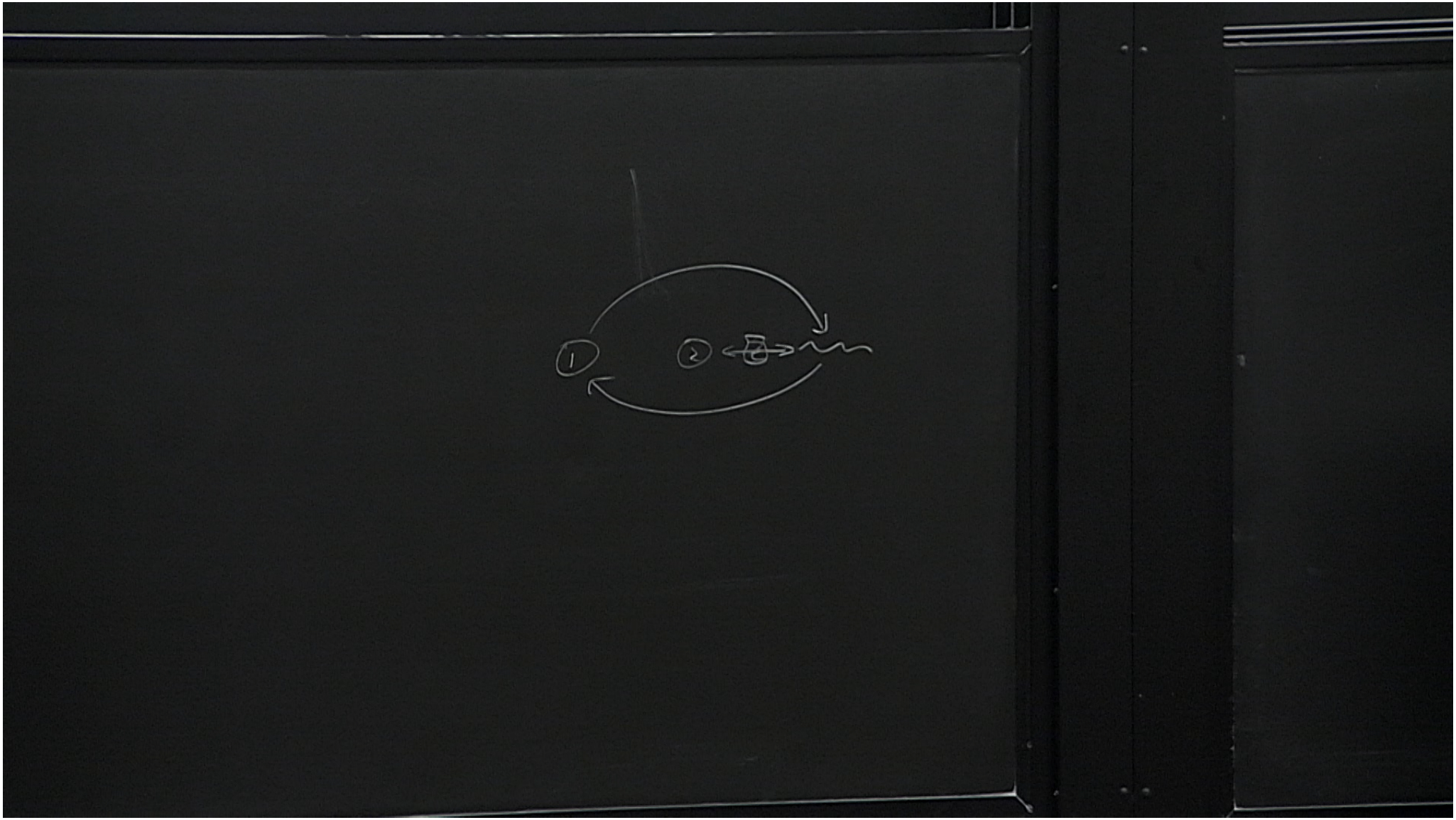
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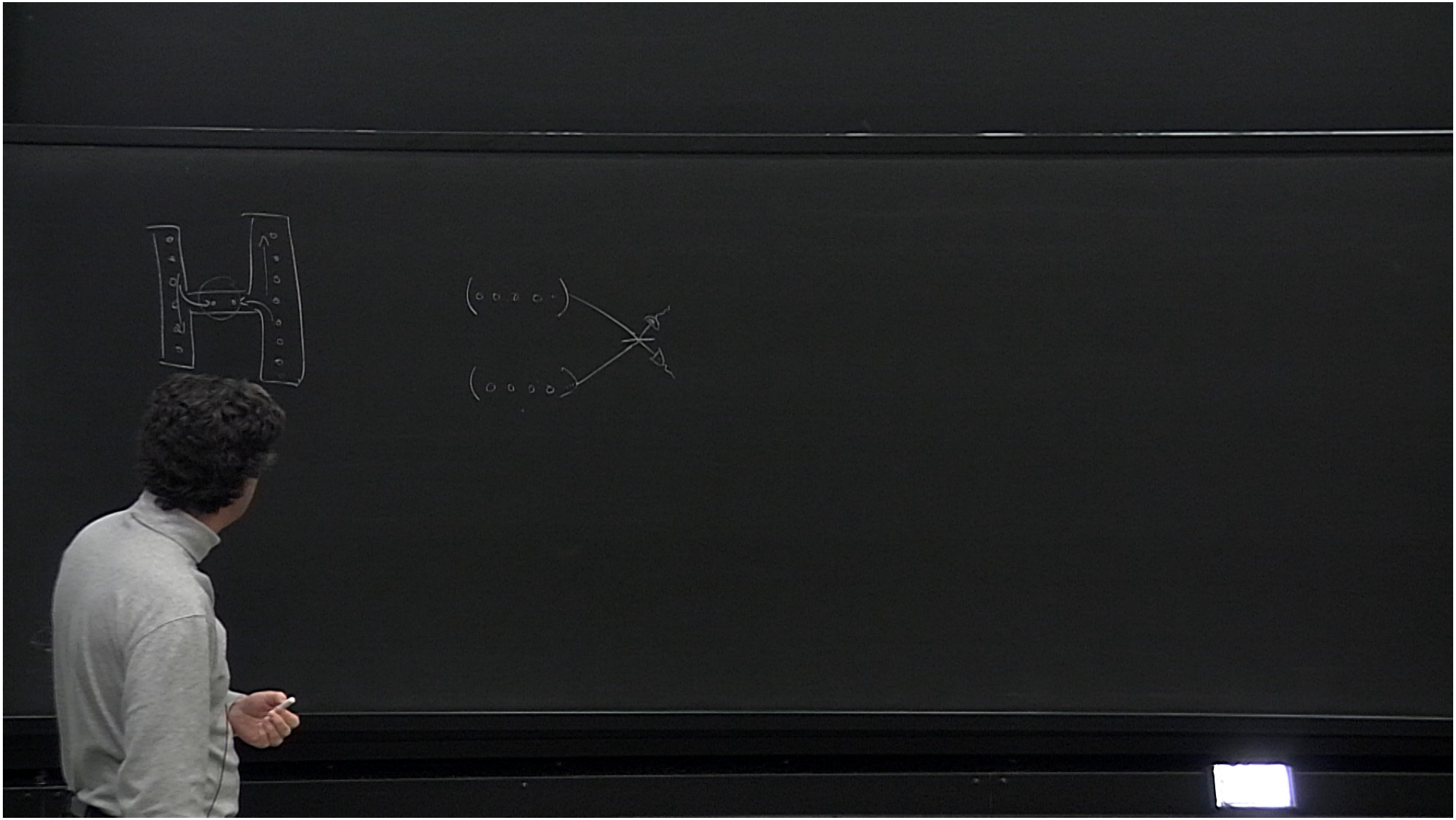
Speakers: Daniel Gottesman

