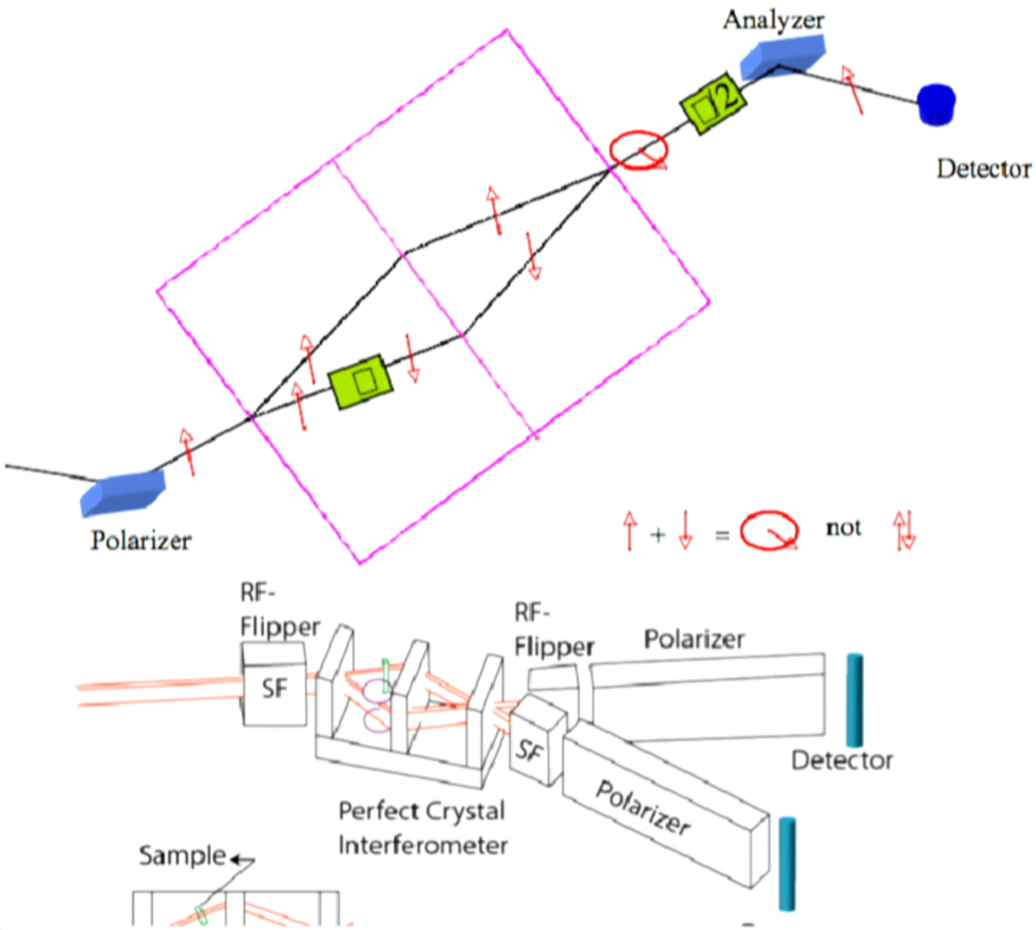
Title: Explorations in Quantum Information - Lecture 6

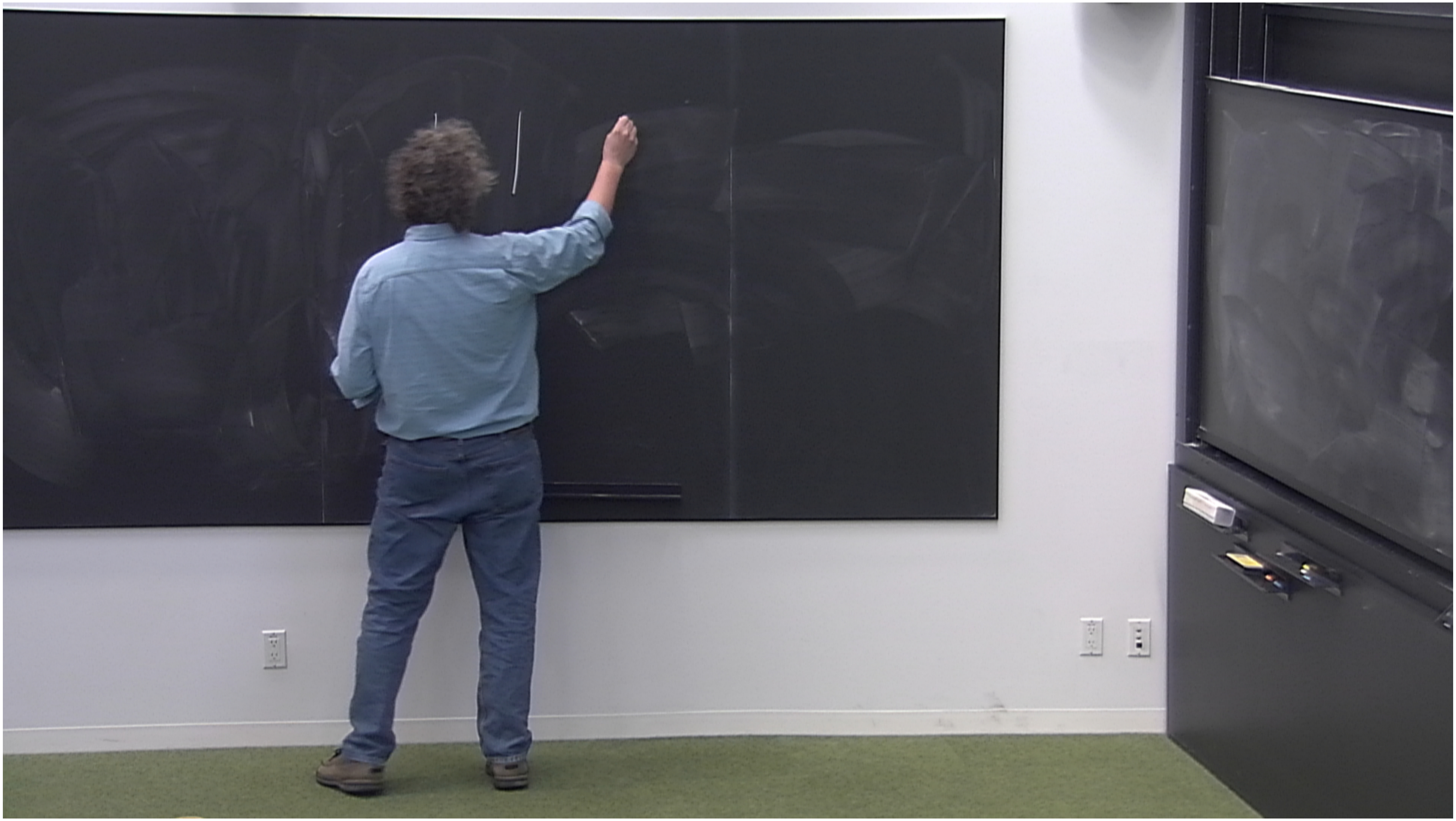
Date: Mar 19, 2012 02:00 PM

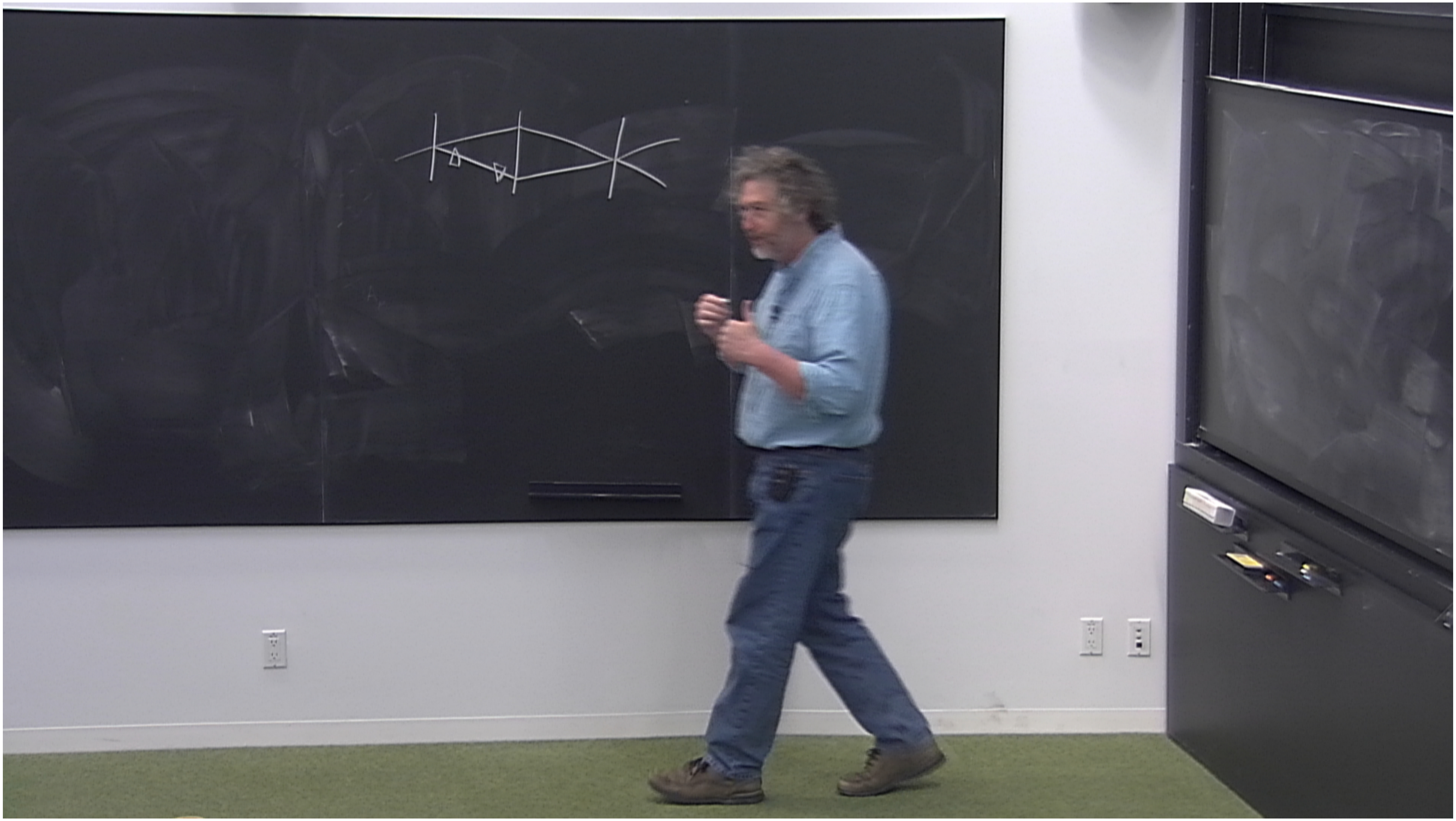
URL: http://pirsa.org/12030008

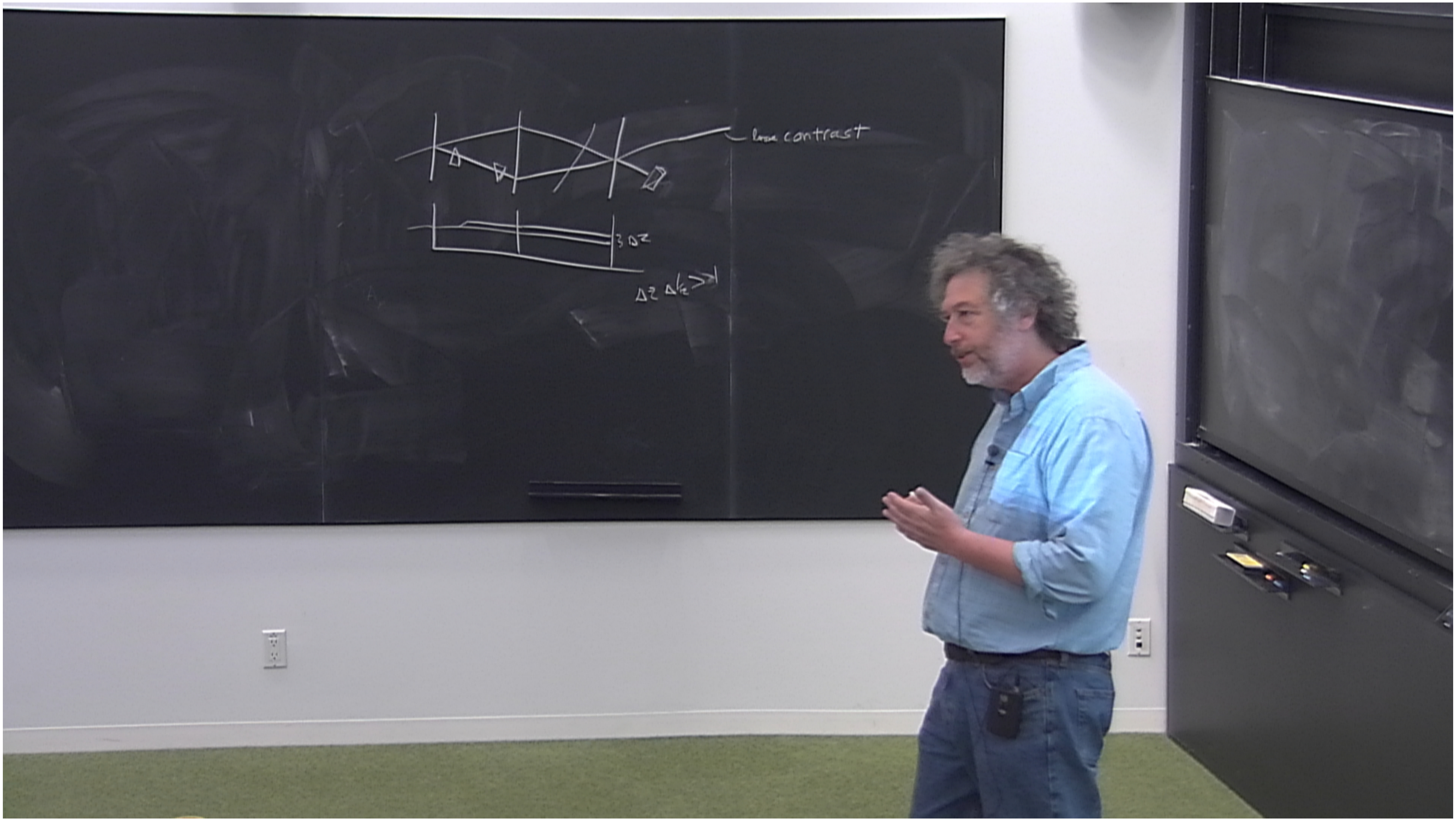
Abstract:

