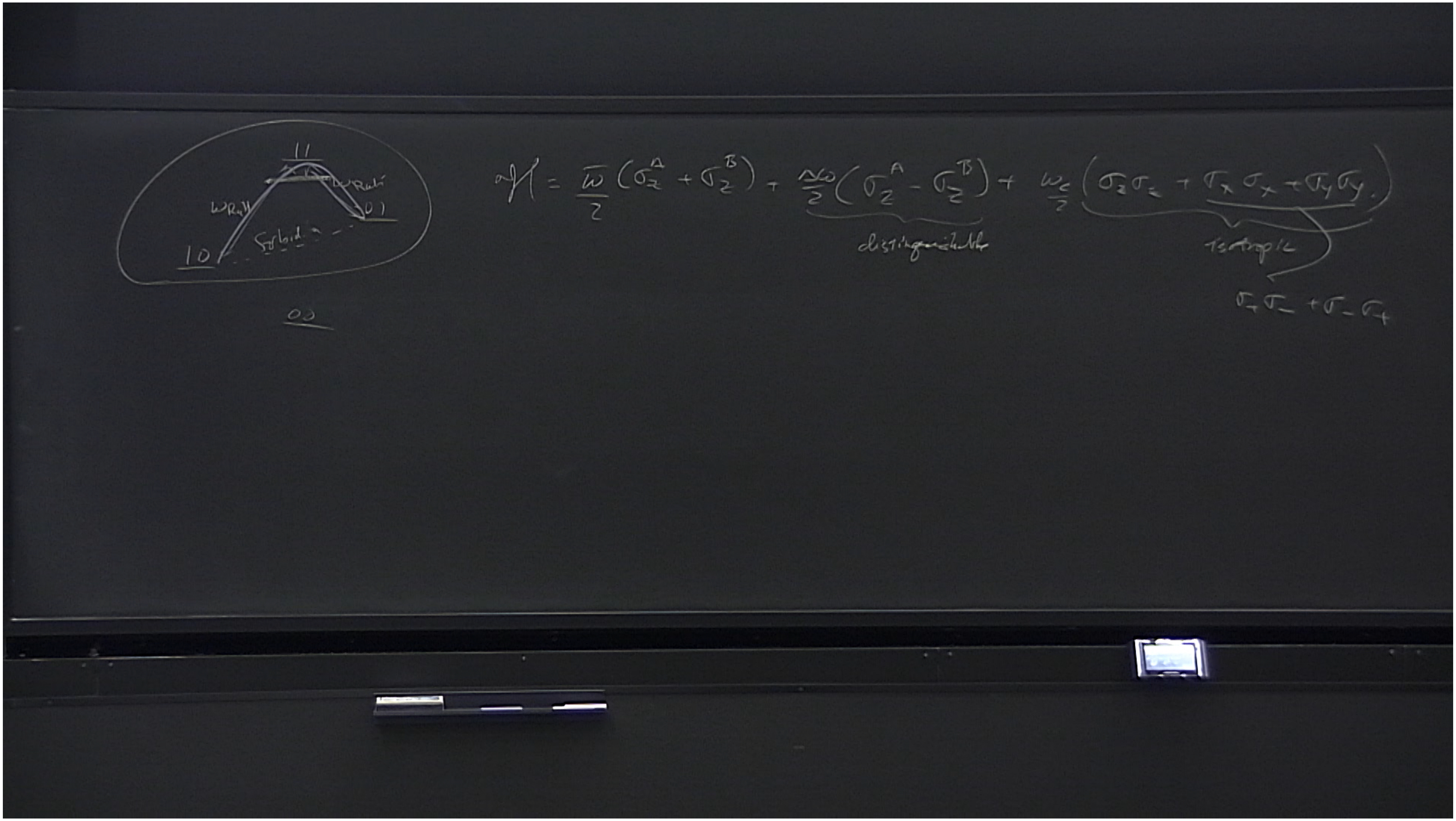
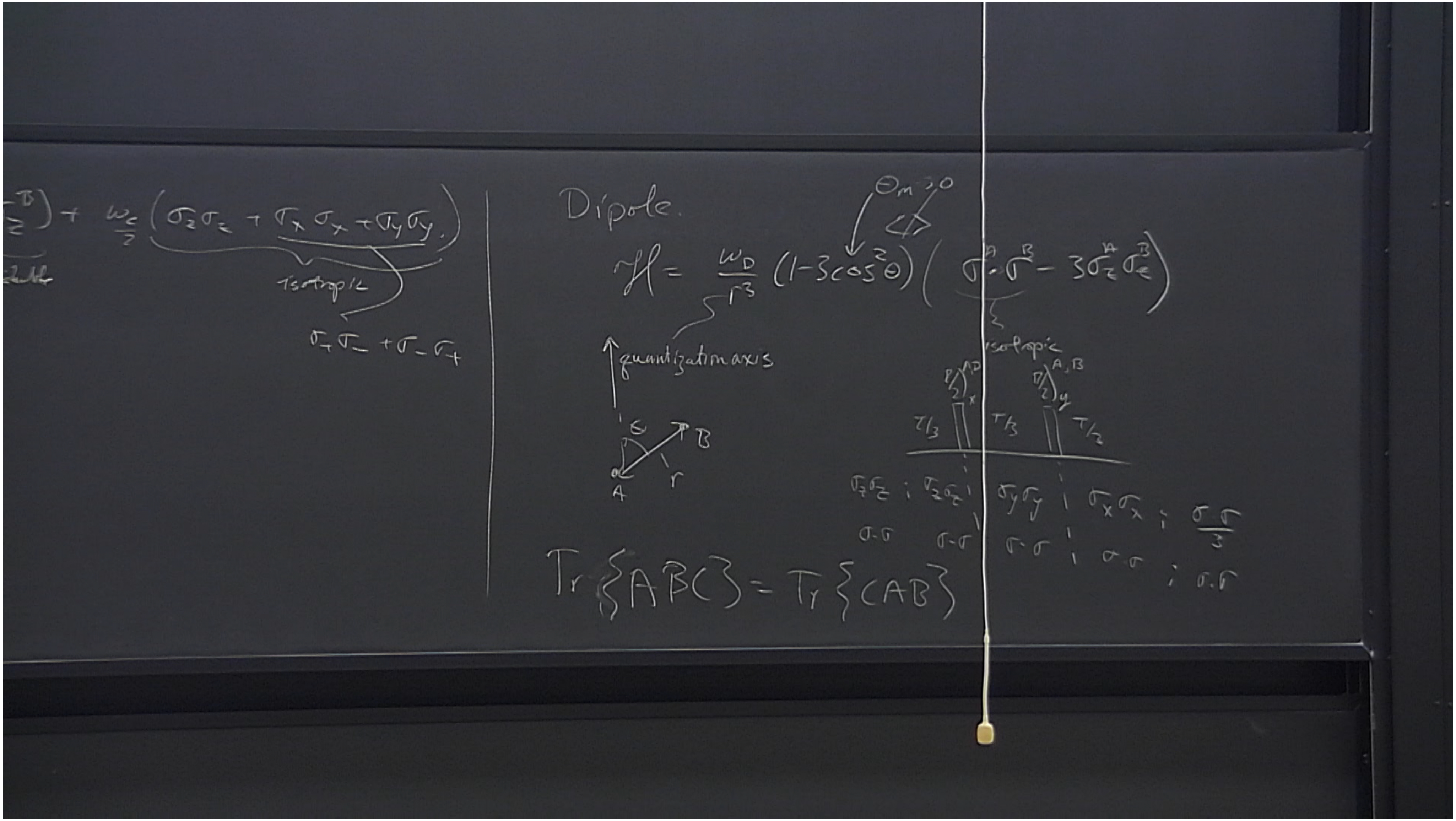
Title: PSI 2016/2017 Explorations in Quantum Information - Lecture 12