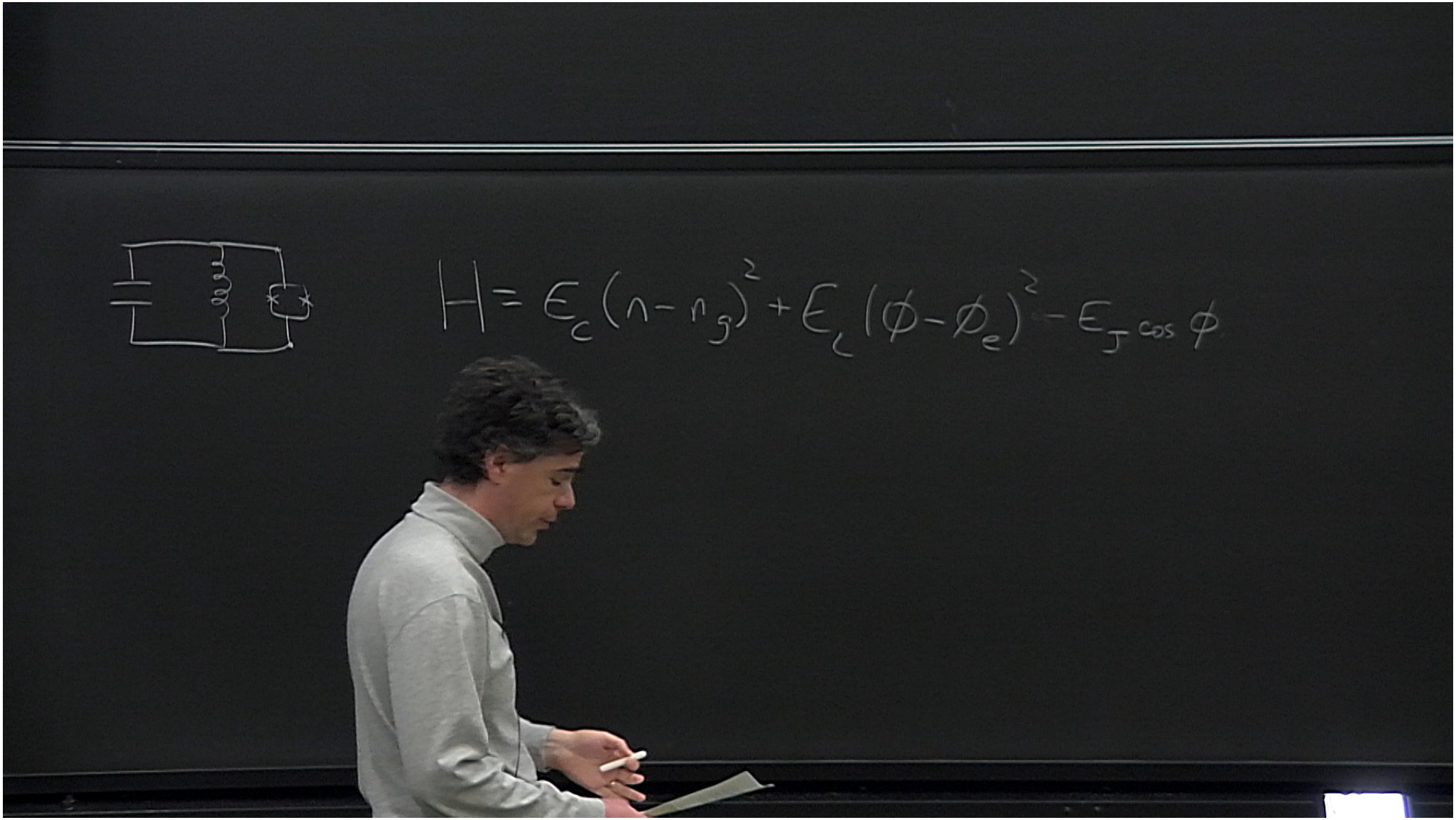
Collection: PSI 2018/2019 - Quantum Information Review (Gottesman)

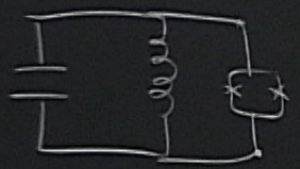
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1
2



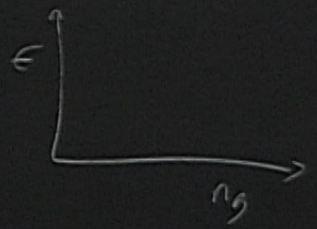

$H = E_c(n - n_g)^2 + E_L(\phi - \phi_e)^2 - E_J \cos\phi$

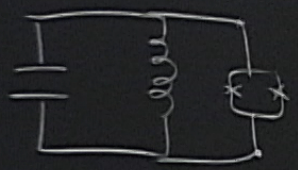


$$H = 4E_c(n - n_g)^2 + \left[\frac{1}{2}E_L(\phi - \phi_e)^2\right] - E_J \cos\phi$$