Operators for various components

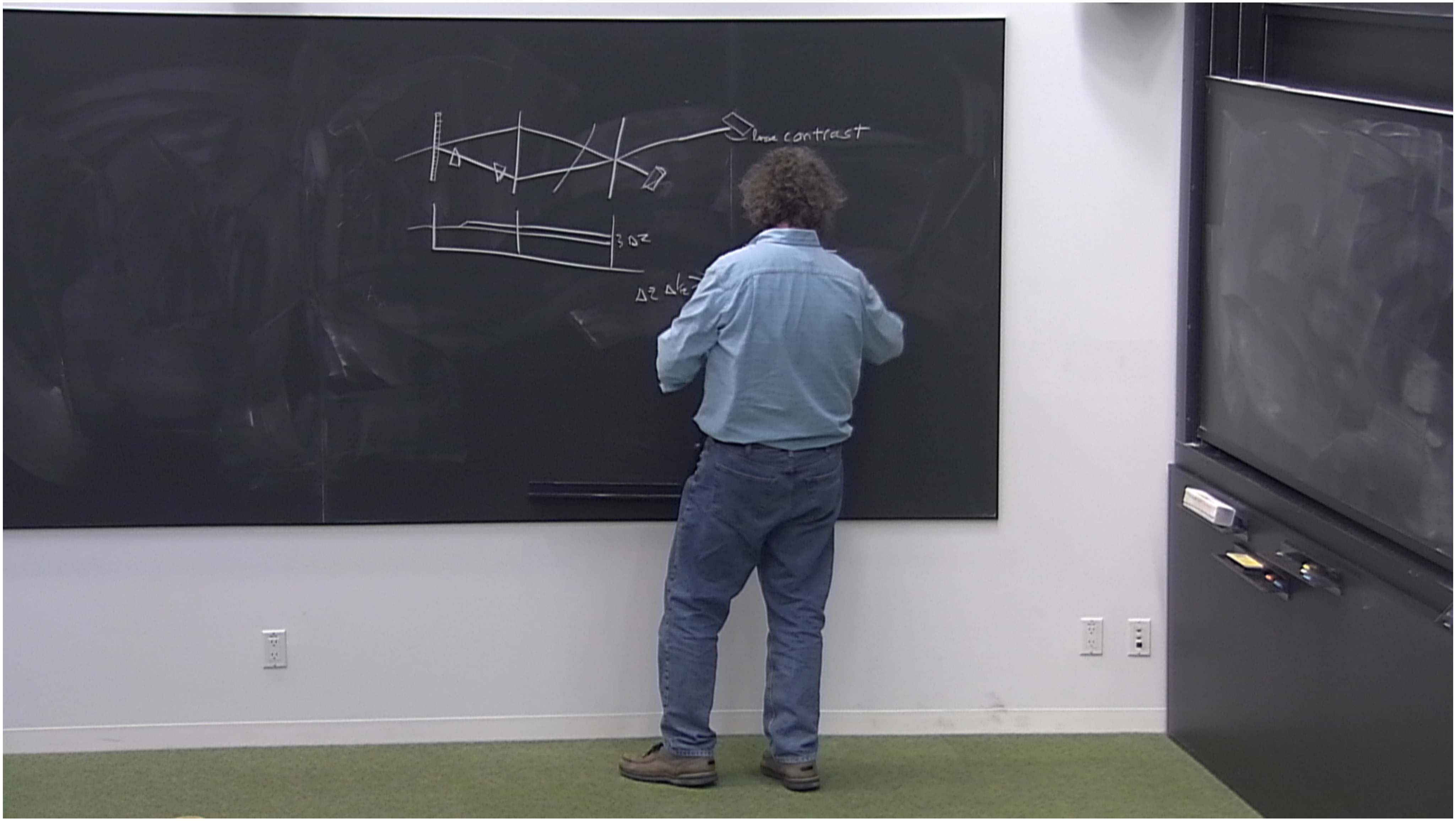


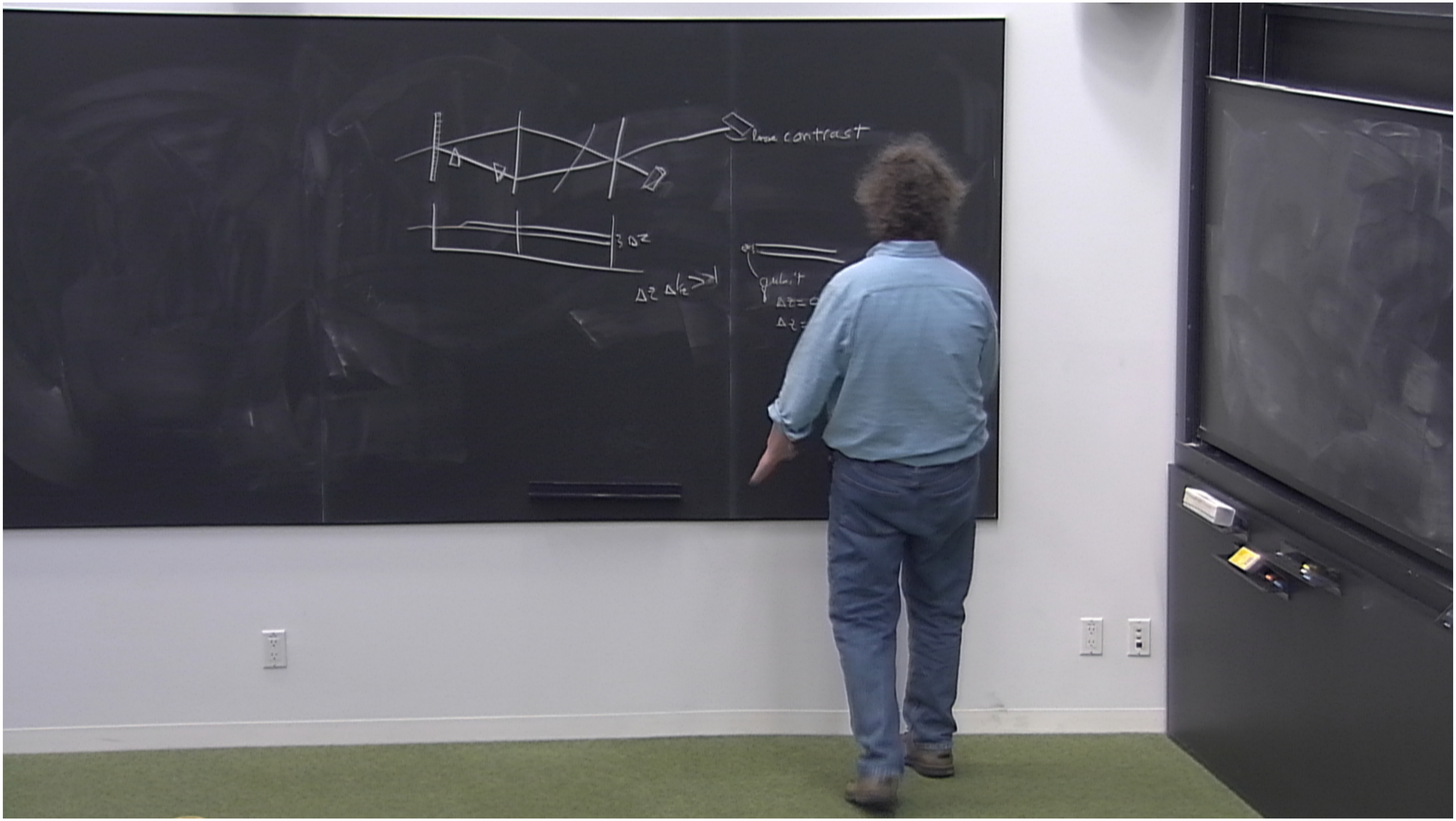


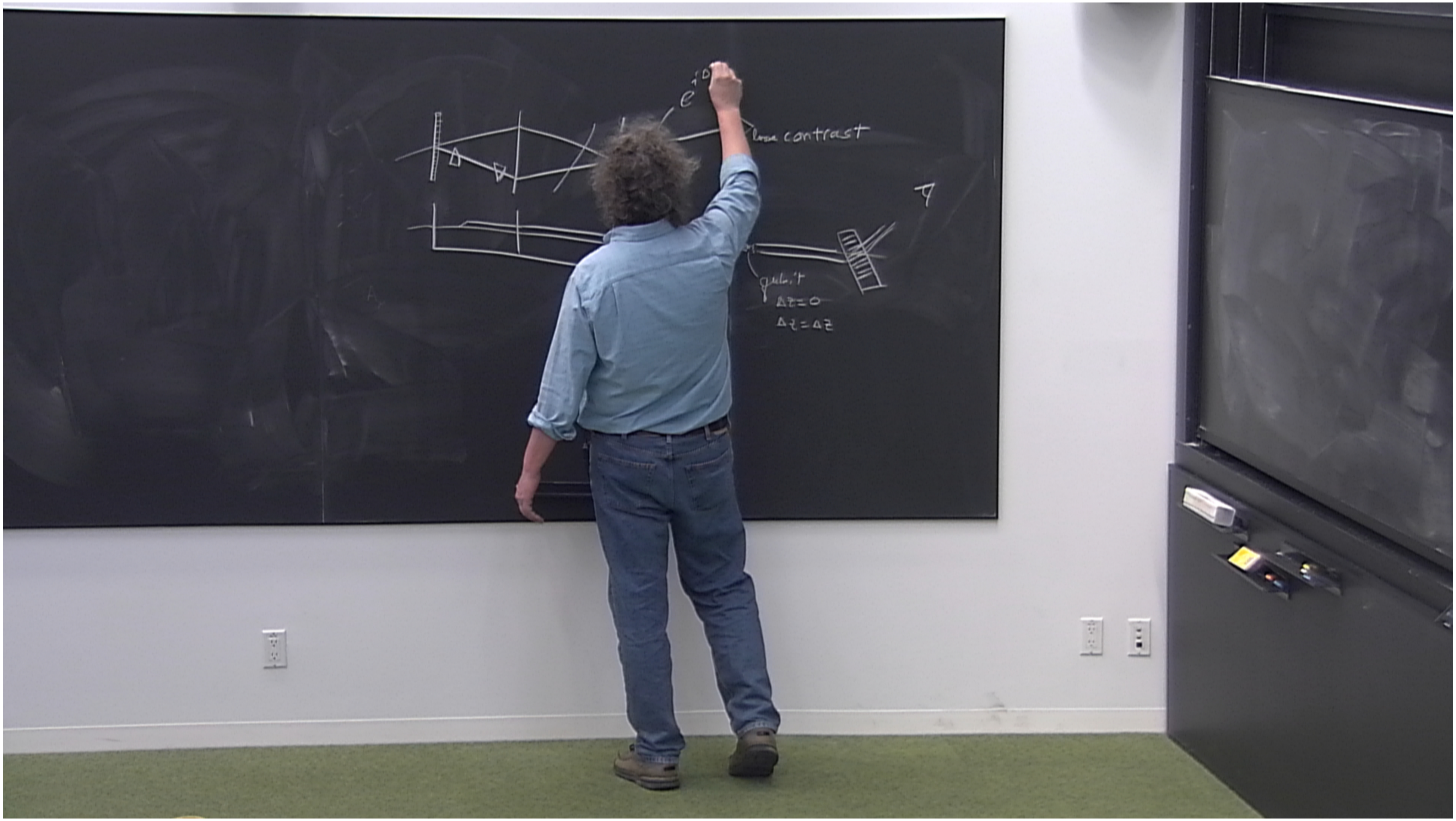


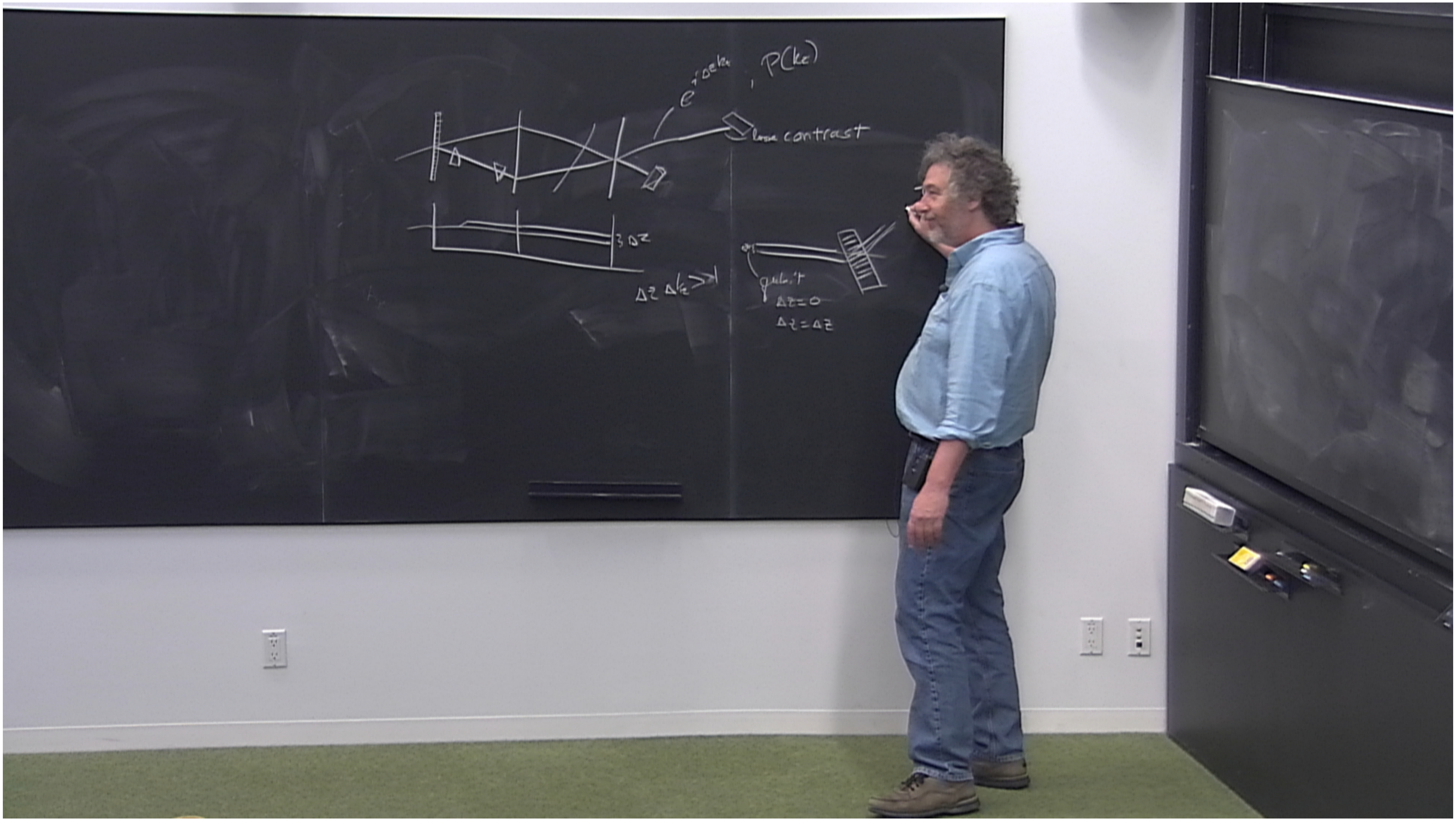

contrast

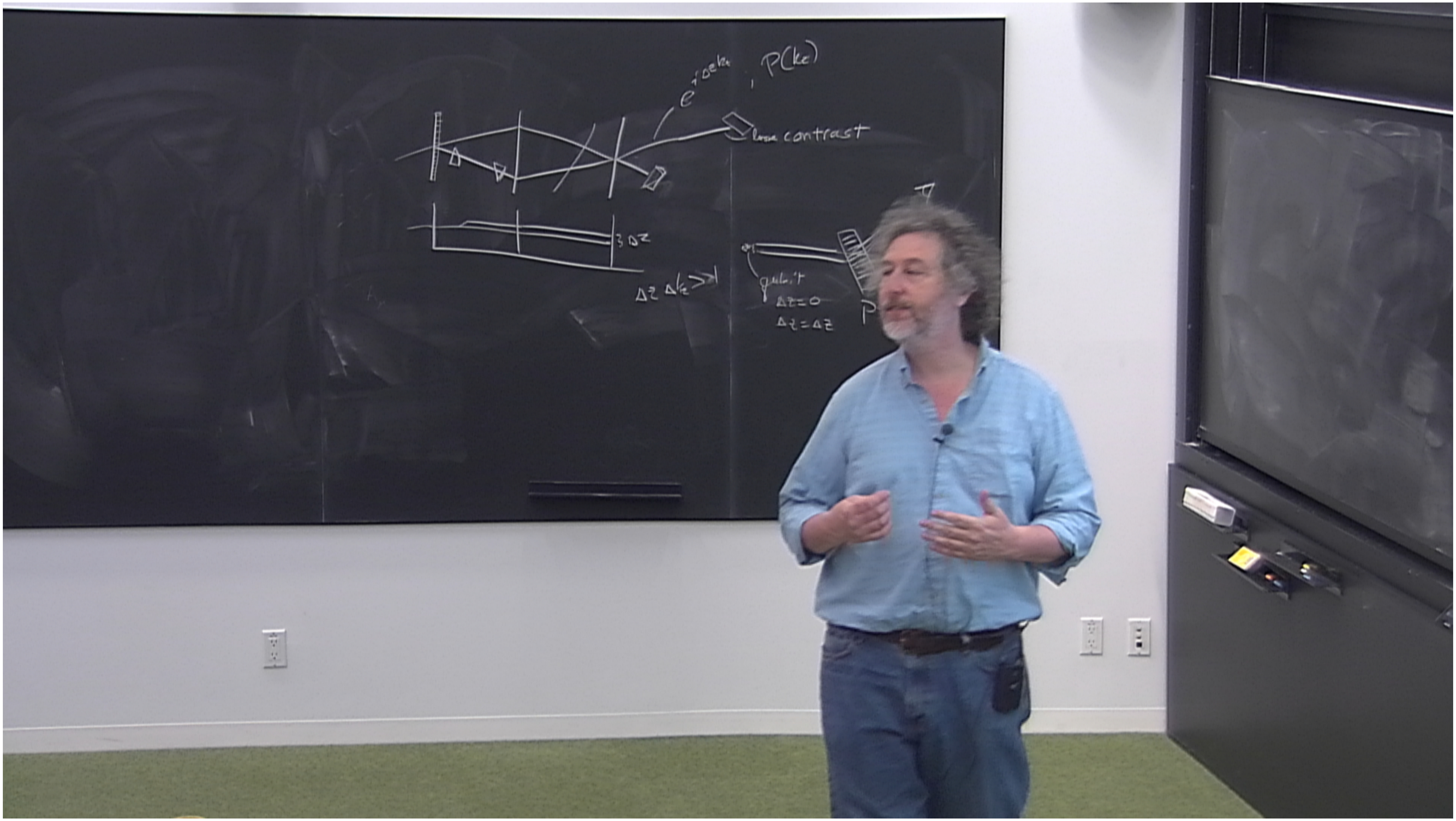

contrast

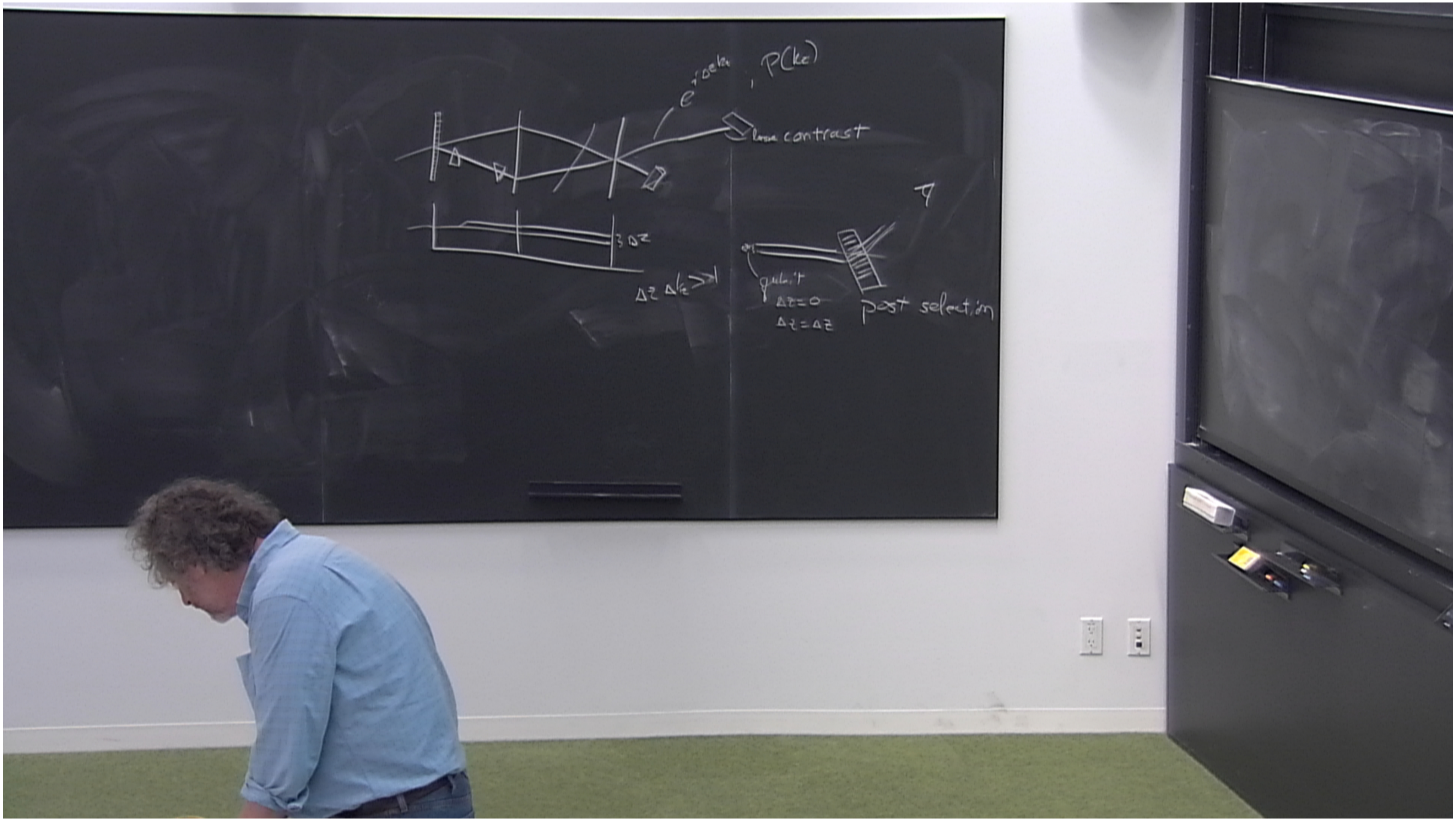

contrast
3 Δz


contrast
qubit

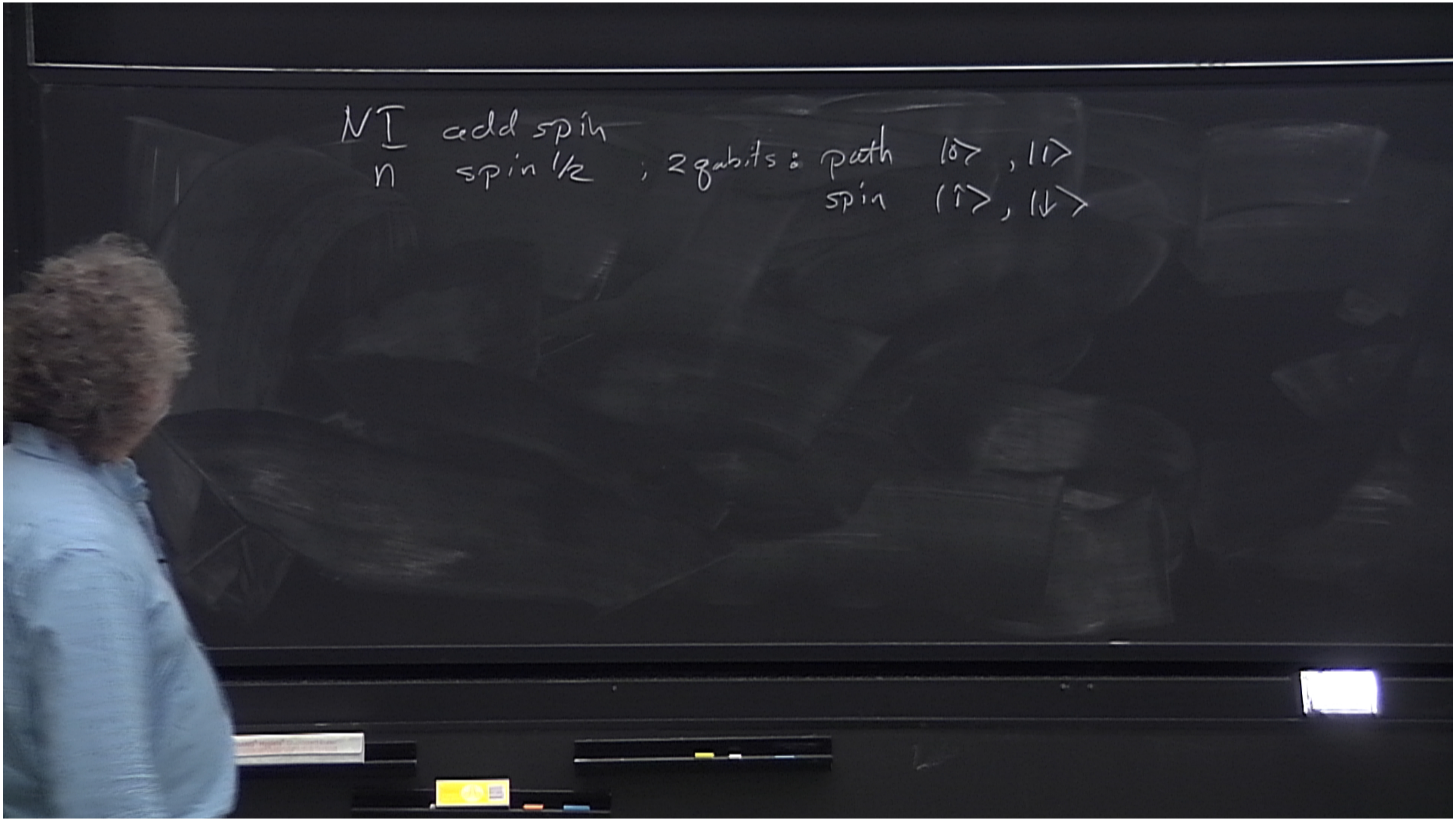

contrast
qubit
ΔZ=0
ΔZ=ΔZ

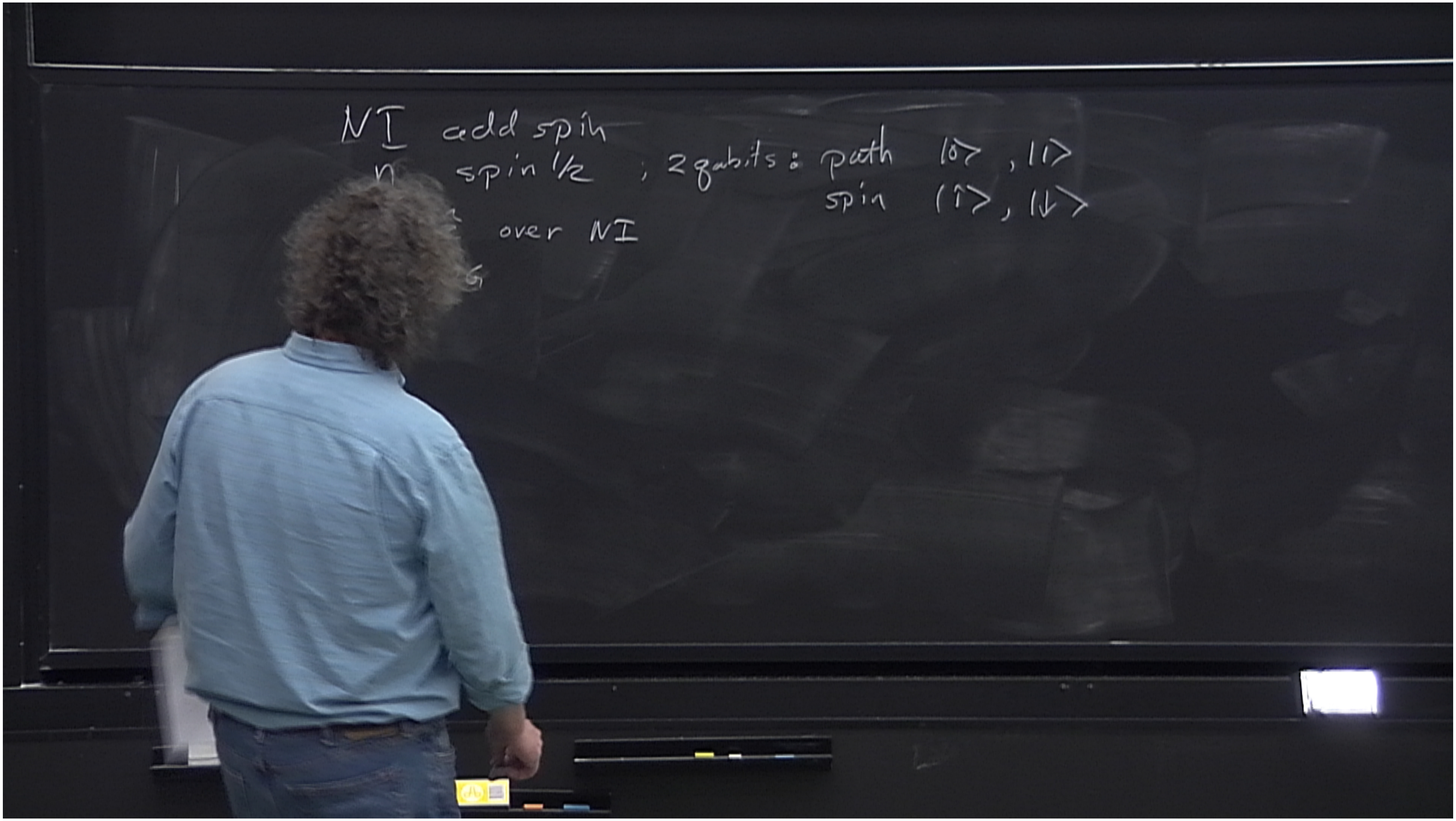

contrast
3Δz
Δz

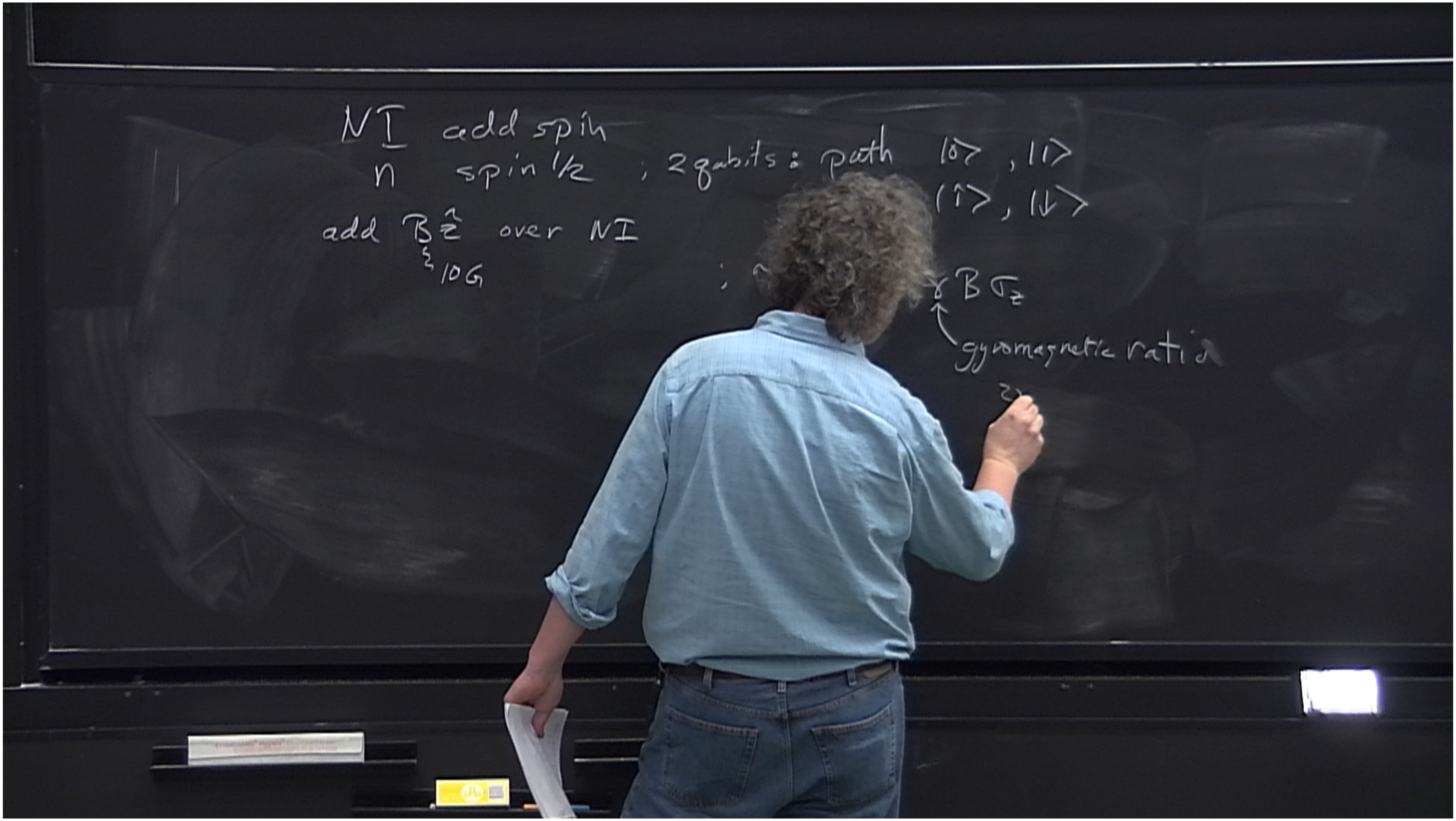