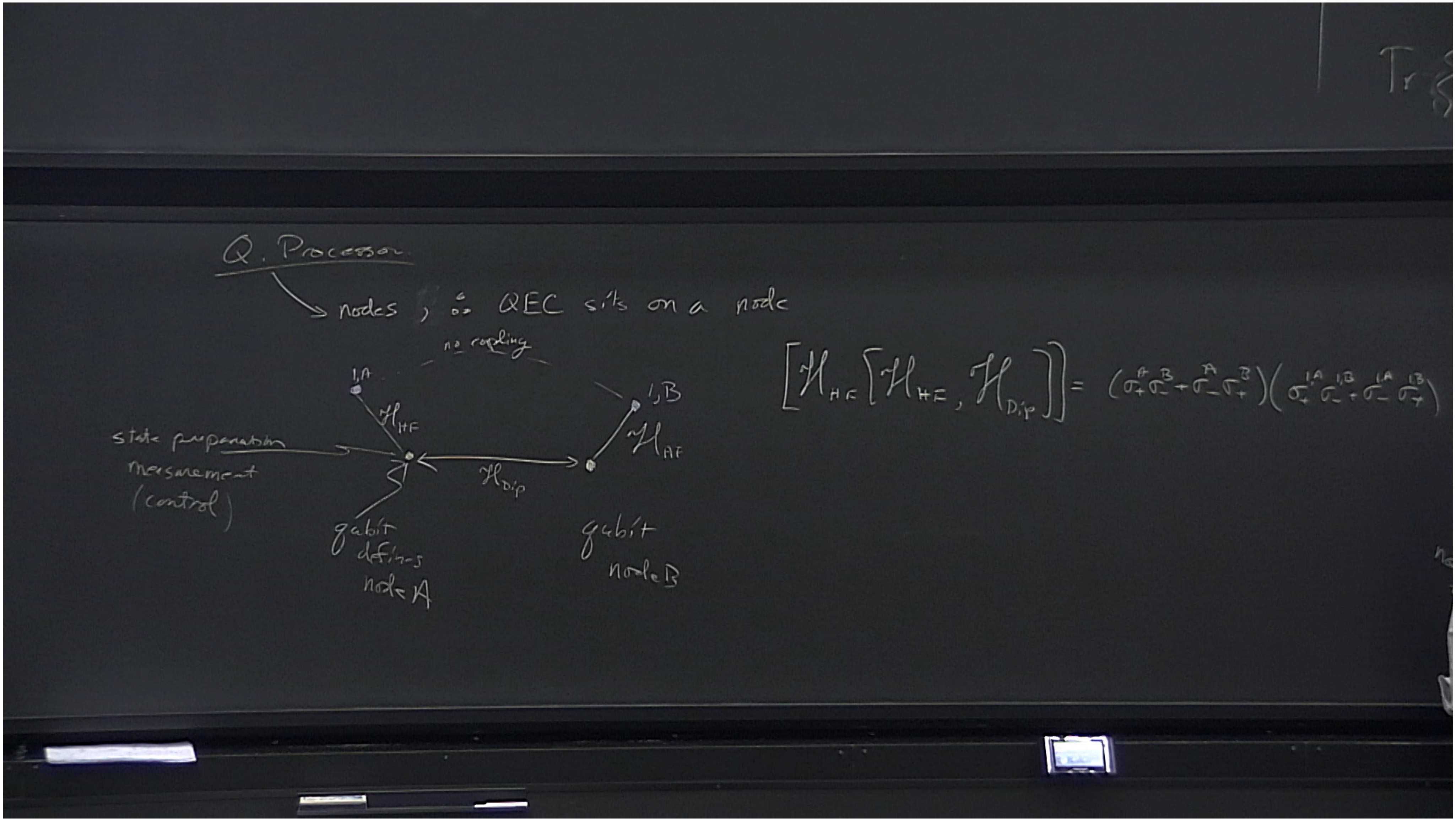
Date: Apr 04, 2017 09:00 AM

URL: http://pirsa.org/17040011

Abstract:

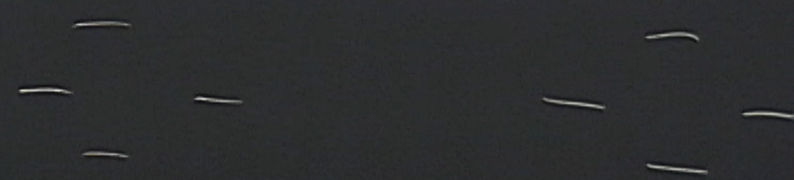

11
10
01
00
$\mathcal{H} = \frac{\bar{\omega}}{2}(\sigma_z^A + \sigma_z^B) + \frac{\Delta\omega}{2}(\sigma_z^A - \sigma_z^B) + \frac{\omega_c}{2}(\sigma_z\sigma_z + \sigma_x\sigma_x + \sigma_y\sigma_y)$
distinguishable
isotropic
$\sigma_+\sigma_- + \sigma_-\sigma_+$


$+\frac{\omega_c}{2}(\sigma_z\sigma_z + \sigma_x\sigma_x + \sigma_y\sigma_y)$
isotropic
$\sigma_+\sigma_- + \sigma_-\sigma_+$
Dipole.
$\theta_m \to 0$
$\mathcal{H} = \frac{\omega_D}{r^3}(1-3\cos^2\theta)(\sigma^A\cdot\sigma^B - 3\sigma_z^A\sigma_z^B)$
quantization axis
isotropic
θ
A
B
r
$T/3$
$T/3$
$T/3$
$\sigma_z\sigma_z$
$\sigma_y\sigma_y$
$\sigma_x\sigma_x$
$\frac{\sigma\cdot\sigma}{3}$
$\sigma\cdot\sigma$
$\mathrm{Tr}\{ABC\} = \mathrm{Tr}\{CAB\}$

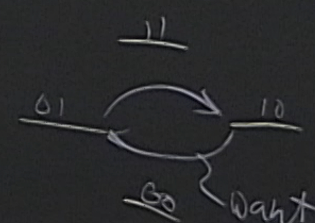

Q. Processor
nodes ; ∴ QEC sits on a node
no coupling
1,A
1,B
$\mathcal{H}_{HF}$
$\mathcal{H}_{HF}$
$\mathcal{H}_{Dip}$
state preparation
measurement
(control)
qubit
defines
node A
qubit
node B
$\left[\mathcal{H}_{HF}\left[\mathcal{H}_{HF}, \mathcal{H}_{Dip}\right]\right] = (\sigma_+^A\sigma_-^B + \sigma_-^A\sigma_+^B)(\sigma_+^{1A}\sigma_-^{1B} + \sigma_-^{1A}\sigma_+^{1B})$