E_J/E_c small

E_J/E_c large

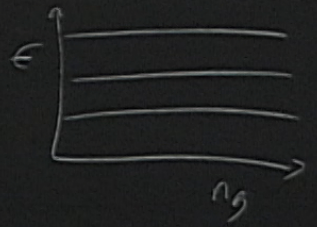


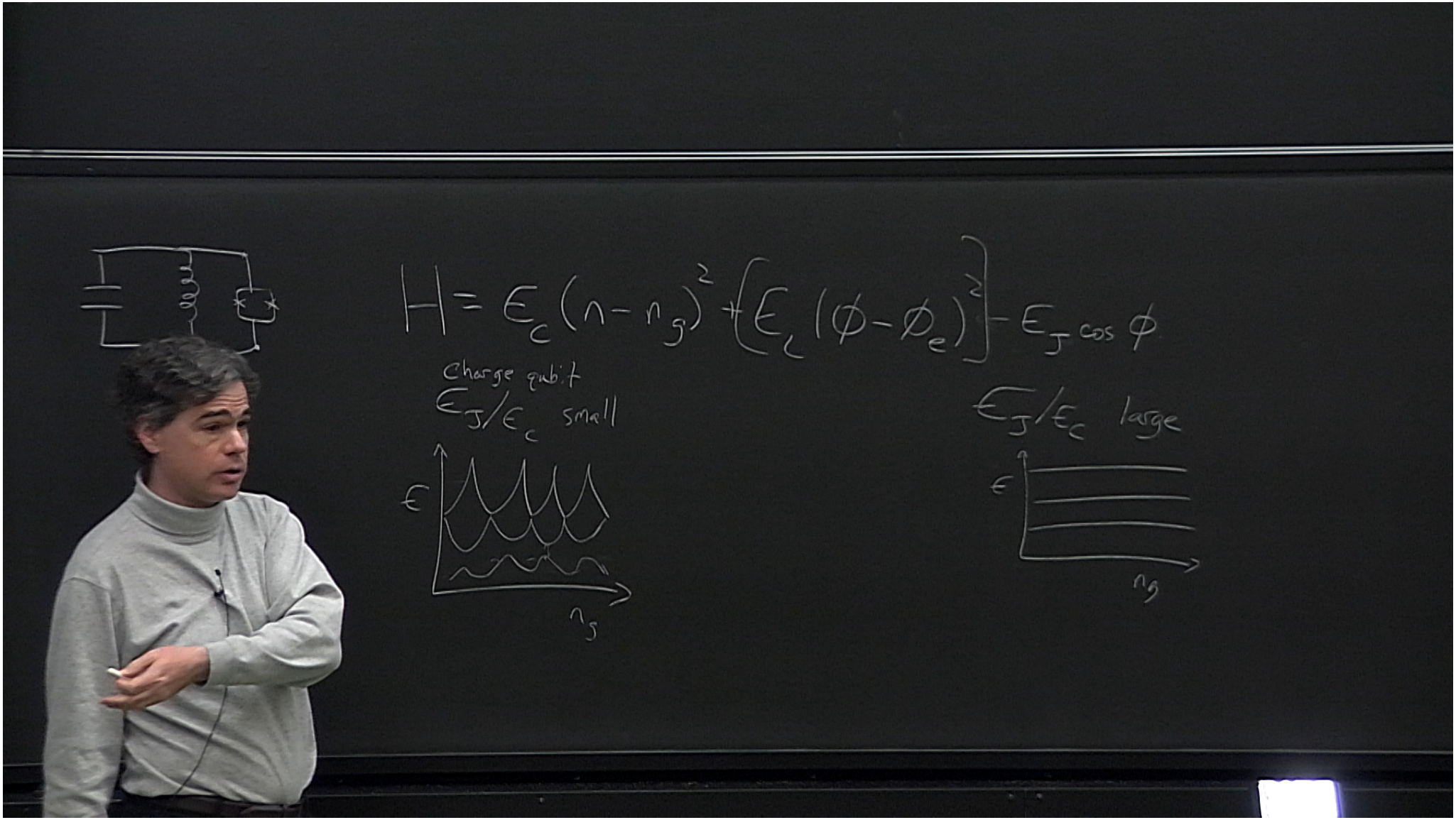


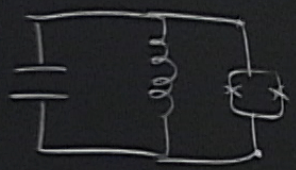
$$H = E_c (n - n_g)^2 + \left[E_L (\phi - \phi_e)^2 \right] - E_J \cos\phi$$

E_J/E_c small

E_J/E_c large



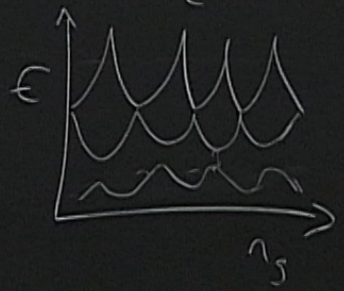

$H = E_c(n - n_g)^2 + \left[\frac{E_L}{2}(\phi - \phi_e)^2\right] - E_J \cos\phi$
charge qubit
E_J/E_c small
E
n_g
E_J/E_c large
E
n_g



$$H = E_c (n - n_g)^2 + \left[E_L (\phi - \phi_e)^2 \right] - E_J \cos\phi$$

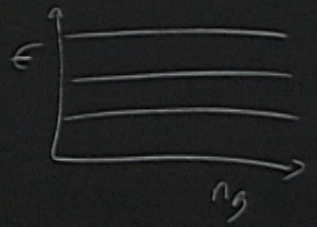
Charge qubit

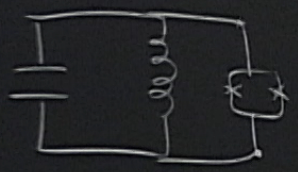
E_J/E_c small



Flux

E_J/E_c large

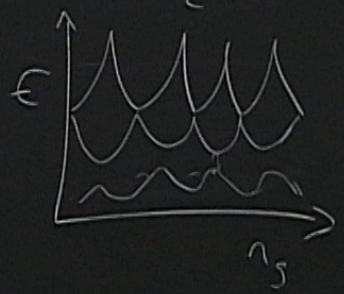




$$H = 4E_c(n - n_g)^2 + \left[\tfrac{1}{2}E_L(\phi - \phi_e)^2\right] - E_J \cos\phi$$