contrast

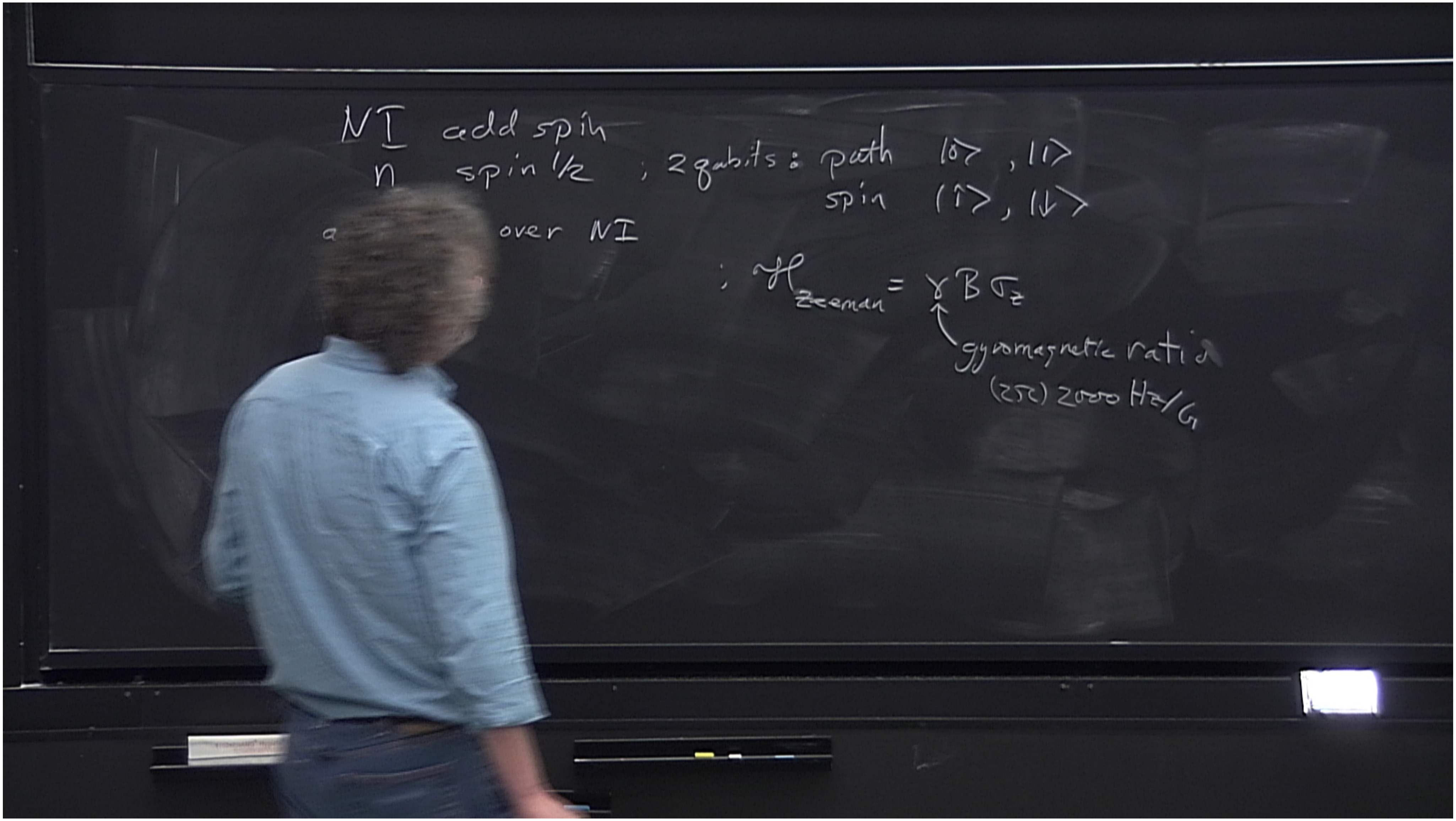


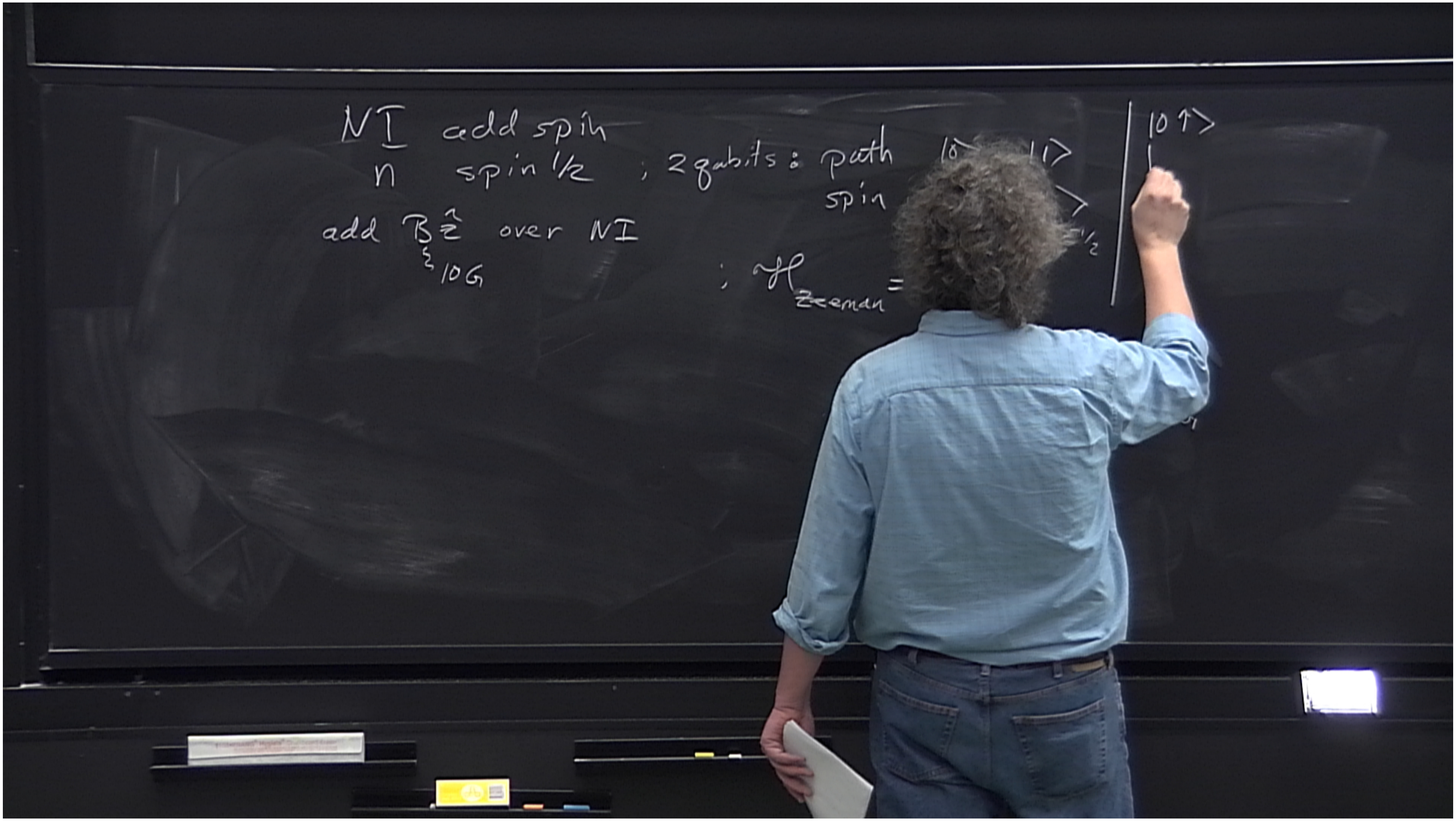
P(kz)
contrast
post selection
qubit

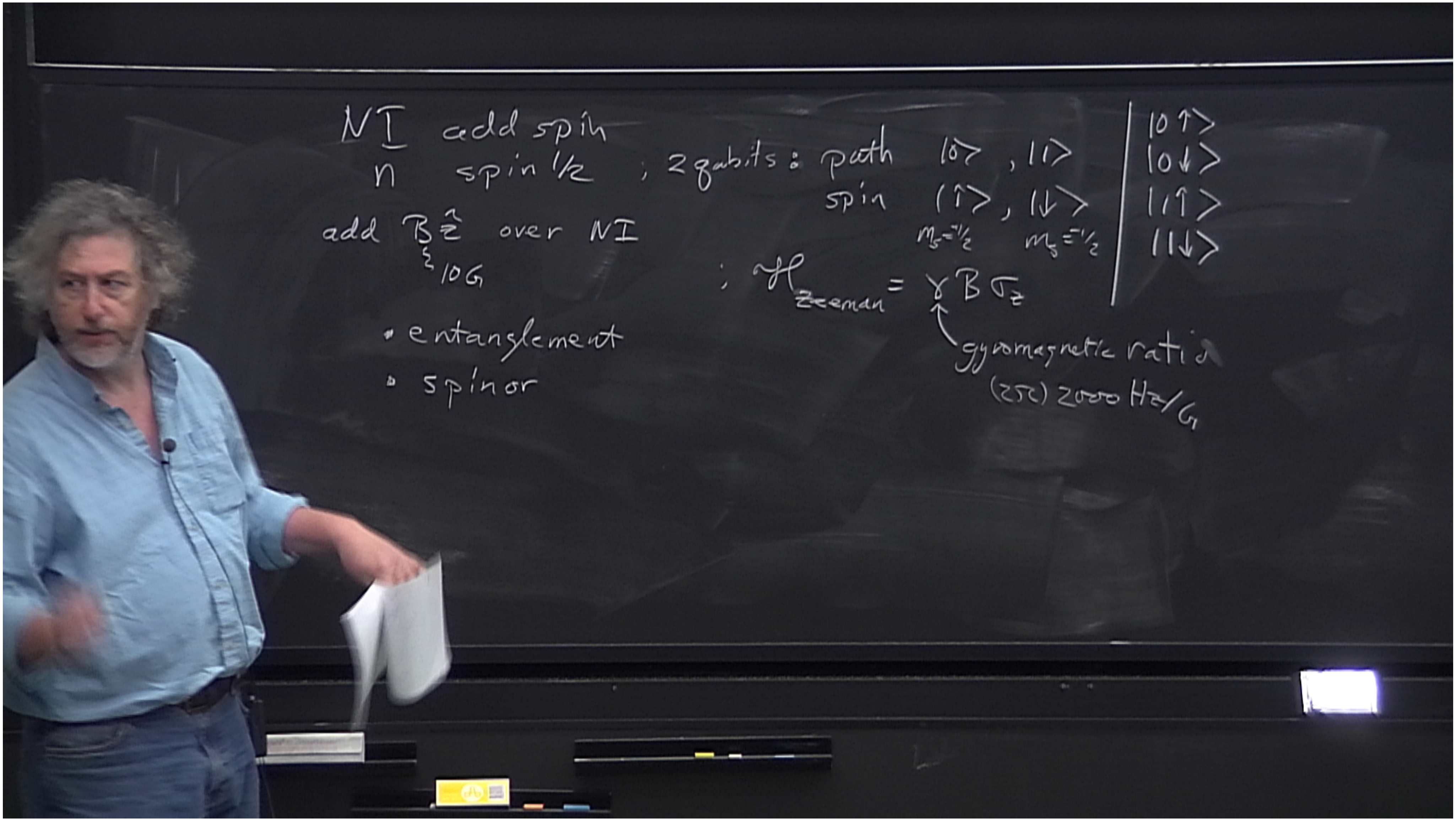

NI add spin
n spin 1/2 ; 2 qubits: path |0>, |1>
spin |↑>, |↓>

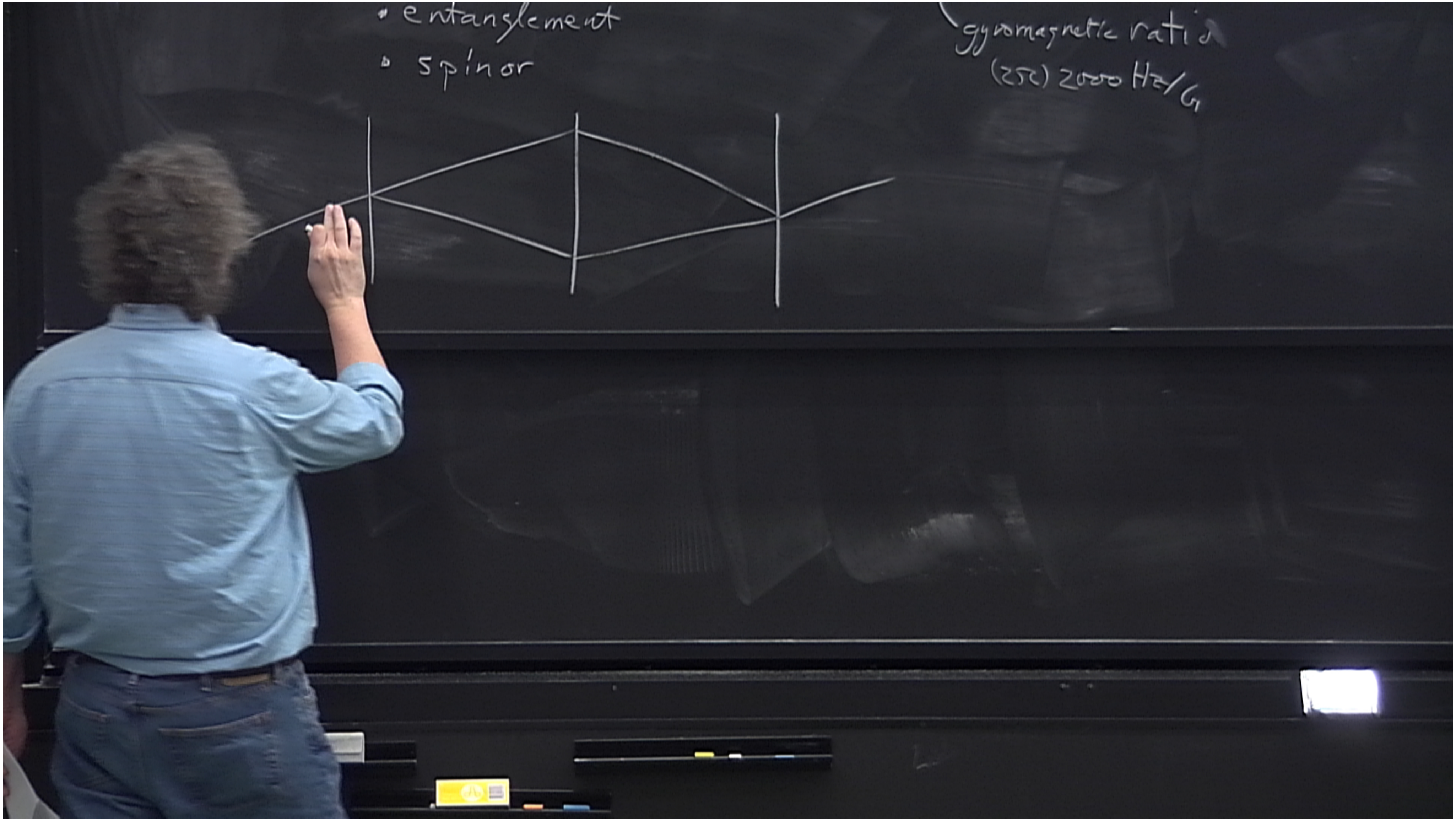

NI add spin
n spin 1/2 ; 2 qubits: path |0>, |1>
spin |↑>, |↓>
over NI

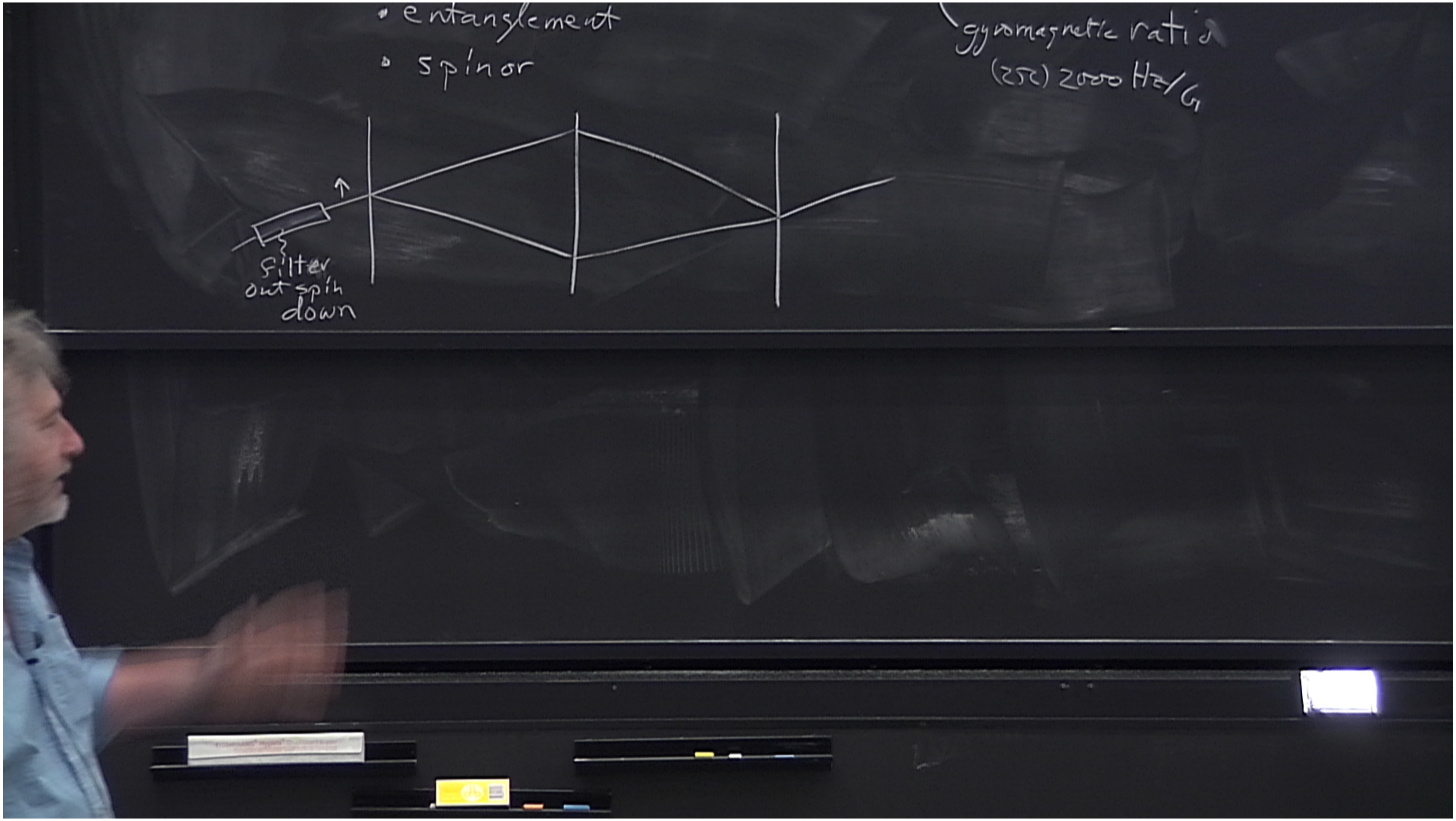

NI add spin
n spin 1/2 ; 2 qubits : path |0> , |1>
|↑> , |↓>
add B ẑ over NI
~10G
γ B σz