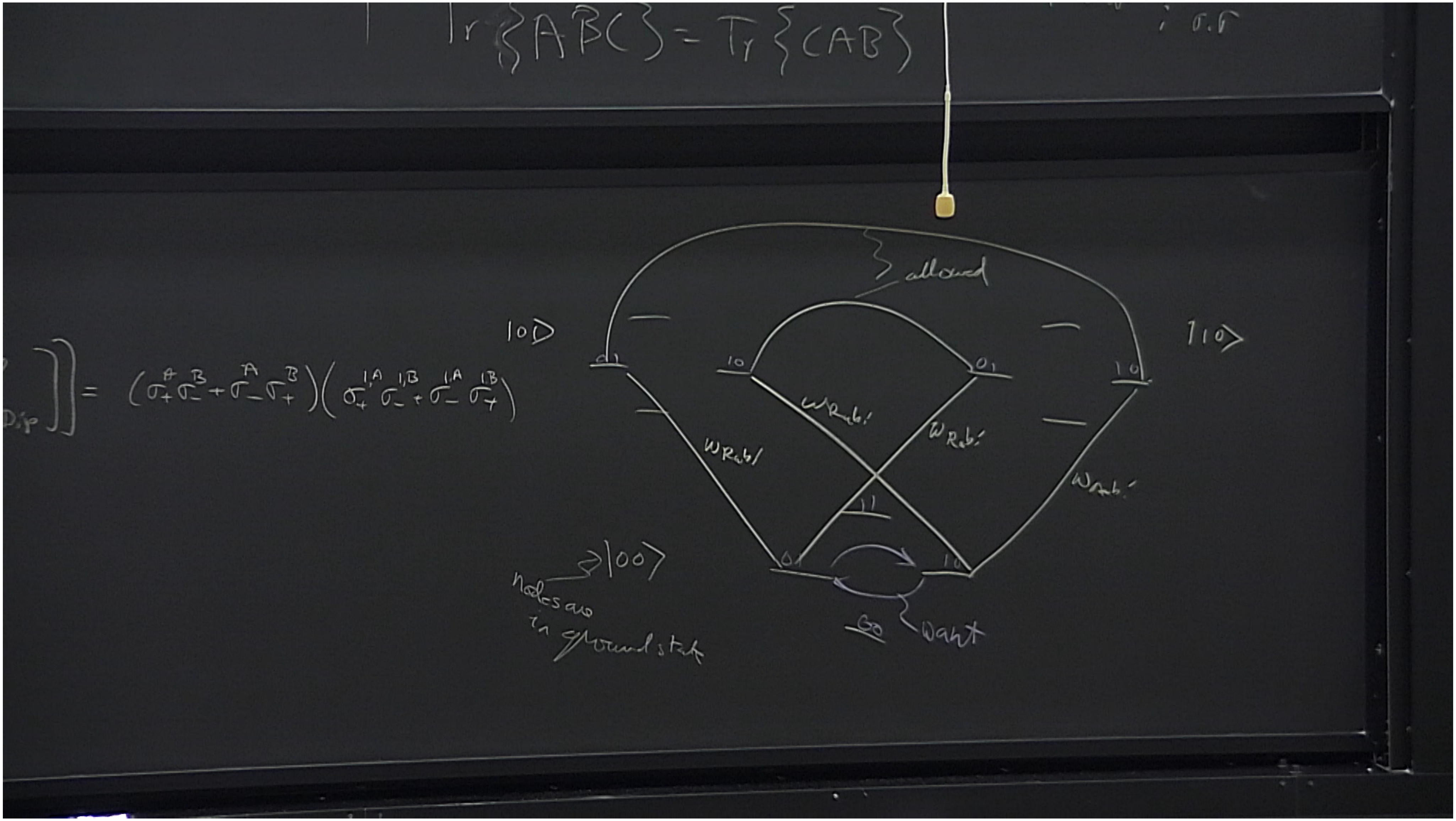
$$\mathrm{Tr}\{ABC\} = \mathrm{Tr}\{CAB\} \quad ; \ \sigma.\sigma$$

$$\mathcal{H}_{Dip}]] = (\sigma_+^A \sigma_-^B + \sigma_-^A \sigma_+^B)(\sigma_+^{1,A} \sigma_-^{1,B} + \sigma_-^{1,A} \sigma_+^{1,B})$$

$|01\rangle$  $|10\rangle$

nodes are in ground state $\rightarrow |00\rangle$

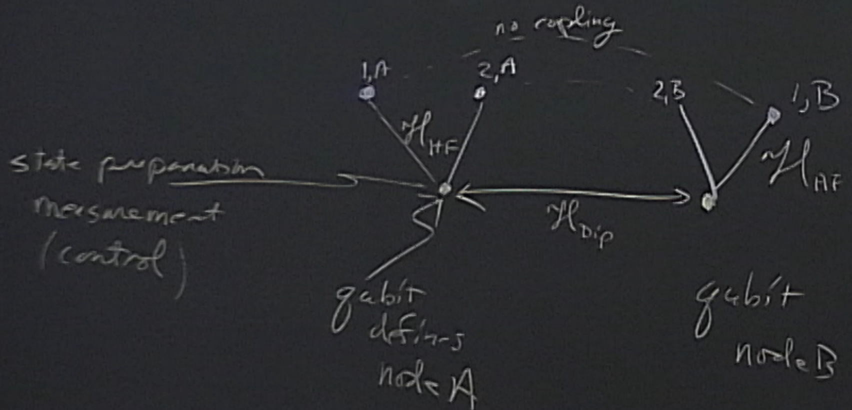



Tr{ABC} = Tr{CAB}
allowed
|01⟩
|10⟩
01
10
01
10
ωRab/
ωRab!
ωRab!
ωRab!
11
01
10
|00⟩
nodes are in ground state
00
want