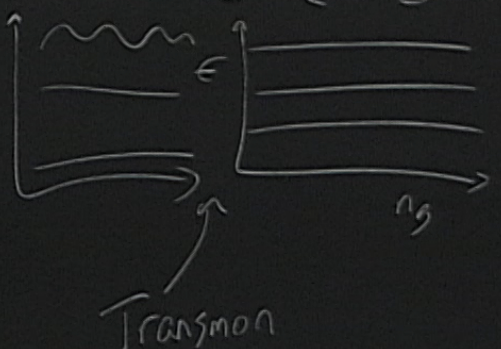
Charge qubit

E_J/E_c small

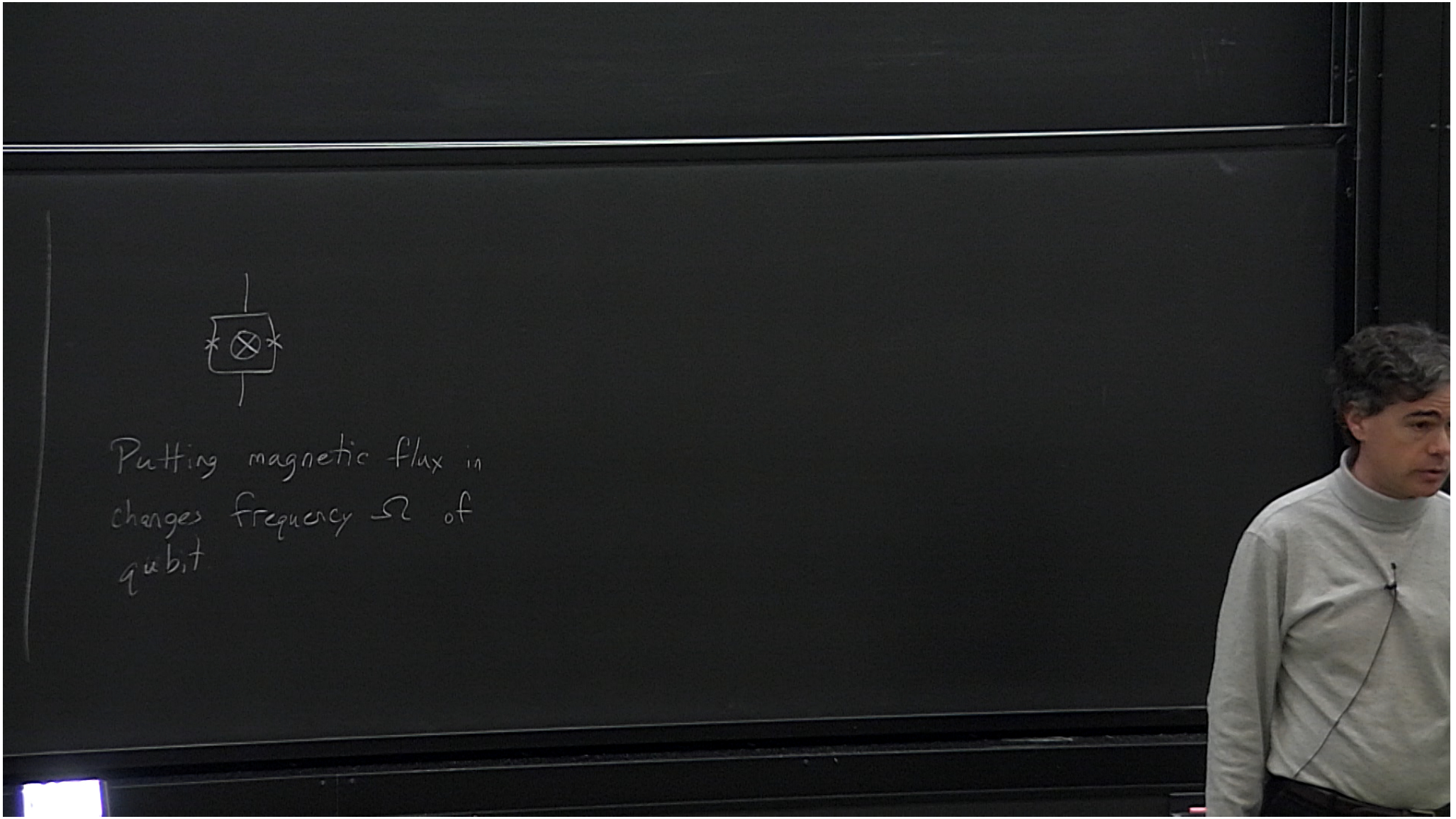


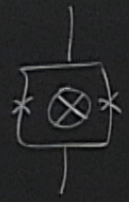
Flux

E_J/E_c large



Transmon

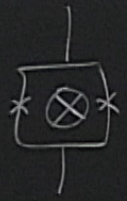

Putting magnetic flux in
changes frequency Ω of
qubit



Putting magnetic flux in changes frequency Ω of qubit

$$H \approx \hbar\omega a^\dagger a + \hbar\frac{\Omega}{2}\sigma^z + \hbar g\left(a^\dagger\sigma^- + a\sigma^+\right)$$

$$\sigma^\pm = (\sigma^x \pm i\sigma^y)/2$$



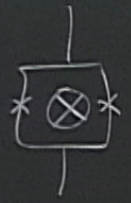
Putting magnetic flux in changes frequency Ω of qubit

Jaynes-Cummings Hamiltonian

$$H \approx \hbar\omega a^\dagger a + \hbar\frac{\Omega}{2}\sigma^z + \hbar g\left(a^\dagger\sigma^- + a\sigma^+\right)$$