gyromagnetic ratio

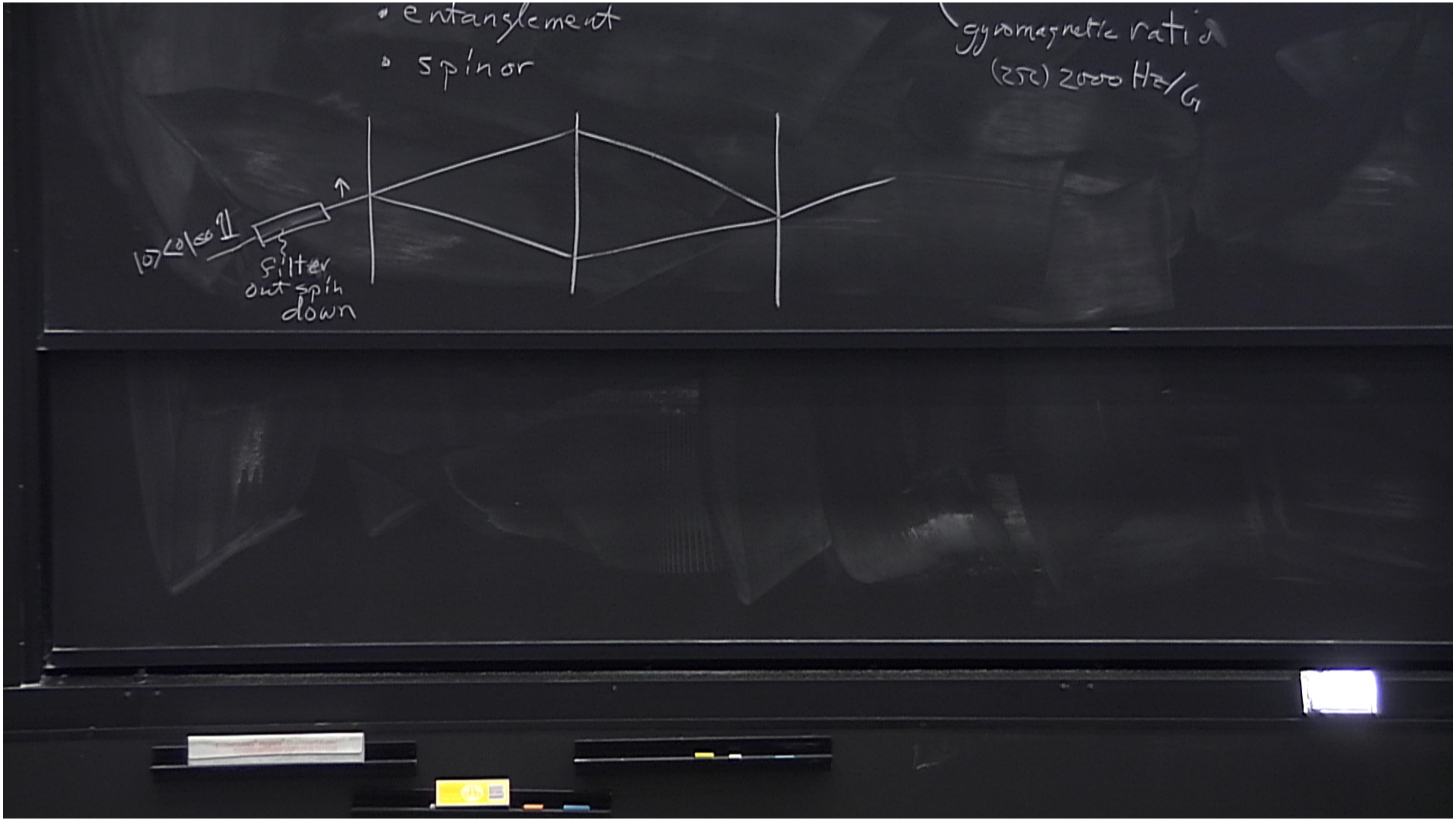

NI add spin
n spin 1/2 ; 2 qubits: path |0>, |1>
spin |↑>, |↓>
over NI
; H_Zeeman = γ B σ_z
gyromagnetic ratio
2000 Hz/G


NI add spin
n spin 1/2
; 2 qubits: path
|1>
spin
add B ẑ over NI
10G
; H Zeeman =
|0↑>

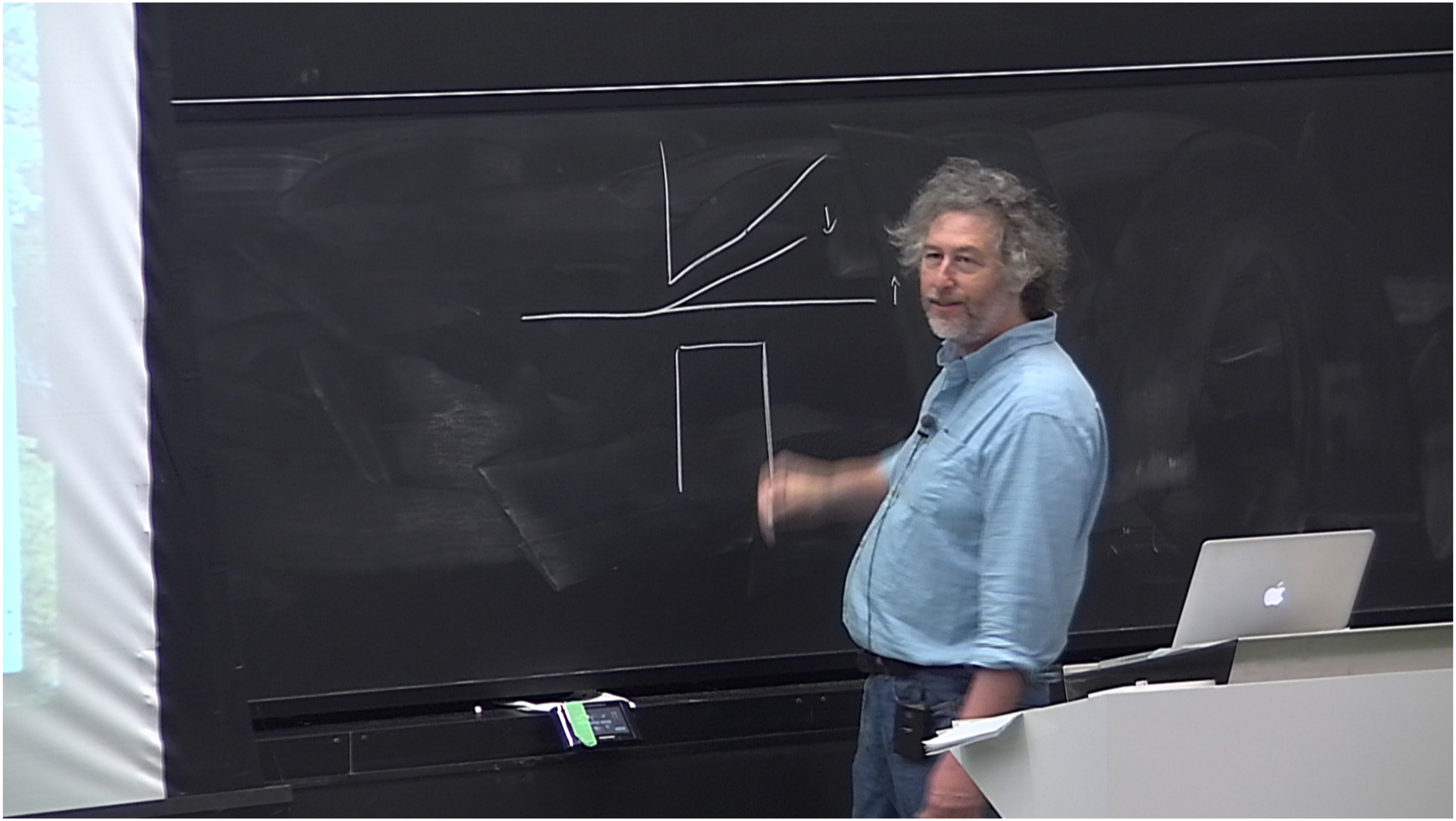

NI add spin
n spin 1/2
; 2 qubits: path |0>, |1>
spin |↑>, |↓>
|0↑>
|0↓>
|1↑>
|1↓>
add B ẑ over NI
~10G
; H Zeeman = γ B σz
gyromagnetic ratio
2000 Hz/G
• entanglement
• spinor