Tr{A

Q. Processor

→ nodes ; ∴ QEC sits on a node



10D

$$\left[\mathcal{H}_{HF},\left[\mathcal{H}_{HF},\mathcal{H}_{Dip}\right]\right] = \underline{\left(\sigma_+^{A}\sigma_-^{B}+\sigma_-^{A}\sigma_+^{B}\right)\left(\sigma_+^{1A}\sigma_-^{1B}+\sigma_-^{1A}\sigma_+^{1B}\right)}$$

nodes a
in g

Coupling to a Cavity

Quantum Rabi Model.

$$\mathcal{H} = \underbrace{\frac{\omega_q}{2}\sigma_z}_{\text{qubit}} + \underbrace{\omega_c\left(a^\dagger a + \tfrac{1}{2}\right)}_{\text{HO}} + g\left(a + a^\dagger\right)\sigma_x$$

coupling constant

$a^\dagger a \equiv N$ = # of excitations in cavity

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

$$a^\dagger|n\rangle = \sqrt{n+1}\,|n+1\rangle$$

$Q \equiv$ quality factor $\sim 10^6$

$$\sigma_x = \sigma_+ + \sigma_-$$

$$\sigma_x\left(a+a^\dagger\right) = \overbrace{\underbrace{\left(\sigma_+ a + \sigma_- a^\dagger\right)}_{\substack{\text{swap an excitation}\\ \text{from qubit to}\\ \text{cavity}}}}^{\omega_q-\omega_c} + \overbrace{\left(\sigma_+ a^\dagger + \sigma_- a\right)}^{\omega_q+\omega_c}$$

create destroy
2 excitations.

Coupling to a Cavity

Quantum Rabi Model.

$|e\rangle$ $\updownarrow \omega_q$
$|g\rangle$

$$\mathcal{H} = \underbrace{\frac{\omega_q}{2}\sigma_z}_{\text{qubit}} + \underbrace{\omega_c\left(a^\dagger a + \tfrac{1}{2}\right)}_{\text{HO}} + g\left(a + a^\dagger\right)\sigma_x$$