$$\sigma^\pm = (\sigma^x \pm i\sigma^y)/2$$

Strong microwaves $\Rightarrow$ measurement



Putting magnetic flux in changes frequency Ω of qubit

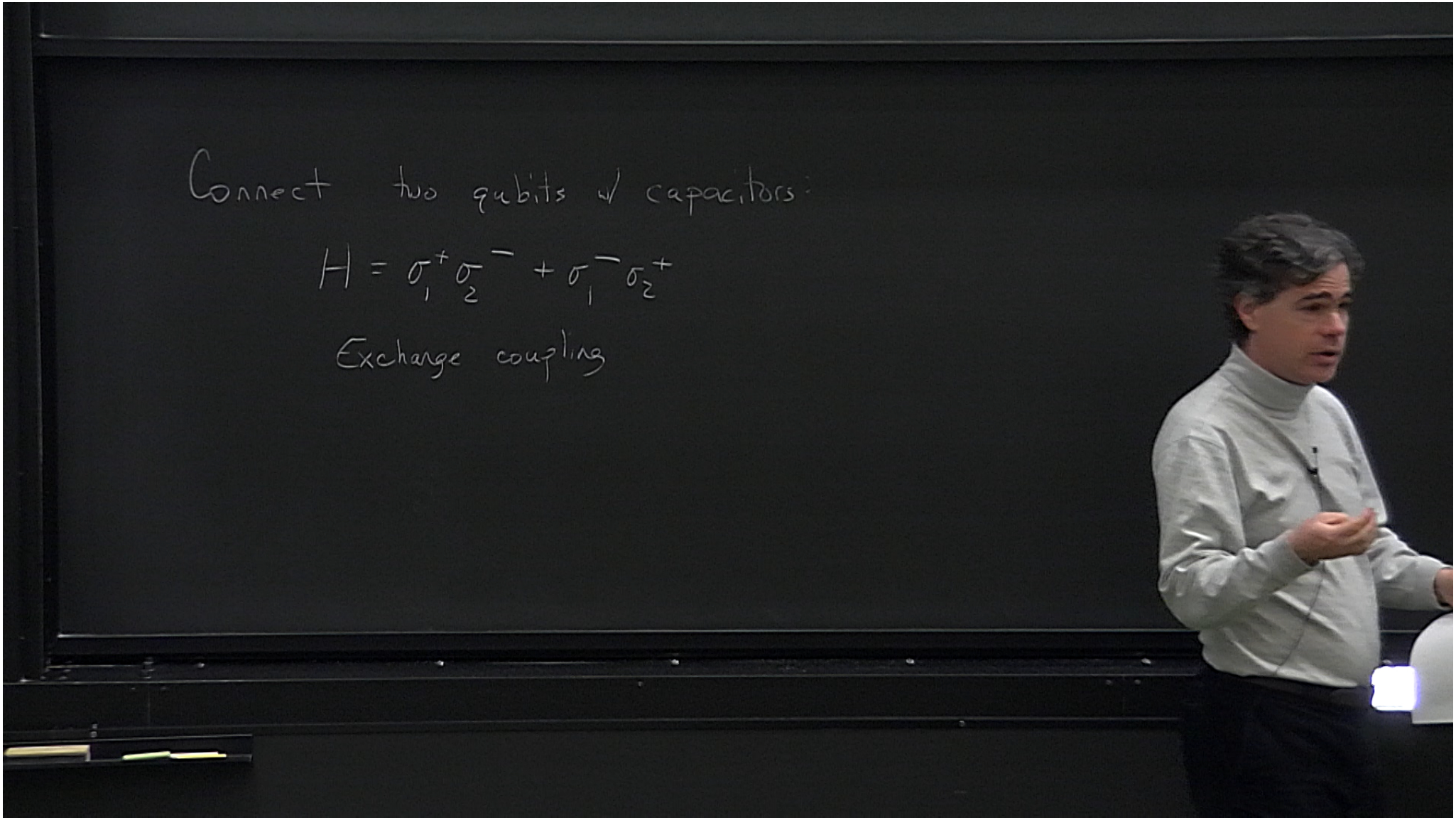
Jaynes-Cummings Hamiltonian

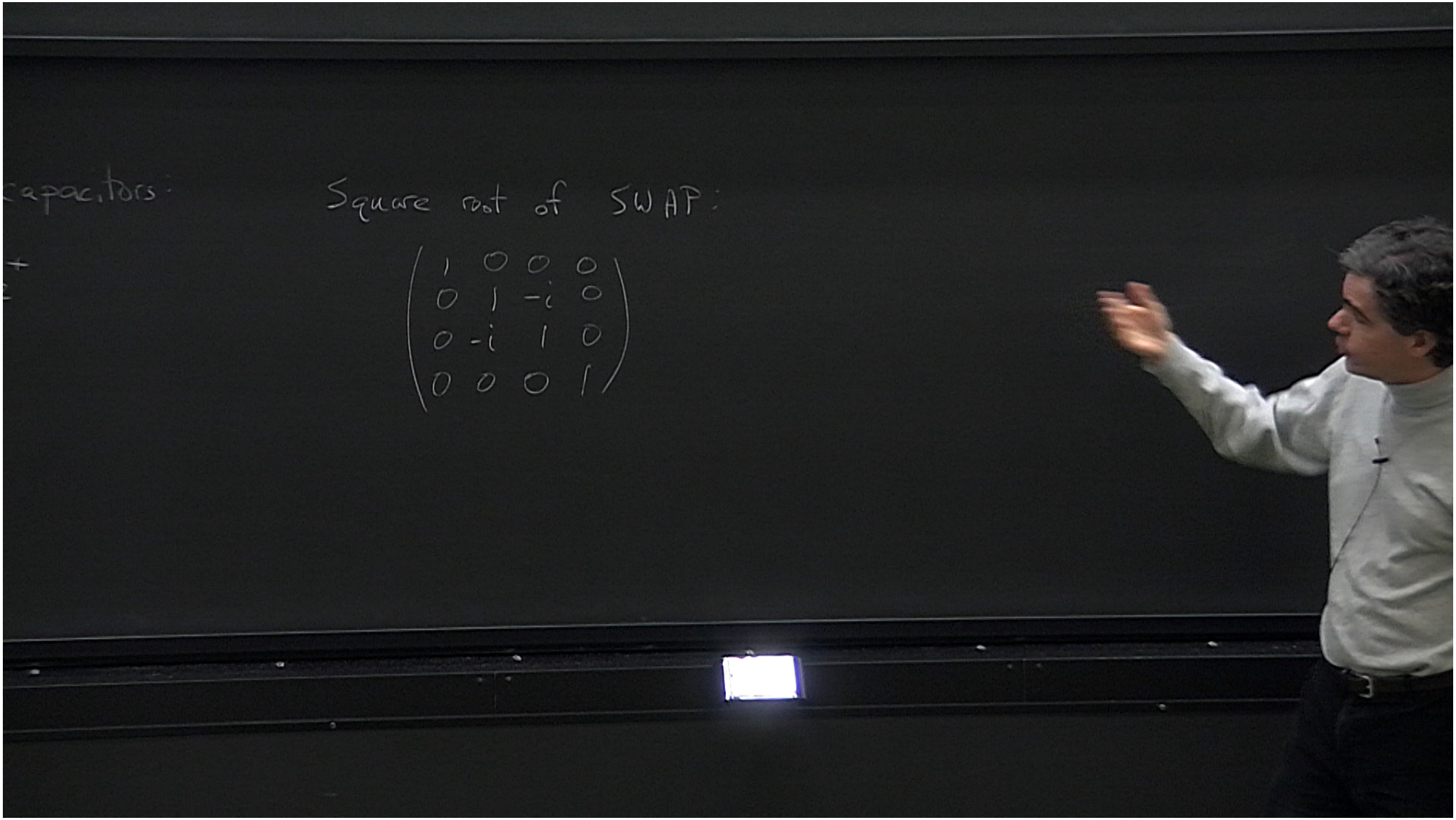
$$H \approx \hbar\omega a^\dagger a + \hbar\frac{\Omega}{2}\sigma^z + \hbar g\left(a^\dagger\sigma^- + a\sigma^+\right)$$

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Strong microwaves $\Rightarrow$ measurement

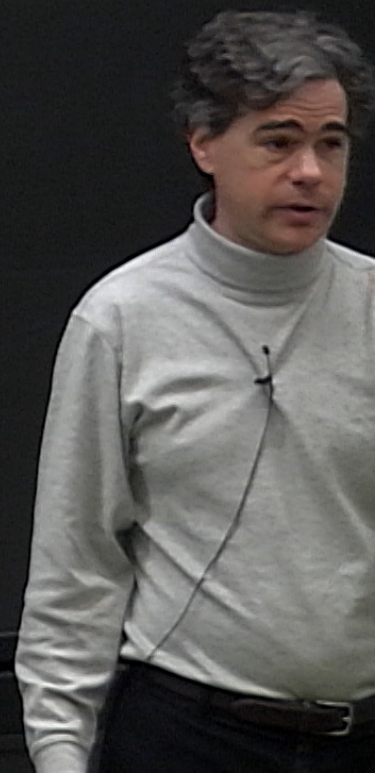
Weaker pulses $\Rightarrow$ X or Y rotations