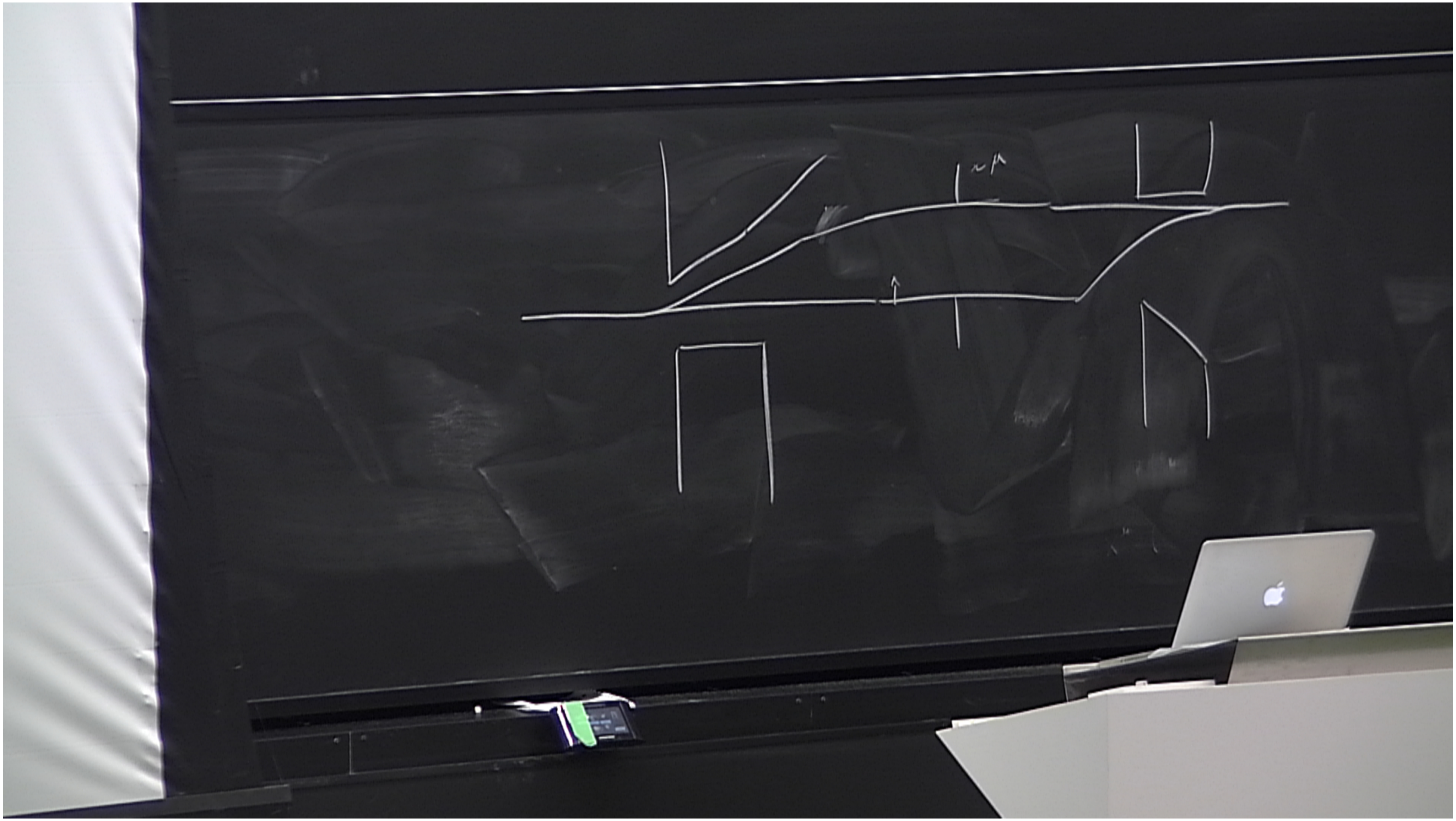

• entanglement
• spinor
gyromagnetic ratio

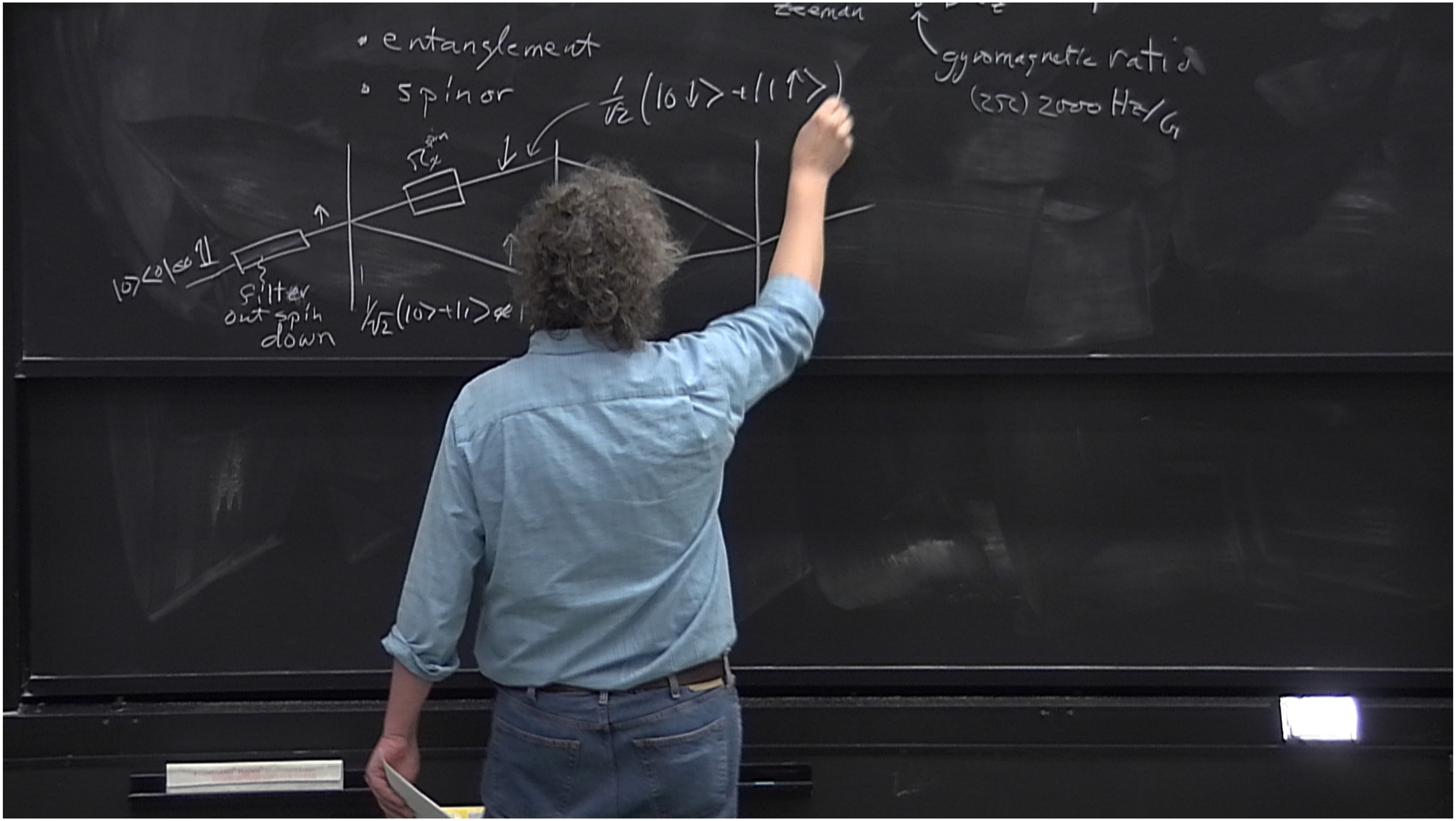

• entanglement
• spinor
gyromagnetic ratio
filter out spin down

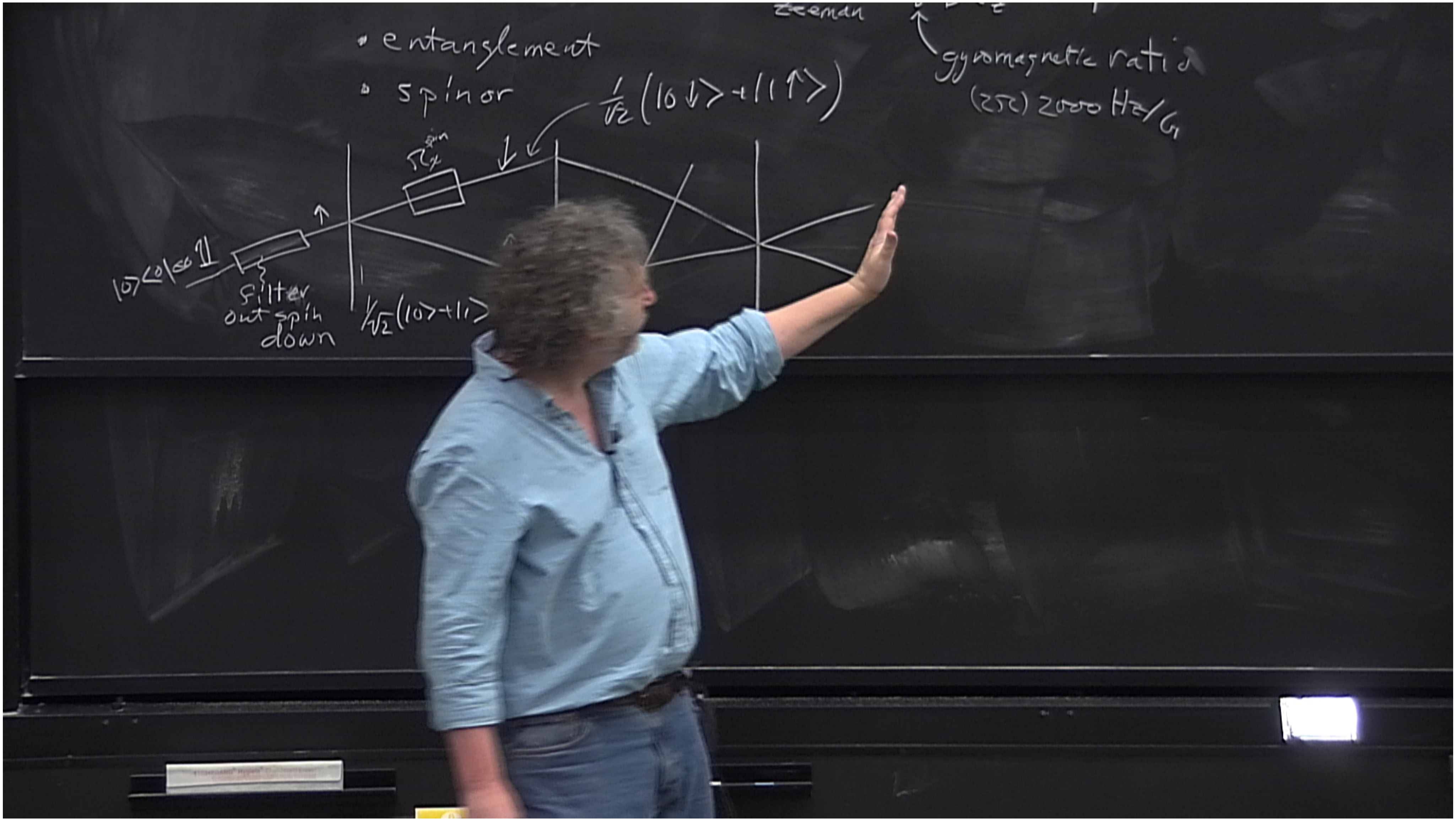


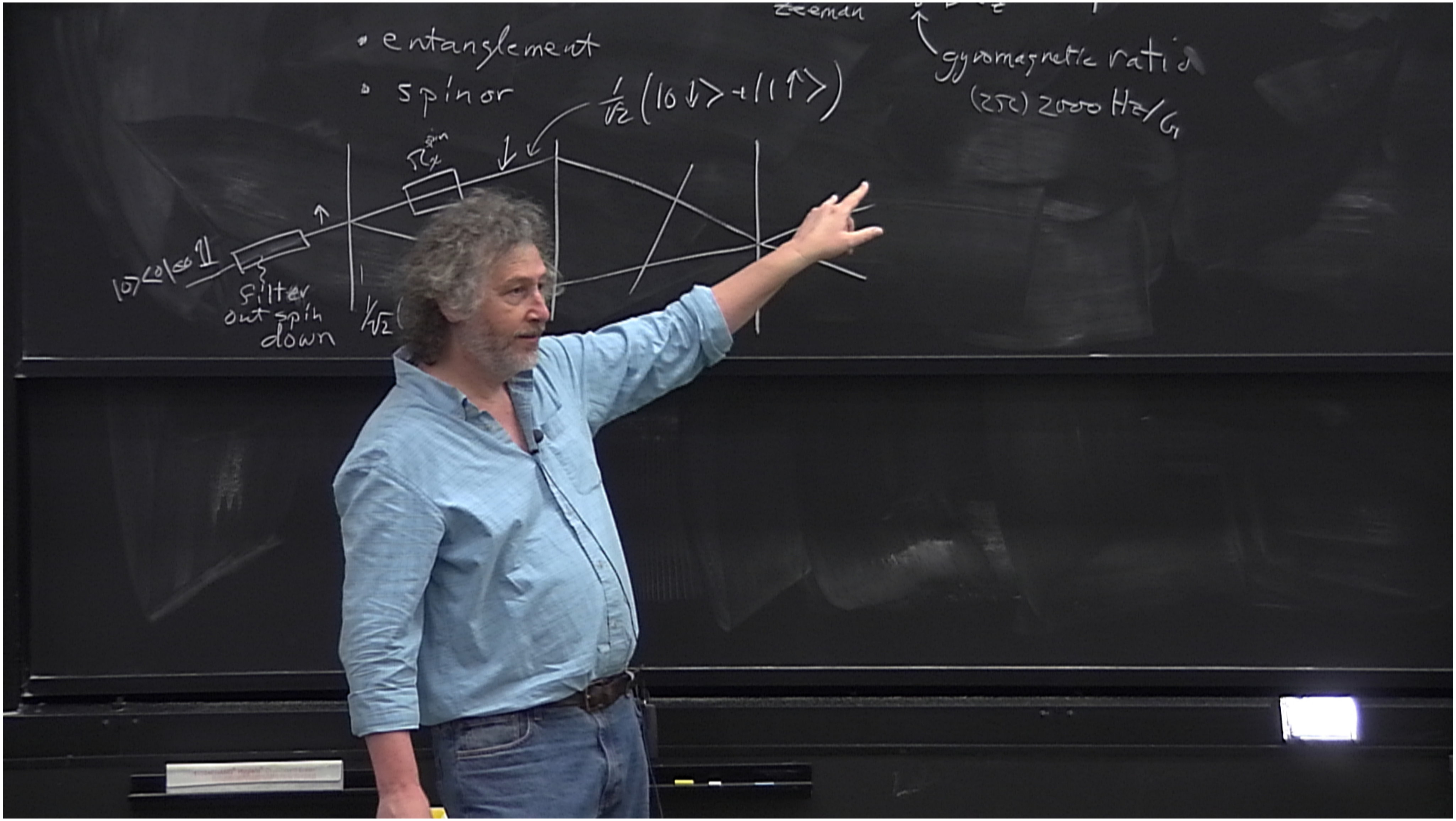
• entanglement
• spinor
gyromagnetic ratio
(2π) 2000 Hz/G
filter
out spin
down