coupling constant

$a^\dagger a \equiv N$ = # of excitations in cavity

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

$$a^\dagger|n\rangle = \sqrt{n+1}\,|n+1\rangle$$

$\omega_q + \omega_c$

$+ \sigma_- a)$

destroy

2 excitations

$\sigma_+ |g\rangle = |e\rangle$

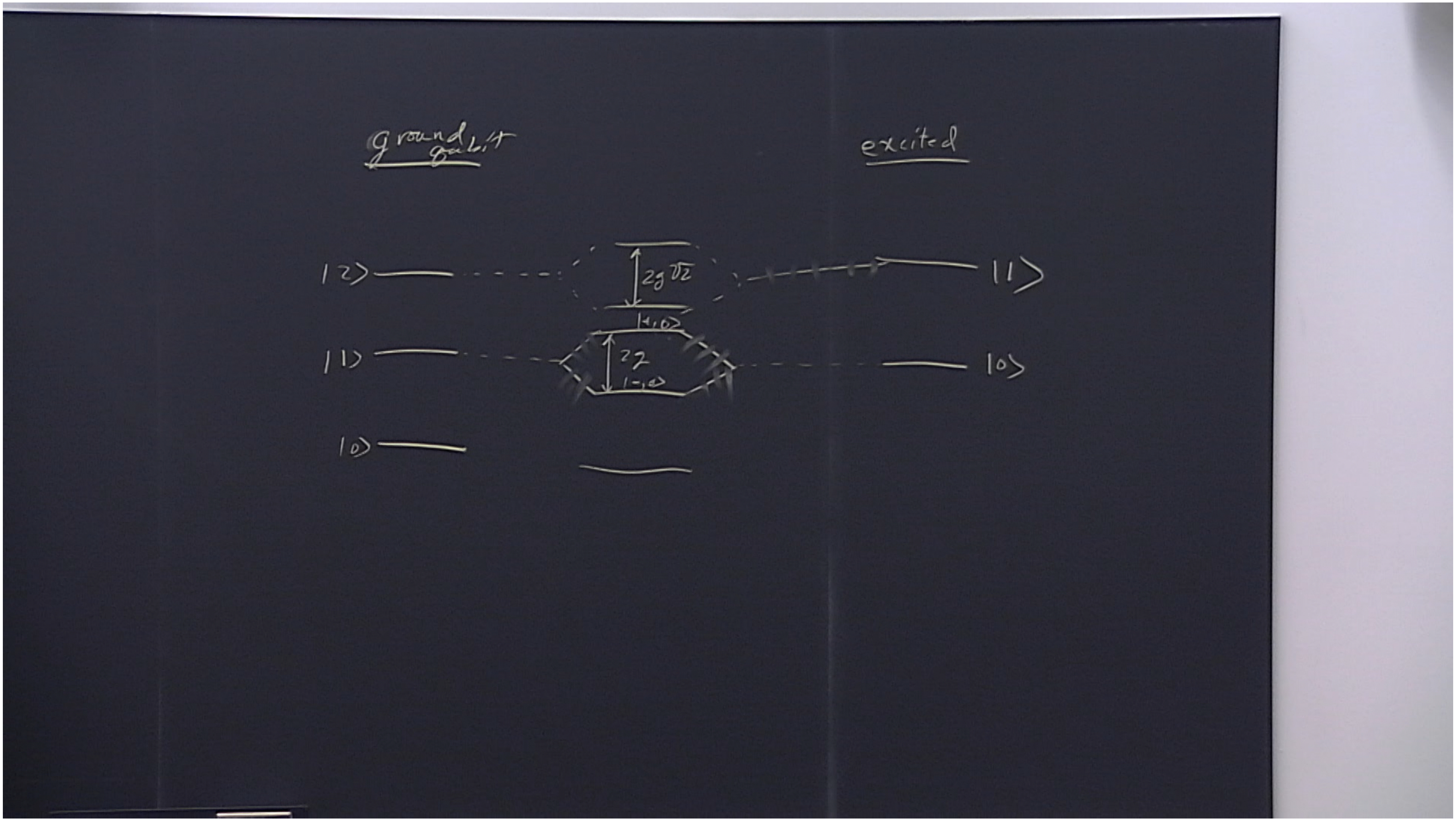
$\sigma_- |e\rangle = |g\rangle$

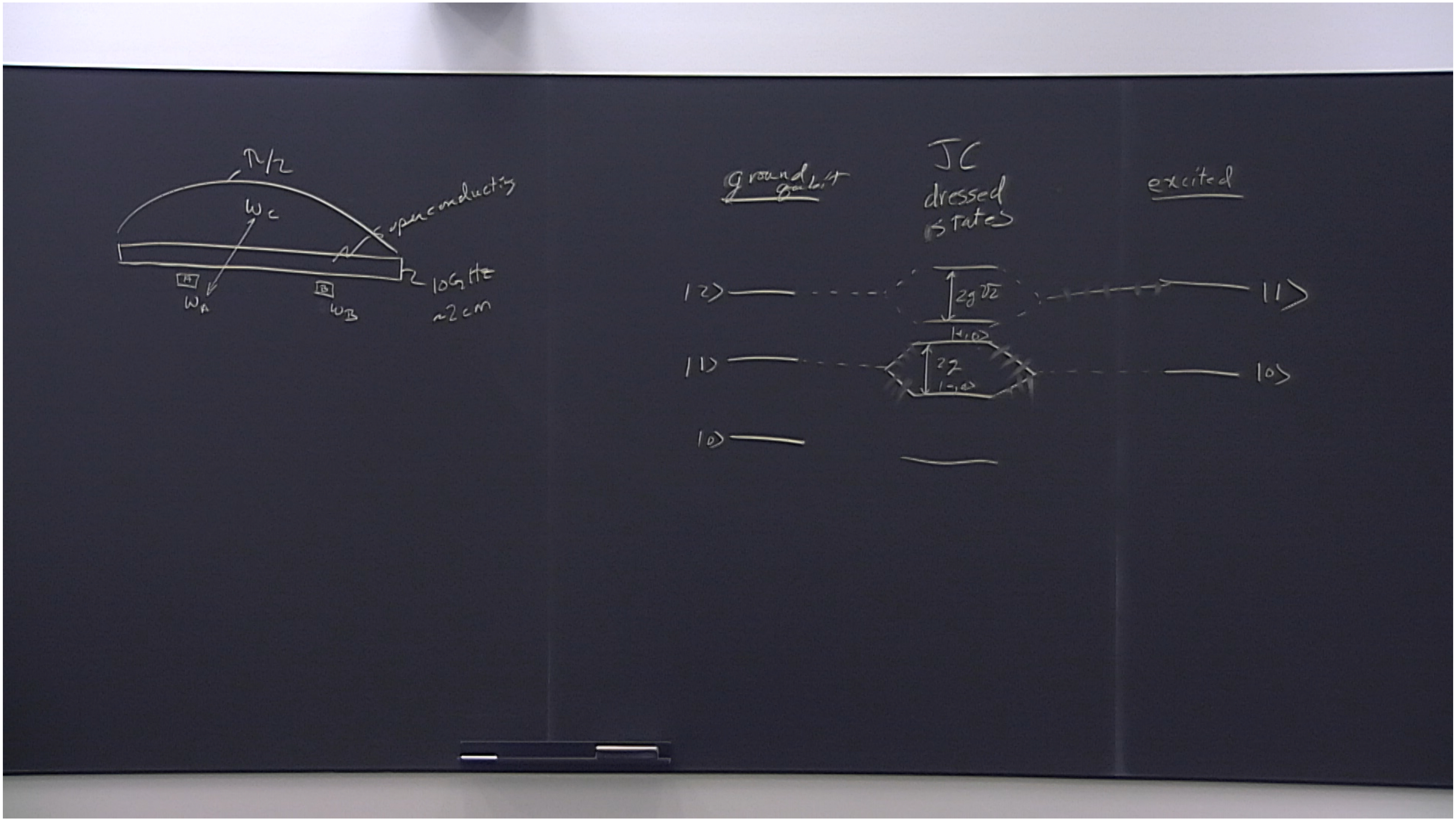
$$\mathcal{H}_{JC} = \frac{\omega_q}{2}\sigma_z + \omega_c\left(a^\dagger a + \tfrac{1}{2}\right) + g\left(a^\dagger\sigma_- + a\sigma_+\right)$$

Jaynes, Cumming

Hilbert space $\{|g\rangle, |e\rangle\} \otimes \{|n\rangle\}$

$$\boxed{\begin{aligned} \mathcal{H}_{JC}|g,n+1\rangle &= \left(-\frac{\omega_q}{2} + \omega_c(n+\tfrac{3}{2})\right)|g,n+1\rangle + g\sqrt{n+1}\,|e,n\rangle \\ \mathcal{H}_{JC}|e,n\rangle &= \left(\frac{\omega_q}{2} + \omega_c(n+1)\right)|e,n\rangle + g\sqrt{n+1}\,|g,n+1\rangle \end{aligned}}$$


ground
excited
|2>
|1>
|0>
2g√2
|+,0>
2g
|−,0>
|1>
|0>


π/2
ω_c
superconducting
10GHz
~2cm
ω_A
ω_B
A
B
ground qubit
JC
dressed
states
excited
|2>
|1>
|0>
2g√2
2g
|1>
|0>