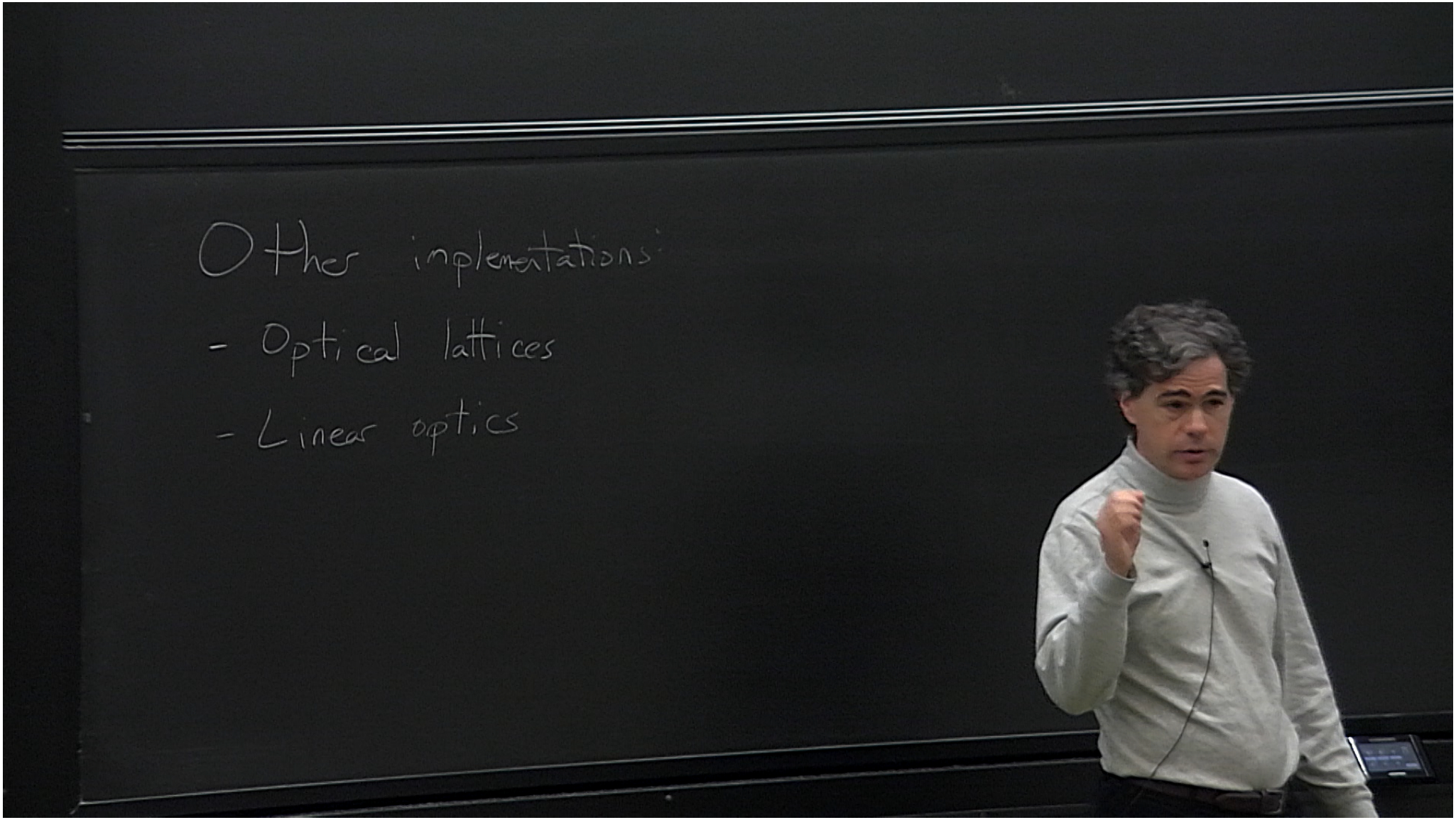

Connect two qubits w/ capacitors:
$H = \sigma_1^+ \sigma_2^- + \sigma_1^- \sigma_2^+$
Exchange coupling