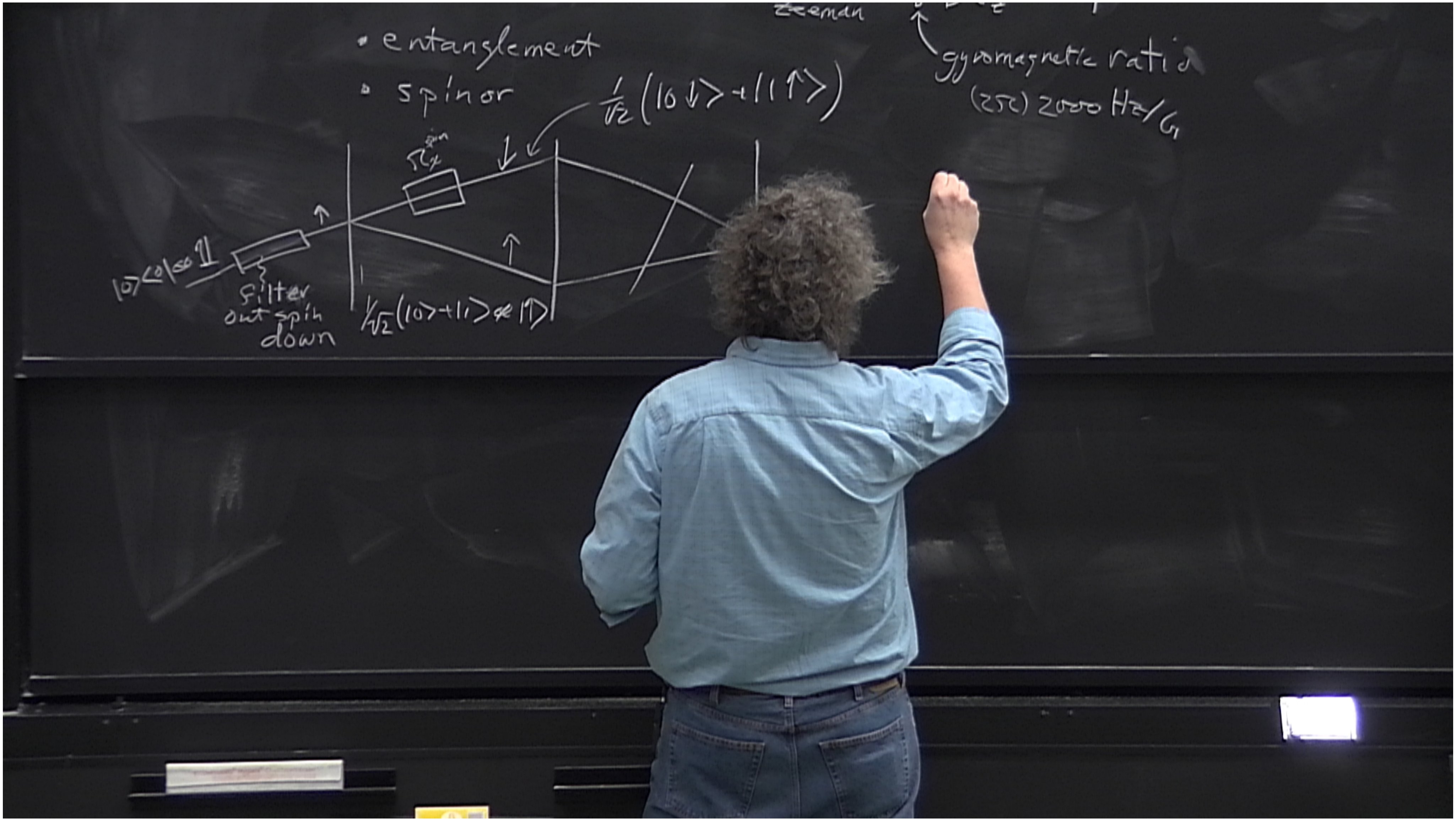




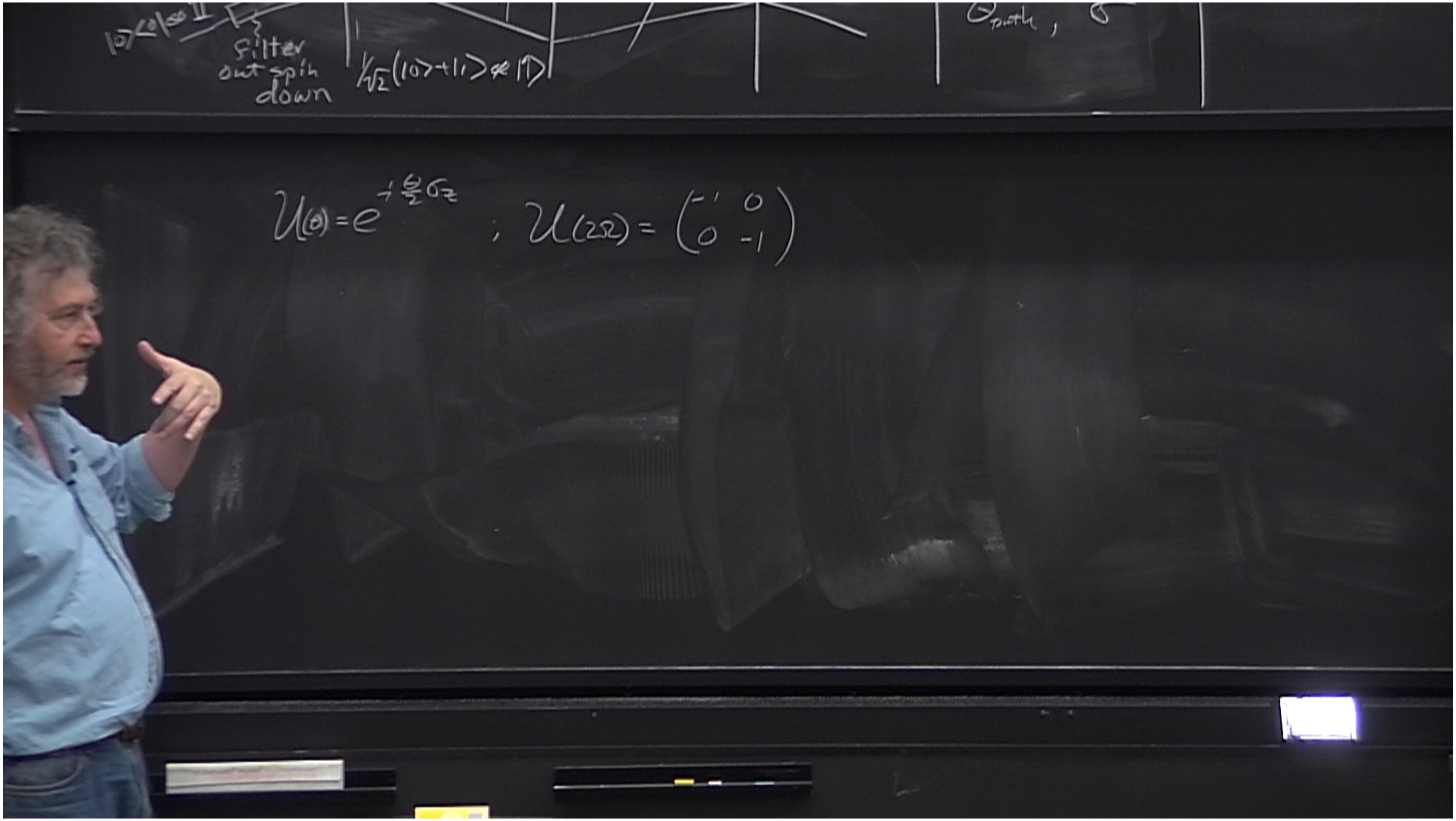

Zeeman
• entanglement
• spinor
gyromagnetic ratio
2000 Hz/G
filter
out spin
down

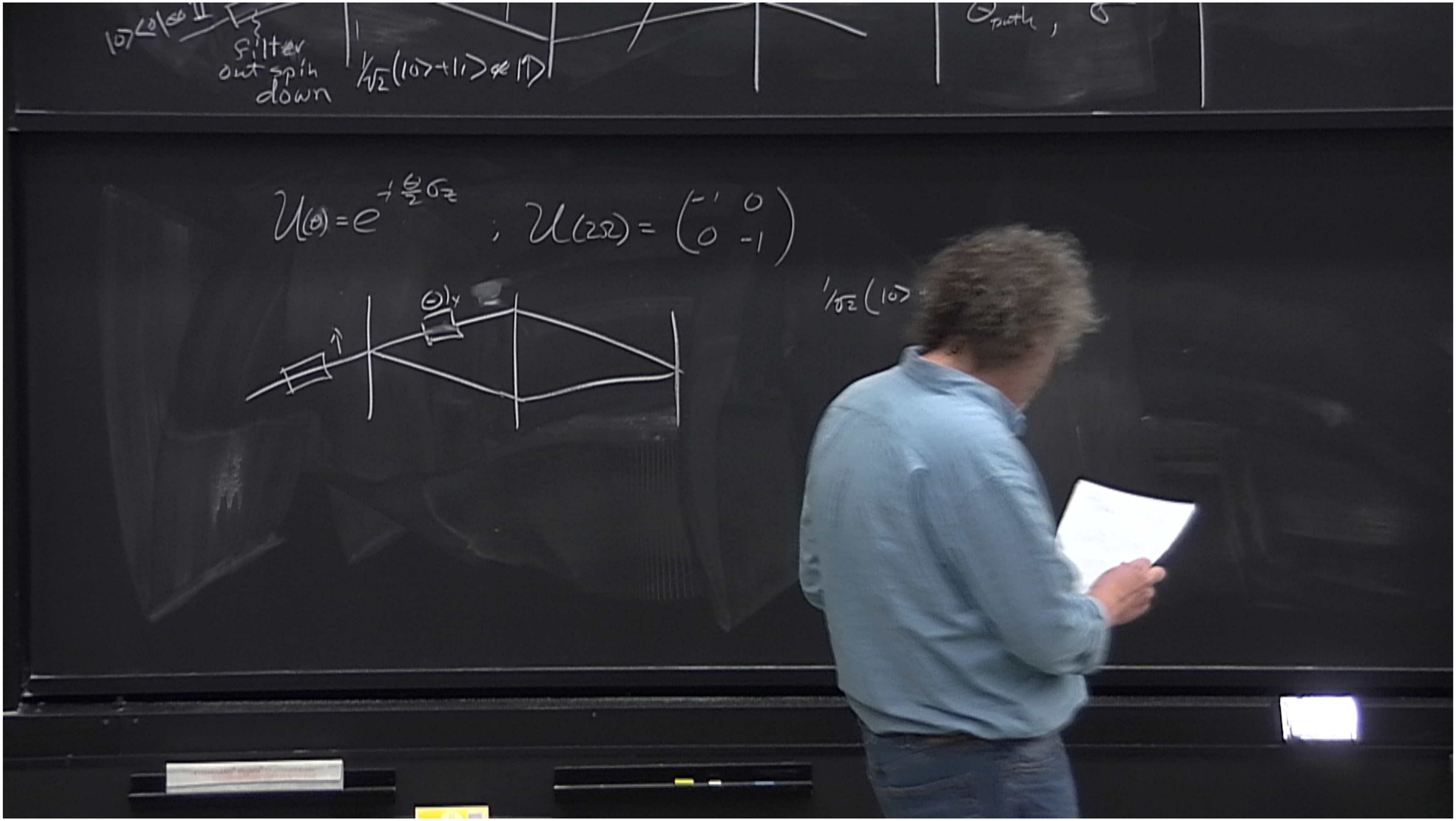

Zeeman
• entanglement
• spinor
gyromagnetic ratio
filter out spin down

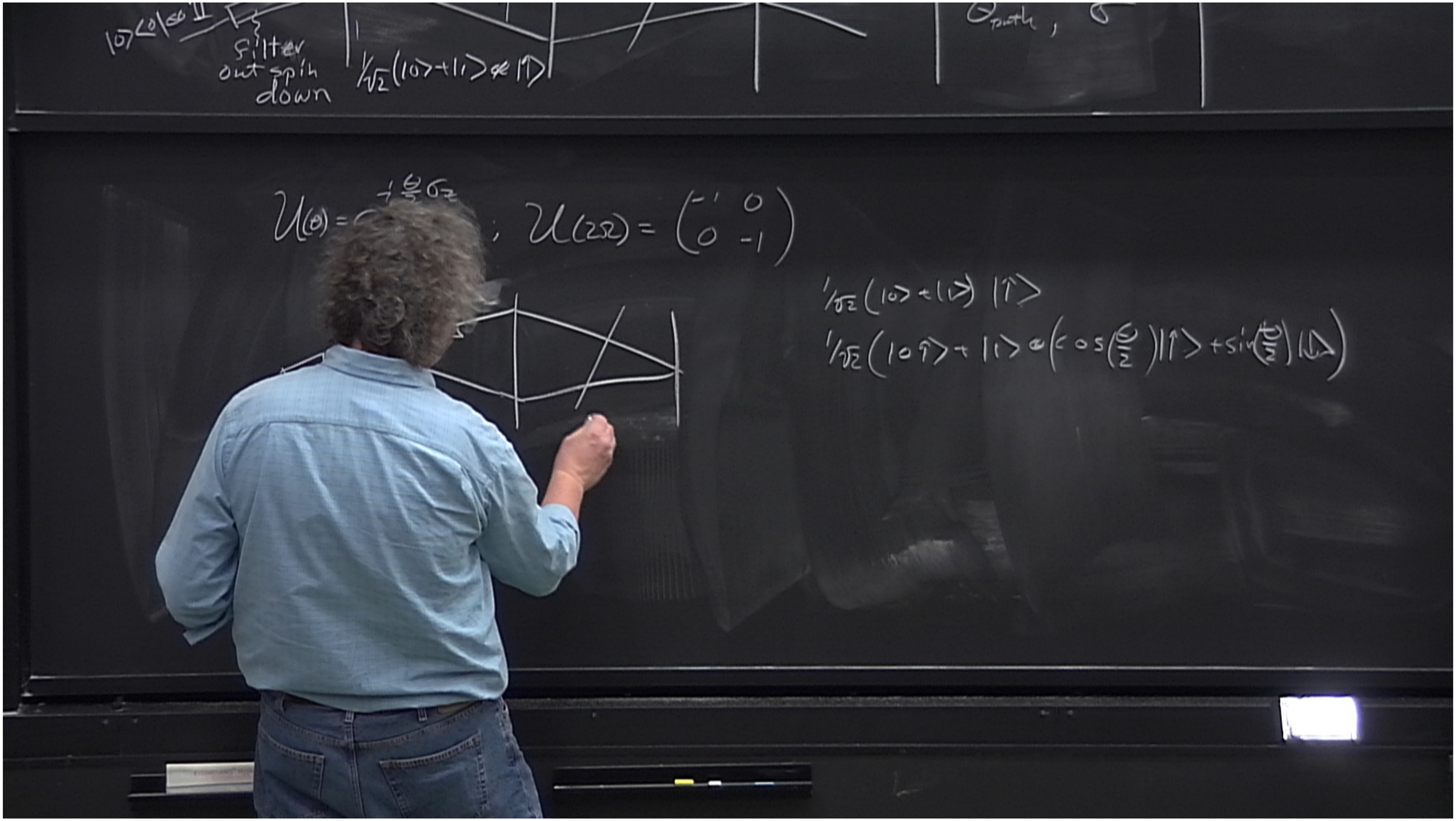

zeeman
• entanglement
• spinor
gyromagnetic ratio
(2π) 2000 Hz/G
filter
out spin
down



• entanglement
• spinor
gyromagnetic ratio
2000 Hz/G
filter out spin down


filter
out spin
down
U(θ) = e^{-i θ/2 σz} ; U(2π) = (-1 0 / 0 -1)


filter
out spin
down
$\frac{1}{\sqrt{2}}(|0\rangle+|1\rangle)\otimes|\uparrow\rangle$
Θ_{path} ,
$\mathcal{U}(\theta)=e^{-i\frac{\theta}{2}\sigma_z}$; $\mathcal{U}(2\pi)=\begin{pmatrix}-1 & 0\\ 0 & -1\end{pmatrix}$
$\frac{1}{\sqrt{2}}(|0\rangle$


filter
out spin
down
U(2π) = (-1 0 / 0 -1)
1/√2 (|0> + |1>) |↑>

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z.

```
gamma = 1.832 × 10^4; (* Hz/G *)
```

■ **Spin filter**

This is a projector along the z-axis of the spin state and the k-x up path

```
Ezp = 1/2 (PauliMatrix[0] + PauliMatrix[3]);
Ezm = 1/2 (PauliMatrix[0] - PauliMatrix[3]);
Uzpup = KroneckerProduct[Ezp, Ezp];
Uzpup // MatrixForm
```

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
Uzpdown = KroneckerProduct[Ezp, Ezm];
Uzpdown // MatrixForm
```

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
Uzmup = KroneckerProduct[Ezm, Ezp];
Uzmup // MatrixForm
```

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
Uzmdown = KroneckerProduct[Ezm, Ezm];
Uzmdown // MatrixForm
```

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

■ **Spin flipper**

Rotate the spin by π about the x axis for the k-x down path

```
Uflip = MatrixExp[I π / 2 PauliMatrix[1]];
Uflip // MatrixForm
```

$$\begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix}$$

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Experimental setup

```
resls[t_, a_] := TrigReduce[ExpToTrig[Simplify[
    Refine[Ubladews . Umws . Urotdown[t] . Uphasews[a] . Ubladews . Uzpup . Ubladewsinv .
      Uphasewsinv[a] . Urotdowninv[t] . Umwsinv . Ubladewsinv], Element[t, Reals]]]]
resls[0, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1+\text{Cos}[a]) & \frac{1}{2}\,i\,\text{Sin}[a] & 0 & 0 \\ -\frac{1}{2}\,i\,\text{Sin}[a] & \frac{1}{2}(1-\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
resls[π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{4} & \frac{1}{4} & \frac{1}{4}(-\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]-i\,\text{Sin}[a]) \\ \frac{1}{4} & \frac{1}{4} & \frac{1}{4}(-\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]-i\,\text{Sin}[a]) \\ \frac{1}{4}(-\text{Cos}[a]-i\,\text{Sin}[a]) & \frac{1}{4}(-\text{Cos}[a]-i\,\text{Sin}[a]) & \frac{1}{4} & -\frac{1}{4} \\ \frac{1}{4}(\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]+i\,\text{Sin}[a]) & -\frac{1}{4} & \frac{1}{4} \end{pmatrix}$$

```
resls[2 π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1-\text{Cos}[a]) & -\frac{1}{2}\,i\,\text{Sin}[a] & 0 & 0 \\ \frac{1}{2}\,i\,\text{Sin}[a] & \frac{1}{2}(1+\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
resls[4 π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1+\text{Cos}[a]) & \frac{1}{2}\,i\,\text{Sin}[a] & 0 & 0 \\ -\frac{1}{2}\,i\,\text{Sin}[a] & \frac{1}{2}(1-\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

So we see that indeed a 4π rotation returns the original state.

- **Put a spin filter in the O-beam and look at the intensity**
- **O-Beam with spin up filter**

```
MOup[t_, a_] := Tr[Uzpup . resls[t, a]]
MOup[t, a]
```

$$\frac{1}{8}\left(3+2\,\text{Cos}\left[a-\frac{t}{2}\right]+2\,\text{Cos}\left[a+\frac{t}{2}\right]+\text{Cos}[t]\right)$$

```
Plot3D[MOup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
```

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Experimental setup

```
res1s[t_, a_] := TrigReduce[ExpToTrig[Simplify[
    Refine[Ubladews . Umws . Urotdown[t] . Uphasews[a] . Ubladews . Uzpup . Ubladewsinv .
      Uphasewsinv[a] . Urotdowninv[t] . Umwsinv . Ubladewsinv], Element[t, Reals]]]]
res1s[0, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1+\text{Cos}[a]) & \frac{1}{2}\, i\, \text{Sin}[a] & 0 & 0 \\ -\frac{1}{2}\, i\, \text{Sin}[a] & \frac{1}{2}(1-\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
res1s[π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{4} & \frac{1}{4} & \frac{1}{4}(-\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]-i\,\text{Sin}[a]) \\ \frac{1}{4} & \frac{1}{4} & \frac{1}{4}(-\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]-i\,\text{Sin}[a]) \\ \frac{1}{4}(-\text{Cos}[a]-i\,\text{Sin}[a]) & \frac{1}{4}(-\text{Cos}[a]-i\,\text{Sin}[a]) & \frac{1}{4} & -\frac{1}{4} \\ \frac{1}{4}(\text{Cos}[a]+i\,\text{Sin}[a]) & \frac{1}{4}(\text{Cos}[a]+i\,\text{Sin}[a]) & -\frac{1}{4} & \frac{1}{4} \end{pmatrix}$$

```
res1s[2 π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1-\text{Cos}[a]) & -\frac{1}{2}\, i\, \text{Sin}[a] & 0 & 0 \\ \frac{1}{2}\, i\, \text{Sin}[a] & \frac{1}{2}(1+\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
res1s[4 π, a] // MatrixForm
```

$$\begin{pmatrix} \frac{1}{2}(1+\text{Cos}[a]) & \frac{1}{2}\, i\, \text{Sin}[a] & 0 & 0 \\ -\frac{1}{2}\, i\, \text{Sin}[a] & \frac{1}{2}(1-\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

So we see that indeed a 4π rotation returns the original state.

- **Put a spin filter in the O-beam and look at the intensity**
- **O-Beam with spin up filter**

```
MOup[t_, a_] := Tr[Uzpup . res1s[t, a]]
MOup[t, a]
```

$$\frac{1}{8}\left(3+2\,\text{Cos}\left[a-\frac{t}{2}\right]+2\,\text{Cos}\left[a+\frac{t}{2}\right]+\text{Cos}[t]\right)$$

```
Plot3D[MOup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
```

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QE Lec 6.nb

$$\begin{pmatrix} -\frac{1}{2}\, i\, \mathrm{Sin}[a] & \frac{1}{2}(1-\mathrm{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

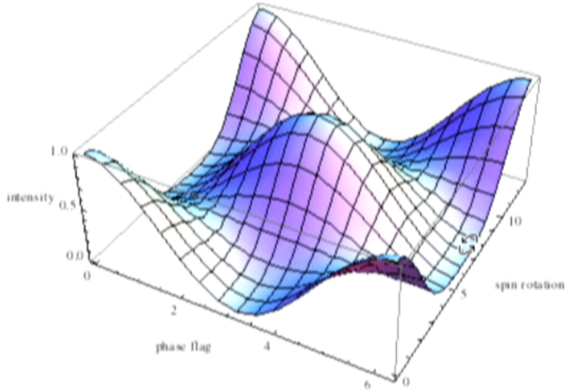
So we see that indeed a 4π rotation returns the original state.

- **Put a spin filter in the O-beam and look at the intensity**
- **O-Beam with spin up filter**

```
MOup[t_, a_] := Tr[Uzpup . res1s[t, a]]
MOup[t, a]
```

$$\frac{1}{8}\left(3+2\,\mathrm{Cos}\left[a-\frac{t}{2}\right]+2\,\mathrm{Cos}\left[a+\frac{t}{2}\right]+\mathrm{Cos}[t]\right)$$

```
Plot3D[MOup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
 {AxesLabel → { "phase flag", "spin rotation", "intensity"}}]
```

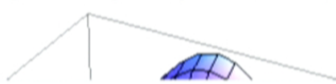


- **H-Beam with spin up filter**

```
MHup[t_, a_] := Tr[Uzpdown . res1s[t, a]]
MHup[t, a]
```

$$\frac{1}{8}\left(3-2\,\mathrm{Cos}\left[a-\frac{t}{2}\right]-2\,\mathrm{Cos}\left[a+\frac{t}{2}\right]+\mathrm{Cos}[t]\right)$$

```
Plot3D[MHup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
 {AxesLabel → { "phase flag", "spin rotation", "intensity"}}]
```



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QE Lec 6.nb

$$\begin{pmatrix} -\frac{1}{2}\, i\, \text{Sin}[a] & \frac{1}{2}(1-\text{Cos}[a]) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

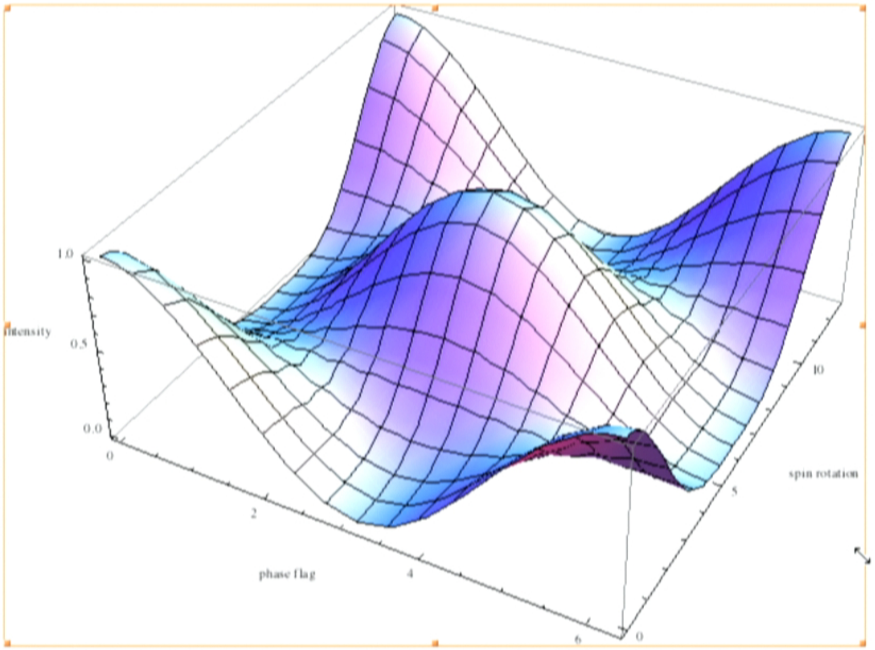
So we see that indeed a 4π rotation returns the original state.

- **Put a spin filter in the O-beam and look at the intensity**
- **O-Beam with spin up filter**

```
MOup[t_, a_] := Tr[Uzpup . resls[t, a]]
MOup[t, a]
```

$$\frac{1}{8}\left(3 + 2\,\text{Cos}\left[a - \frac{t}{2}\right] + 2\,\text{Cos}\left[a + \frac{t}{2}\right] + \text{Cos}[t]\right)$$

```
Plot3D[MOup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
 {AxesLabel → {"phase flag", "spin rotation", "intensity"}}]
```



- **H-Beam with spin up filter**

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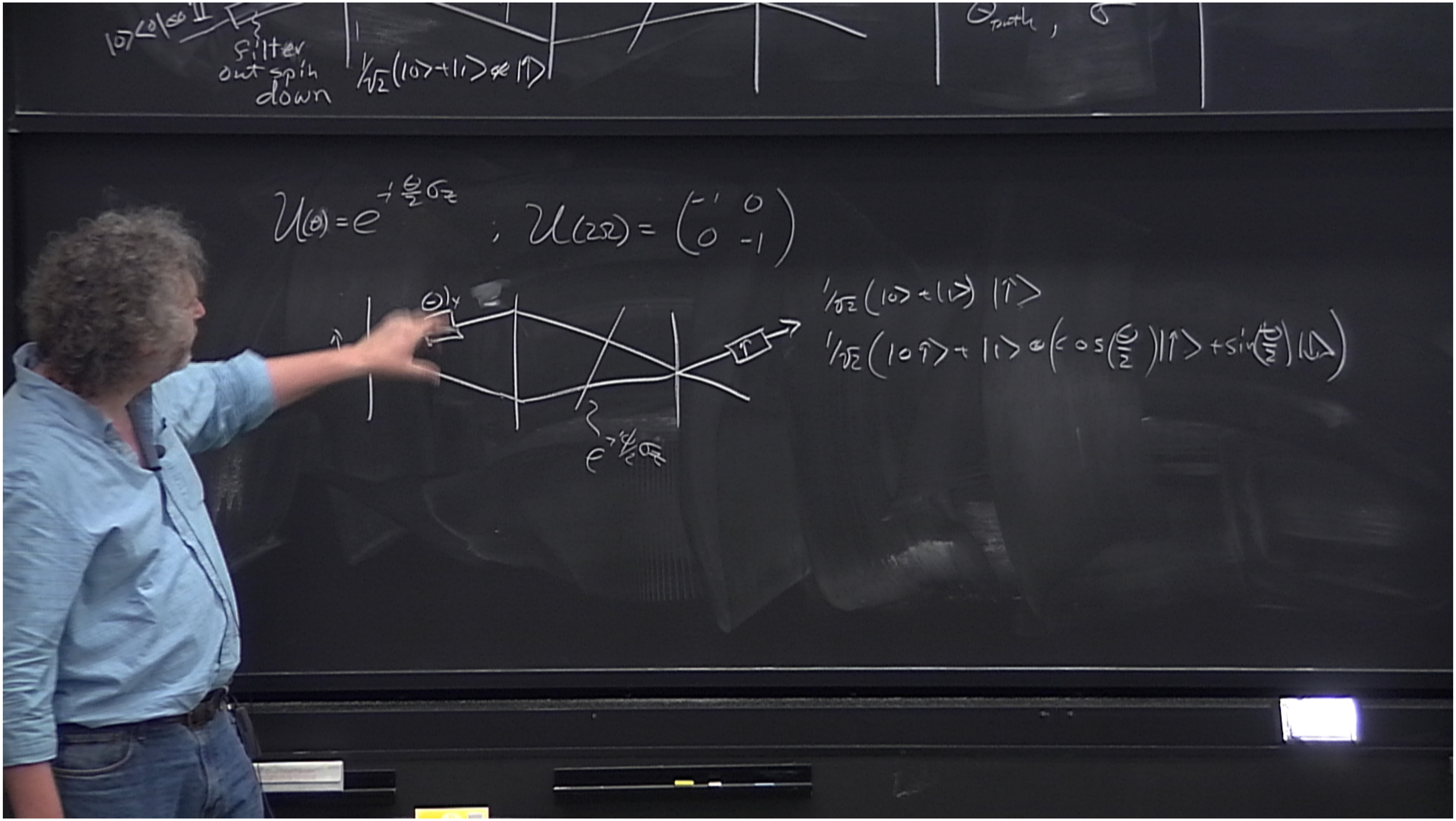
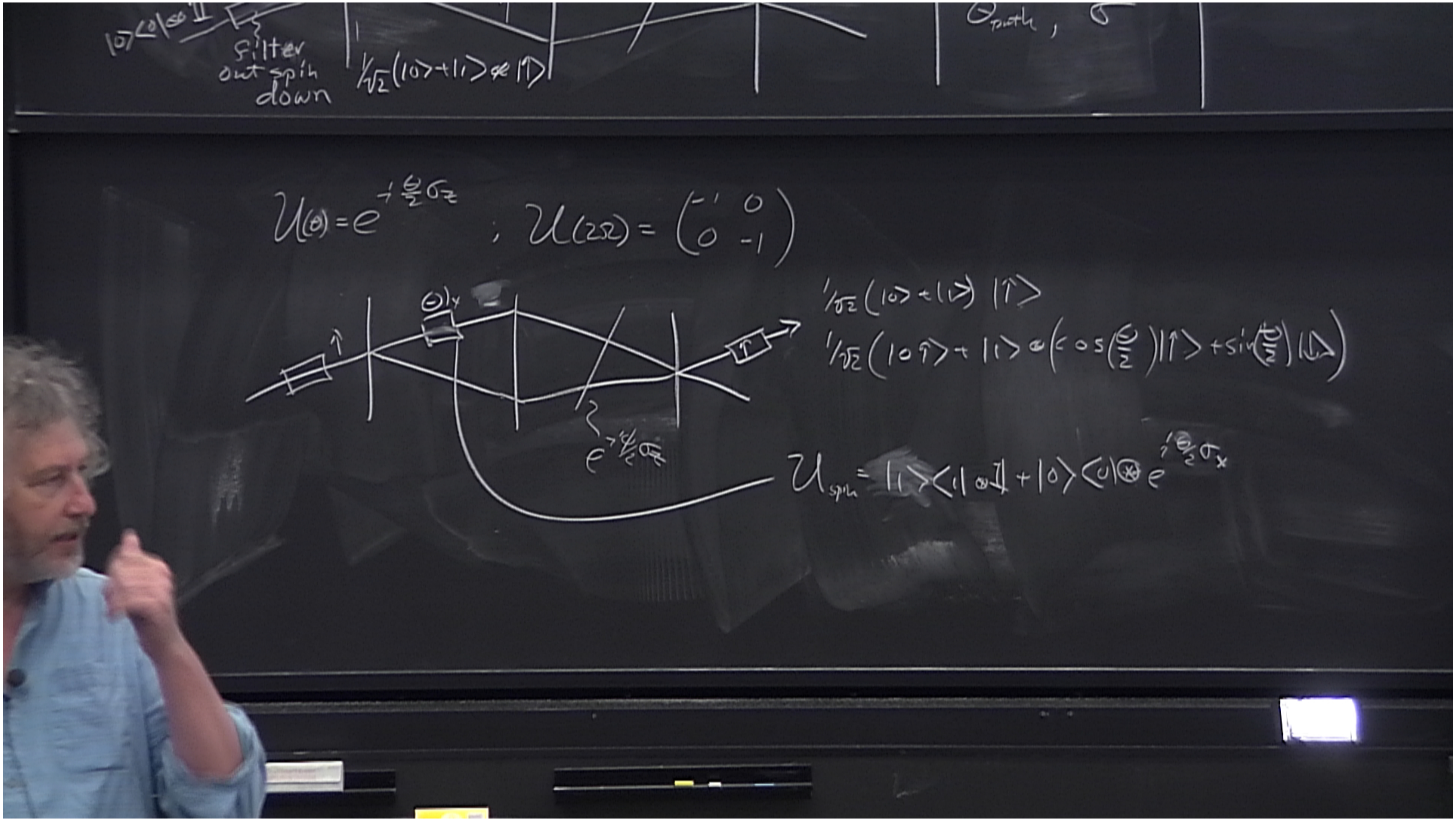
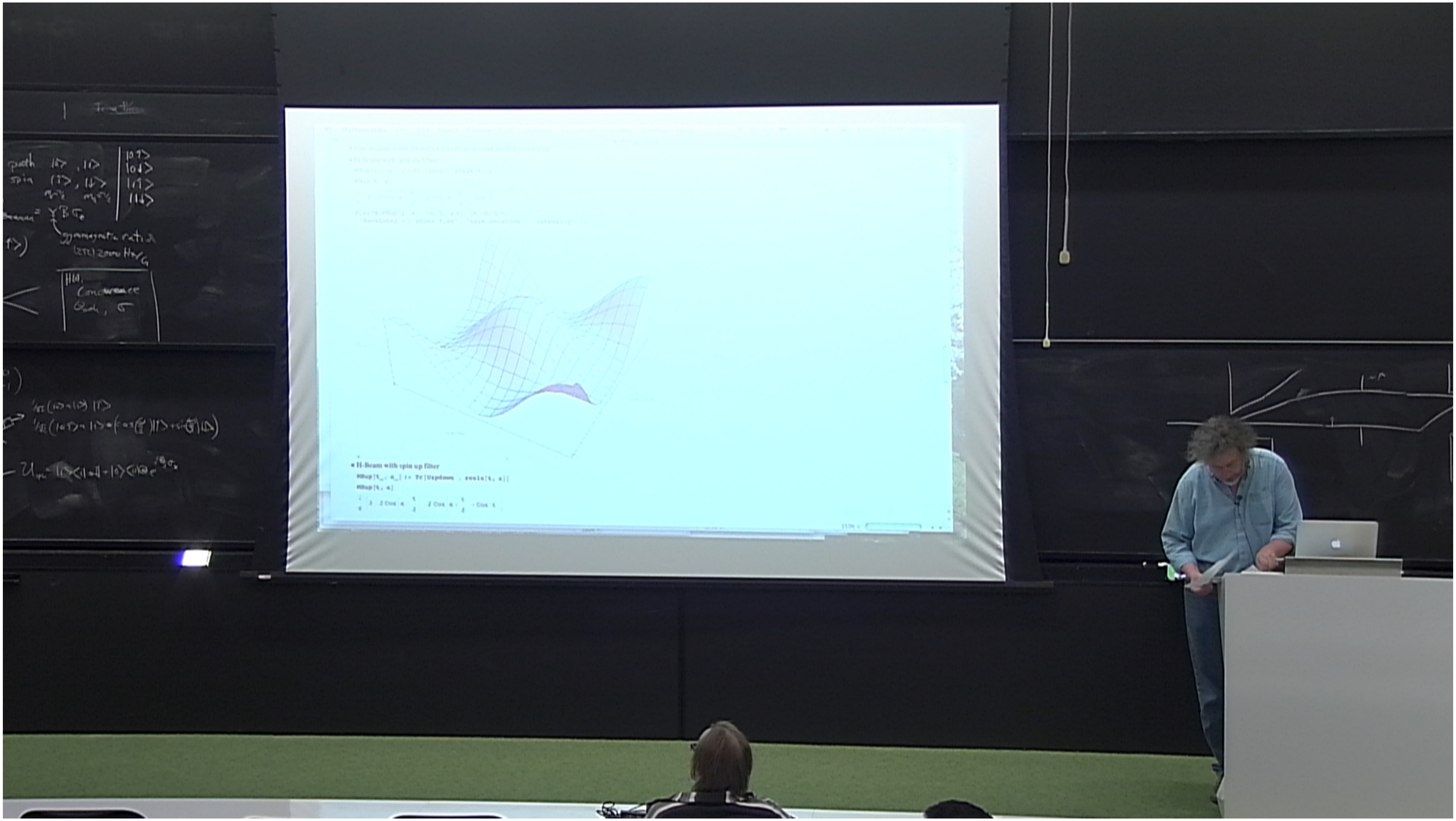
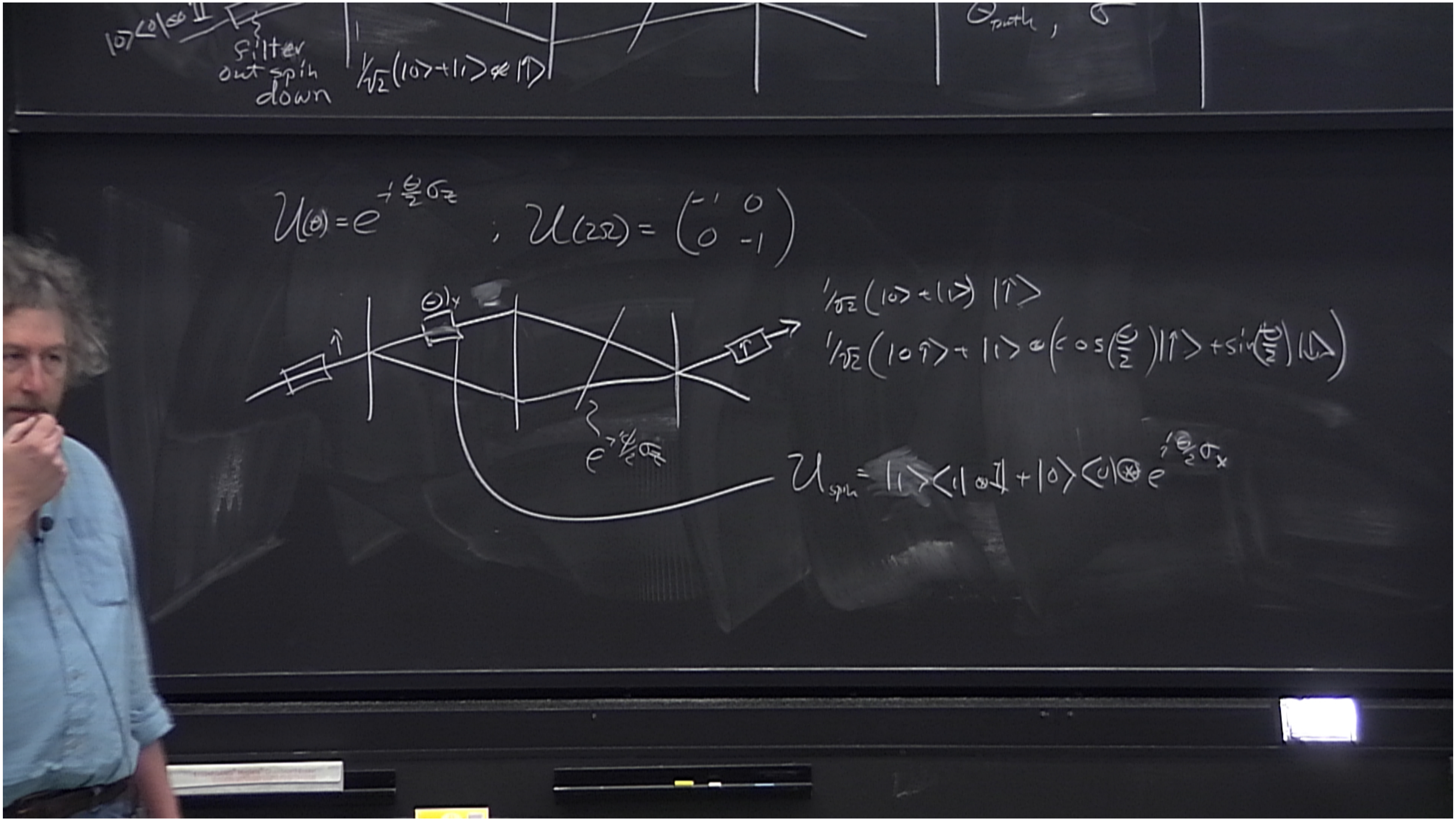
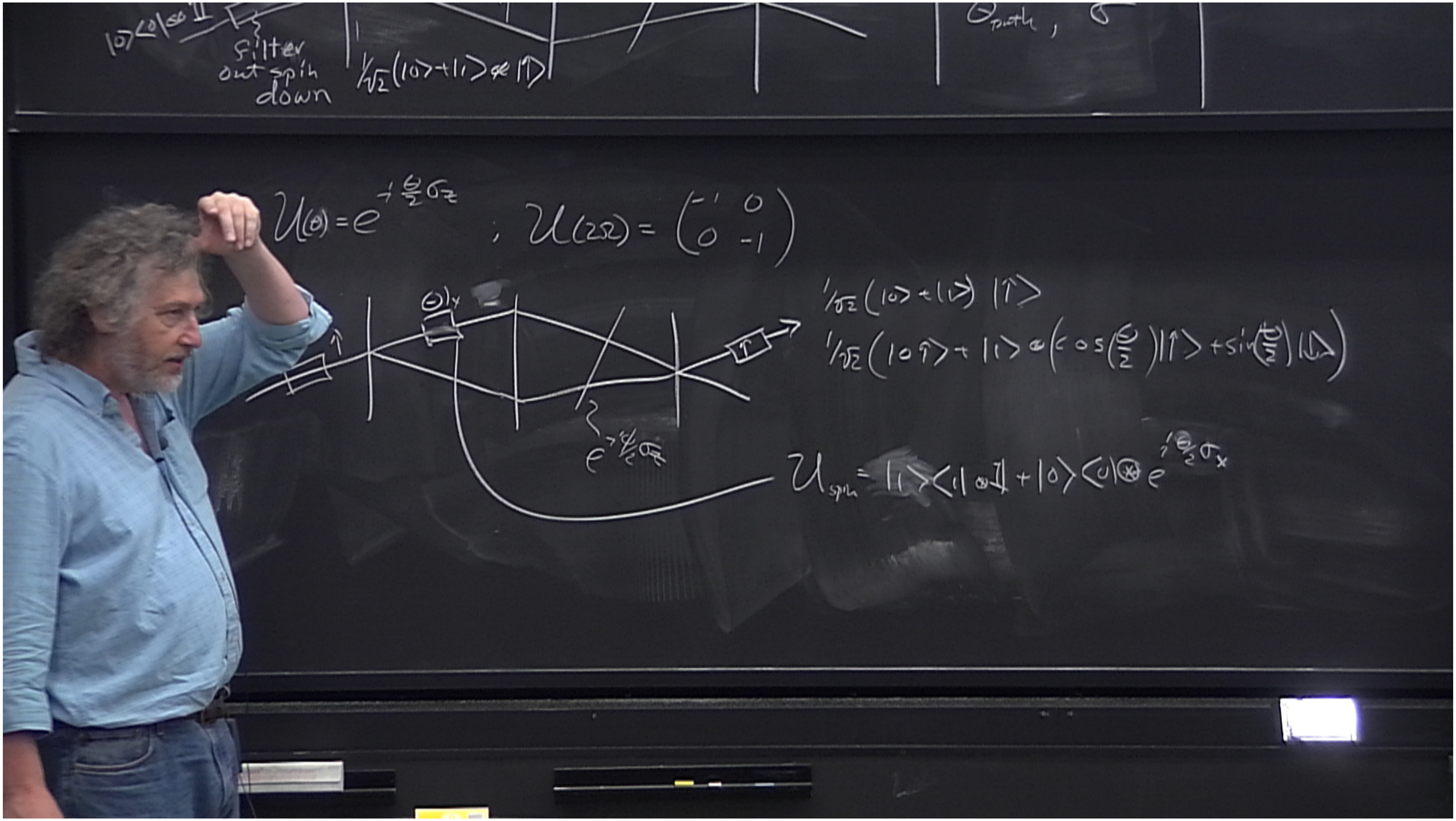
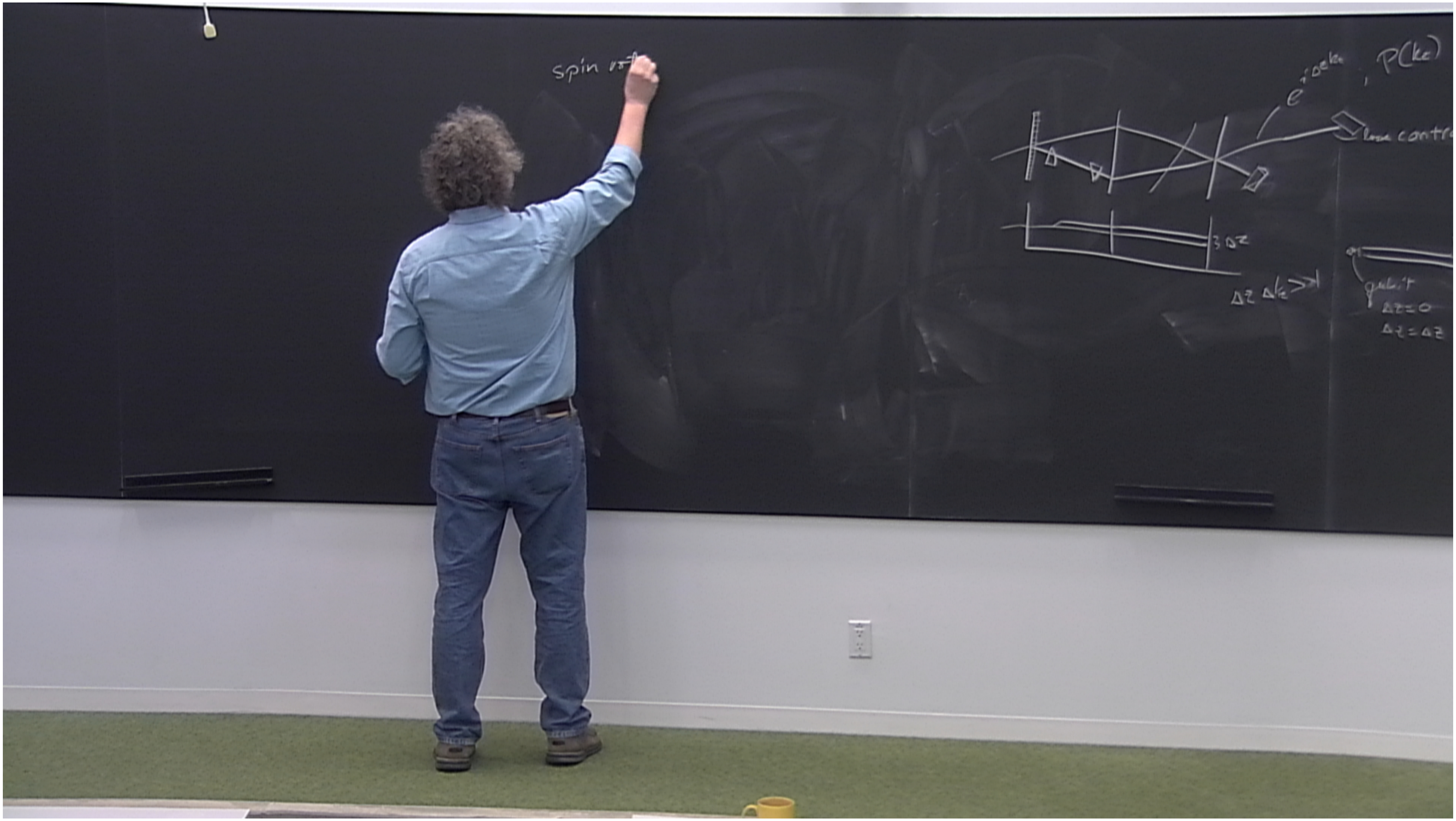