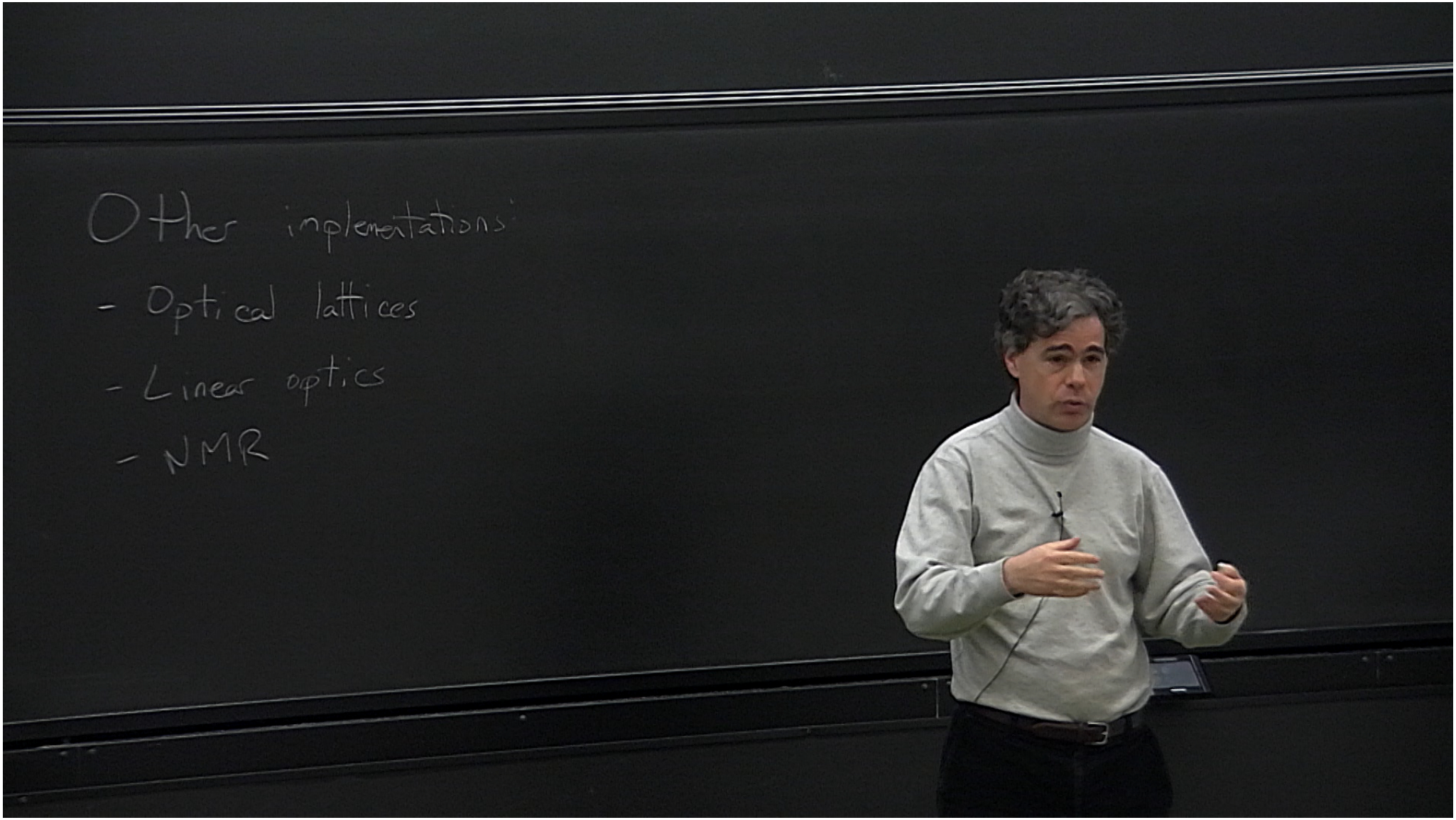

capacitors:
Square root of SWAP:
$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -i & 0 \\ 0 & -i & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

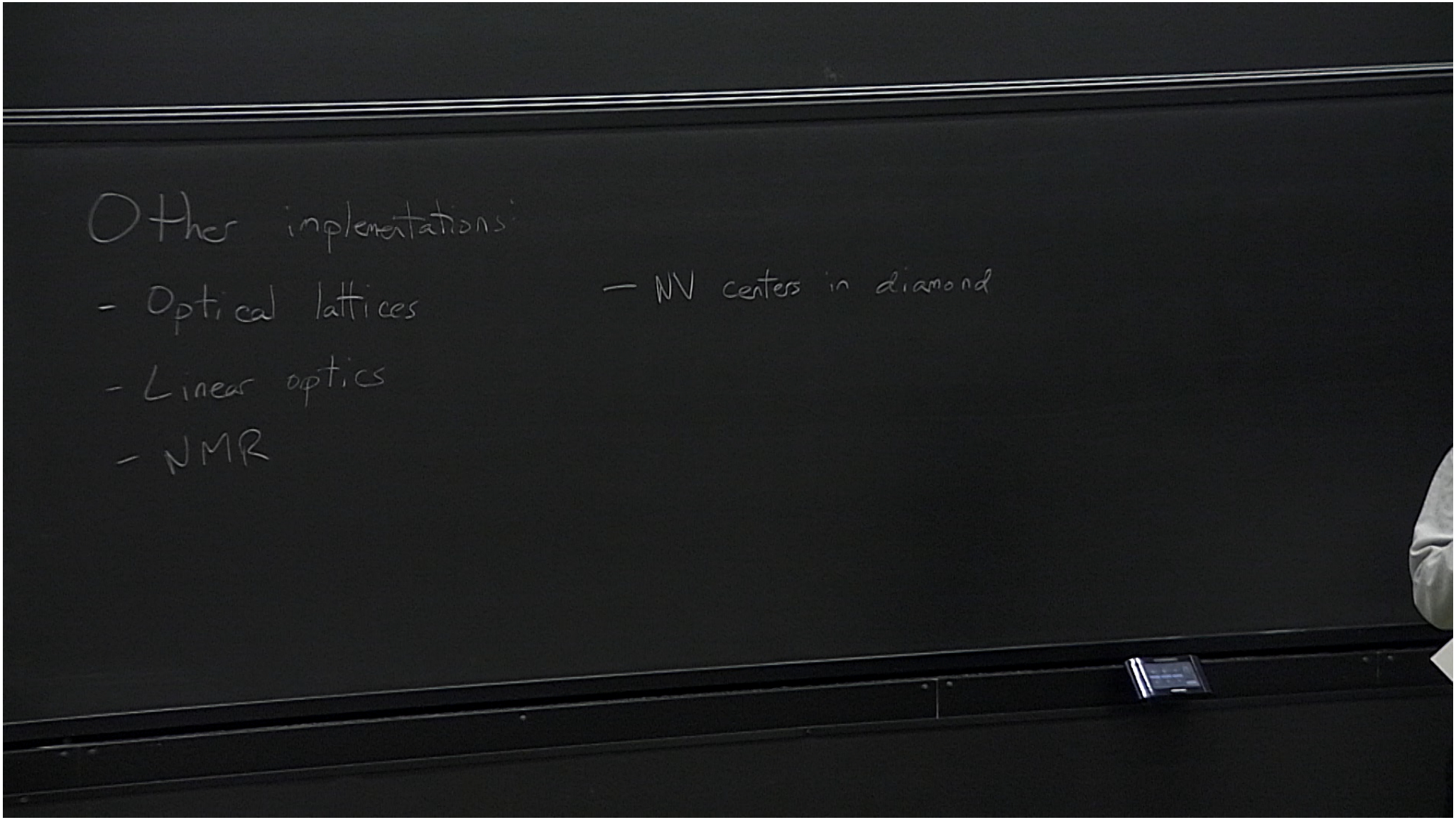
Other implementations:

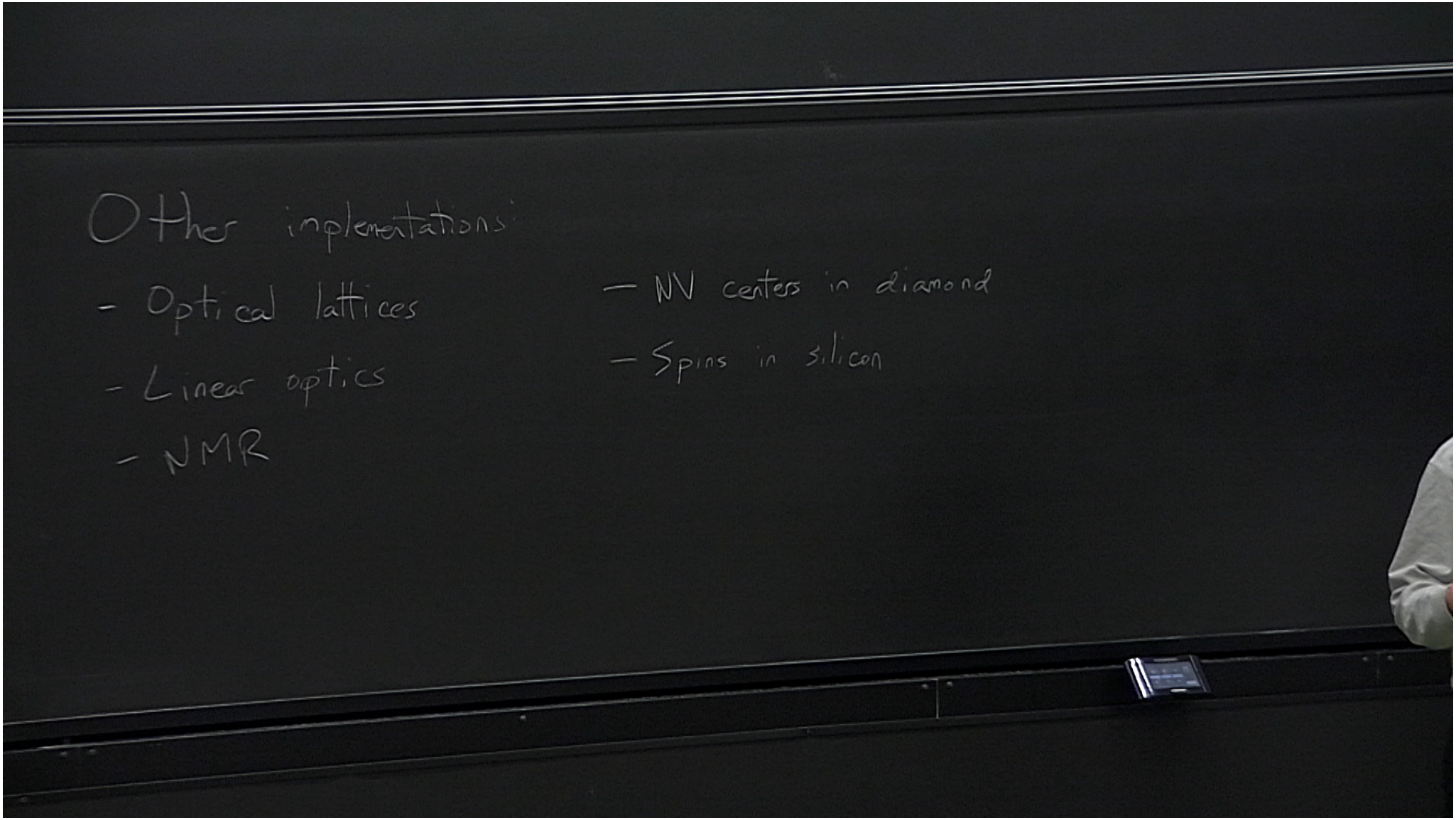
- Optical lattices

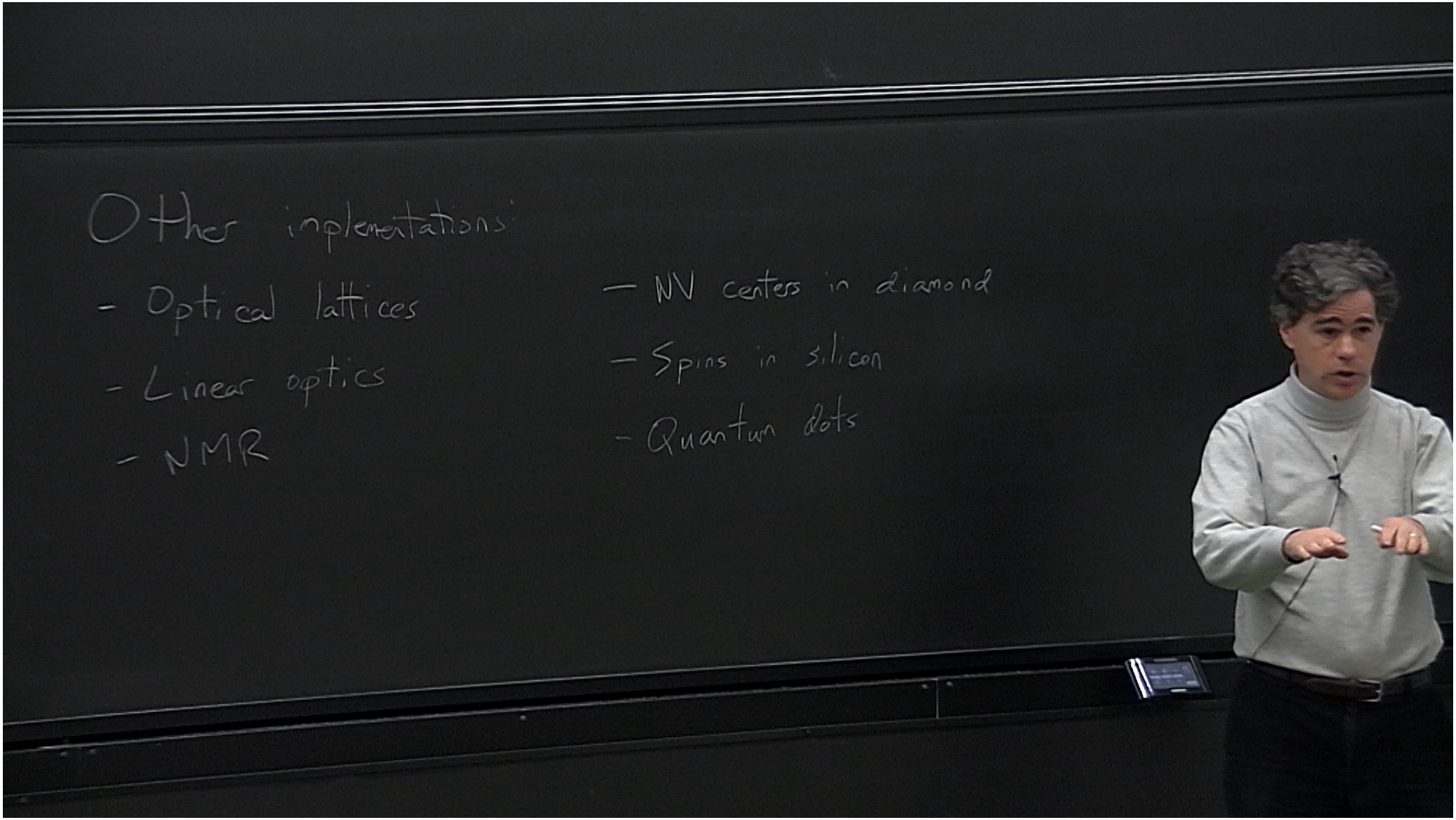



Other implementations:
- Optical lattices
- Linear optics


Other implementations:
- Optical lattices
- Linear optics
- NMR


Other implementations:
- Optical lattices
- Linear optics
- NMR
- NV centers in diamond


Other implementations:
- Optical lattices
- Linear optics
- NMR
- NV centers in diamond
- Spins in silicon


Other implementations:
- Optical lattices
- Linear optics
- NMR
- NV centers in diamond
- Spins in silicon
- Quantum dots