filter
out spin
down
U(θ) = e^{-i θ/2 σz}
U(2π) = (-1 0 / 0 -1)
e^{-i θ/2 σz}

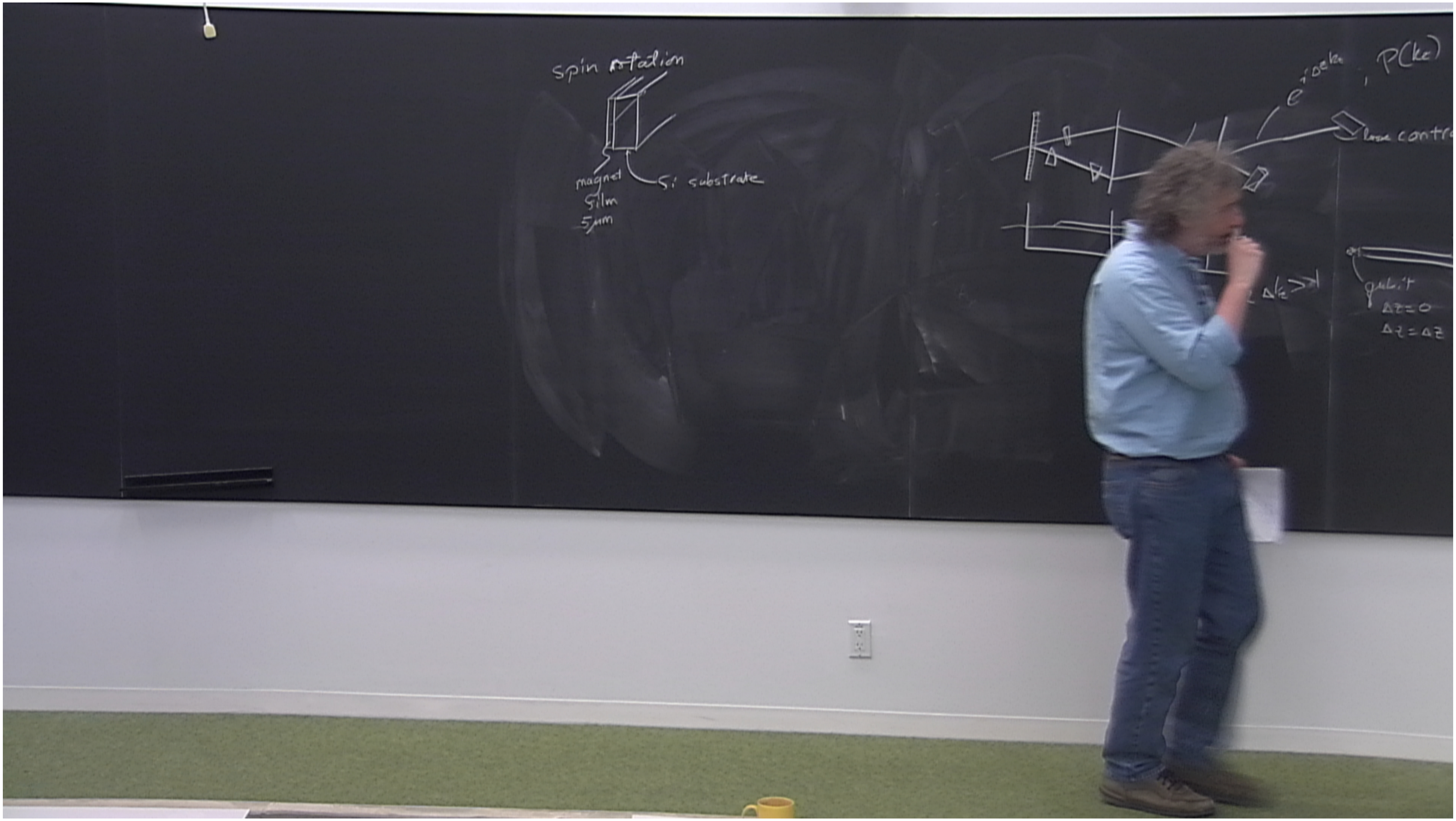

filter
out spin
down
Θpath , σ
U(θ) = e^{-iθ/2 σz} ; U(2π) = (-1 0 / 0 -1)
1/√2 (|0> + |1>) |↑>
1/√2 (|0↑> + |1> ⊗ (cos(θ/2)|↑> + sin(θ/2)|↓>))
Uspin = |1><1| ⊗ 𝟙 + |0><0| ⊗ e^{-iθ/2 σx}

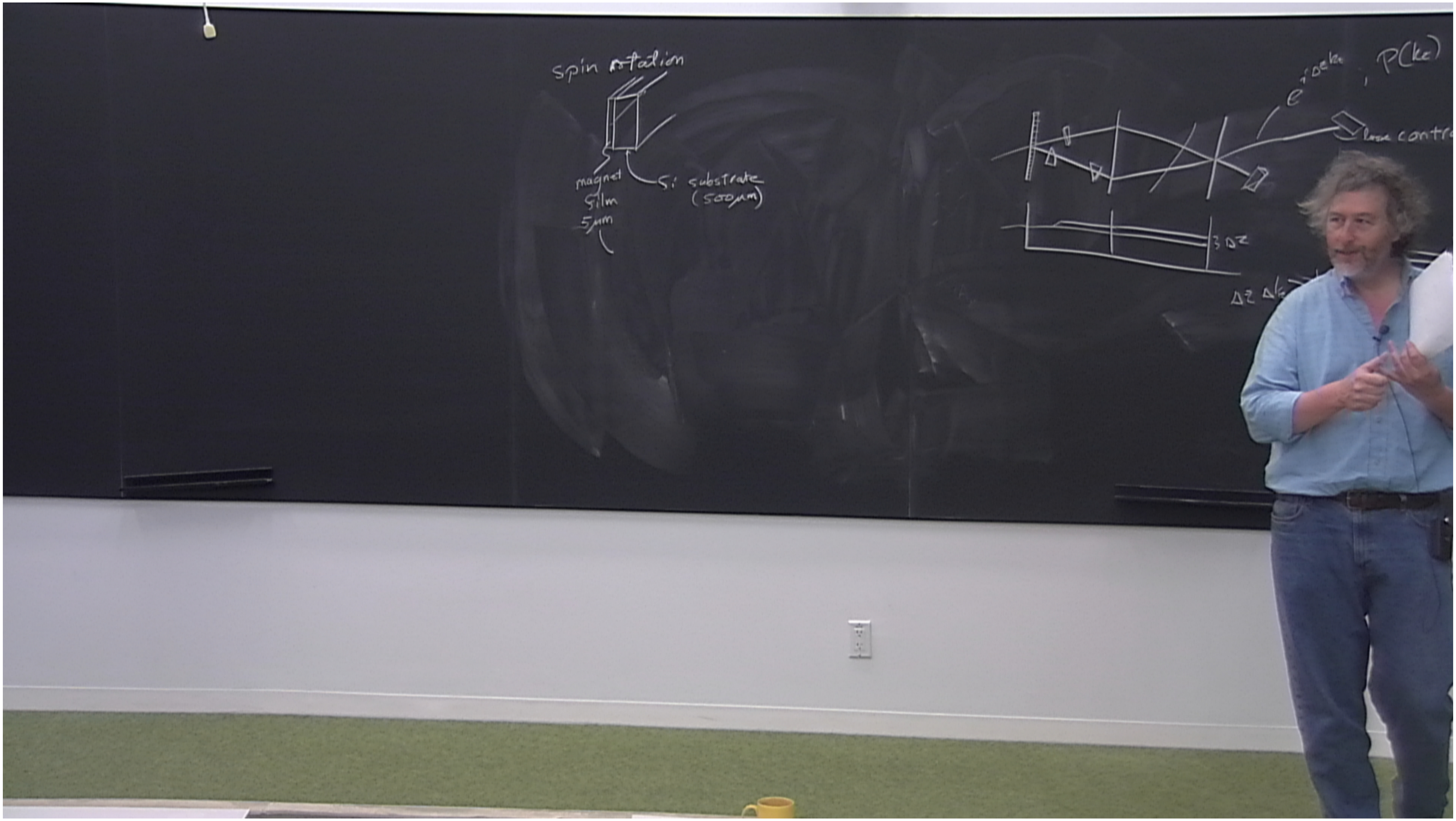

H-Beam with spin up filter

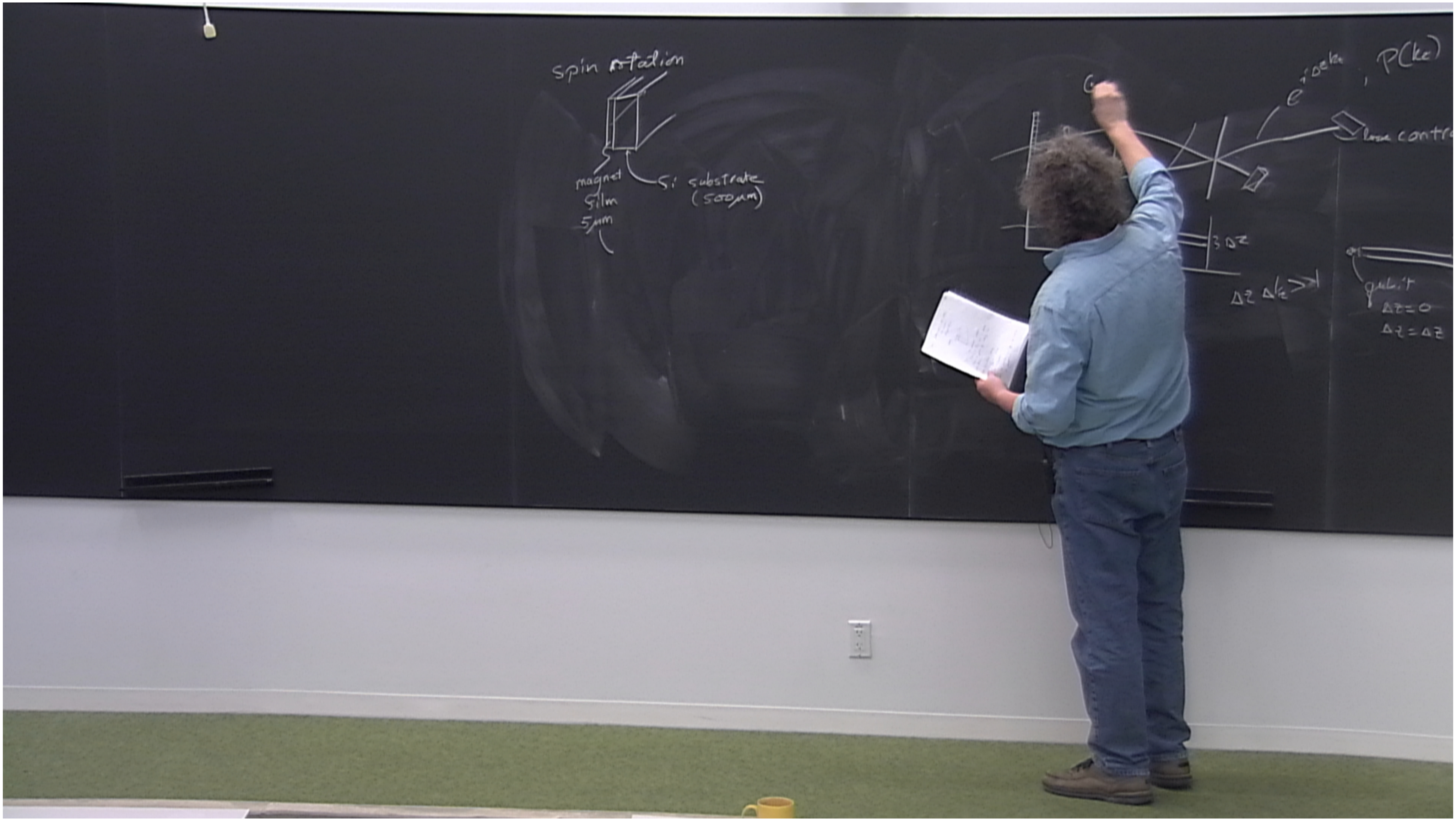

filter
out spin
down
Θ_path, σ
U(2π) = (-1 0; 0 -1)
U_spin = |1⟩⟨1| ⊗ I + |0⟩⟨0| ⊗ e^{i θ/2 σ_x}

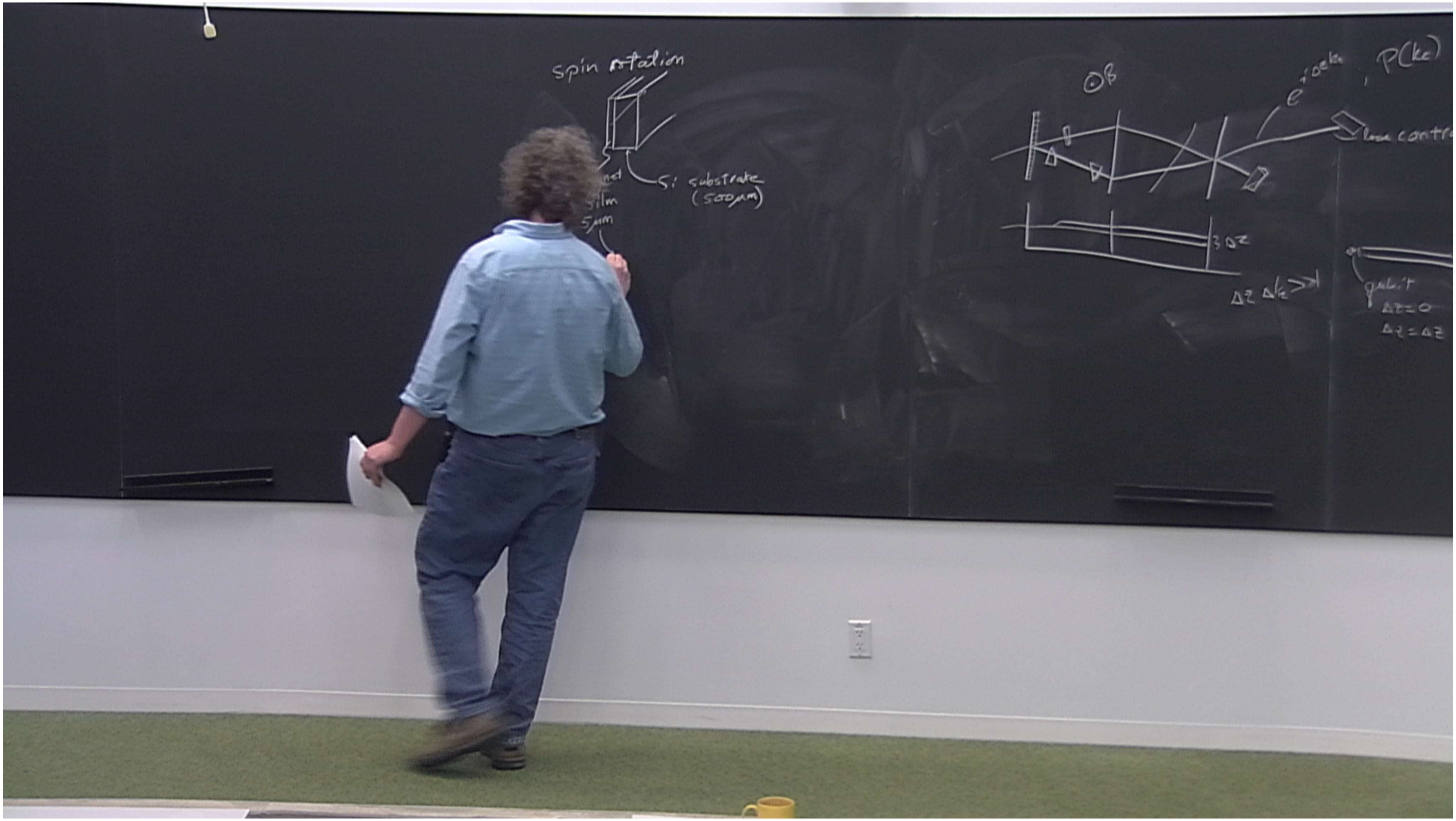

Filter out spin down
U(θ) = e^{-i θ/2 σ_z}
U(2π) = (-1 0; 0 -1)
1/√2 (|0> + |1>) |↑>
U_spin = |1><1| ⊗ I + |0><0| ⊗ e^{-i θ/2 σ_x}

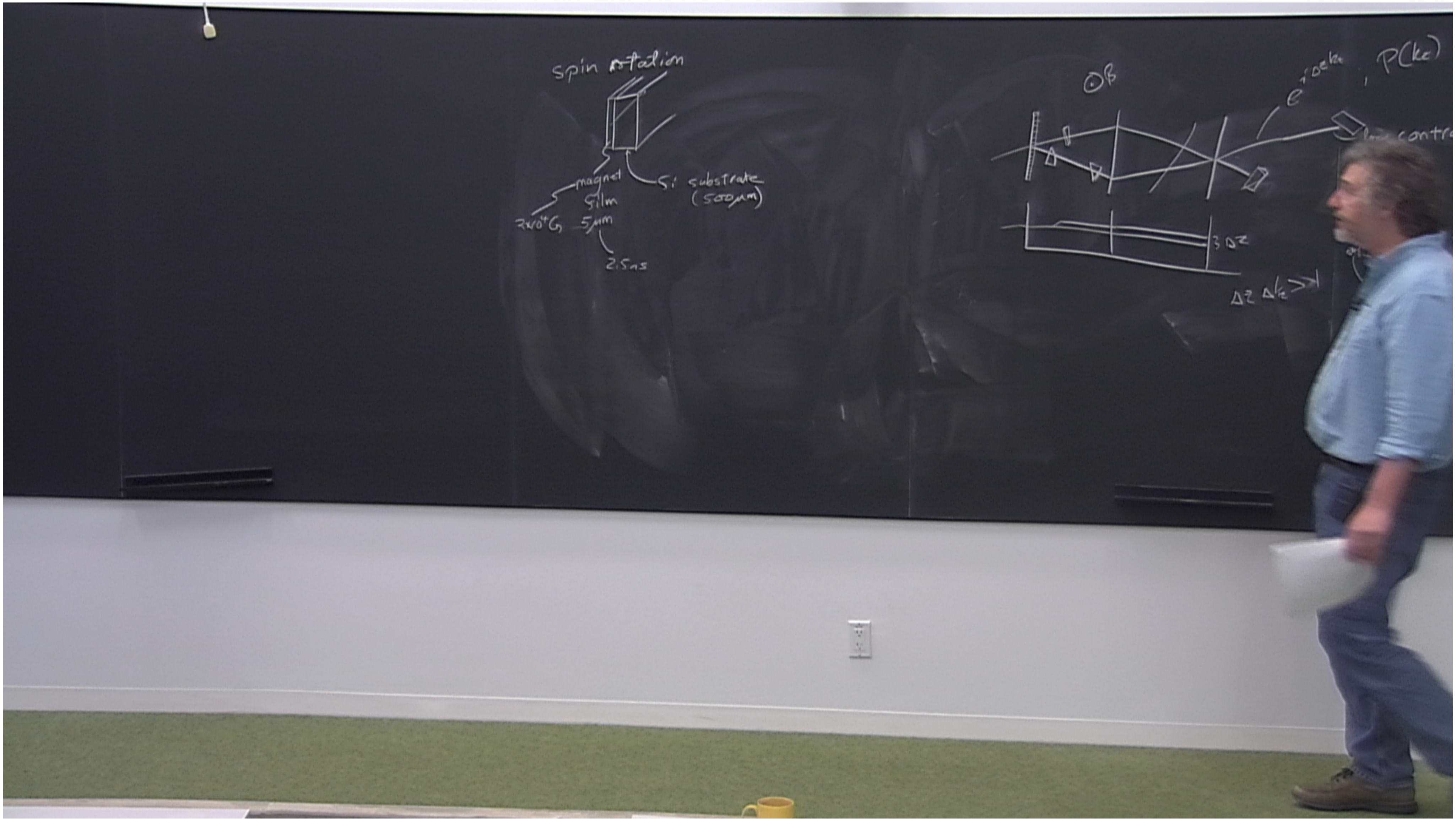

spin

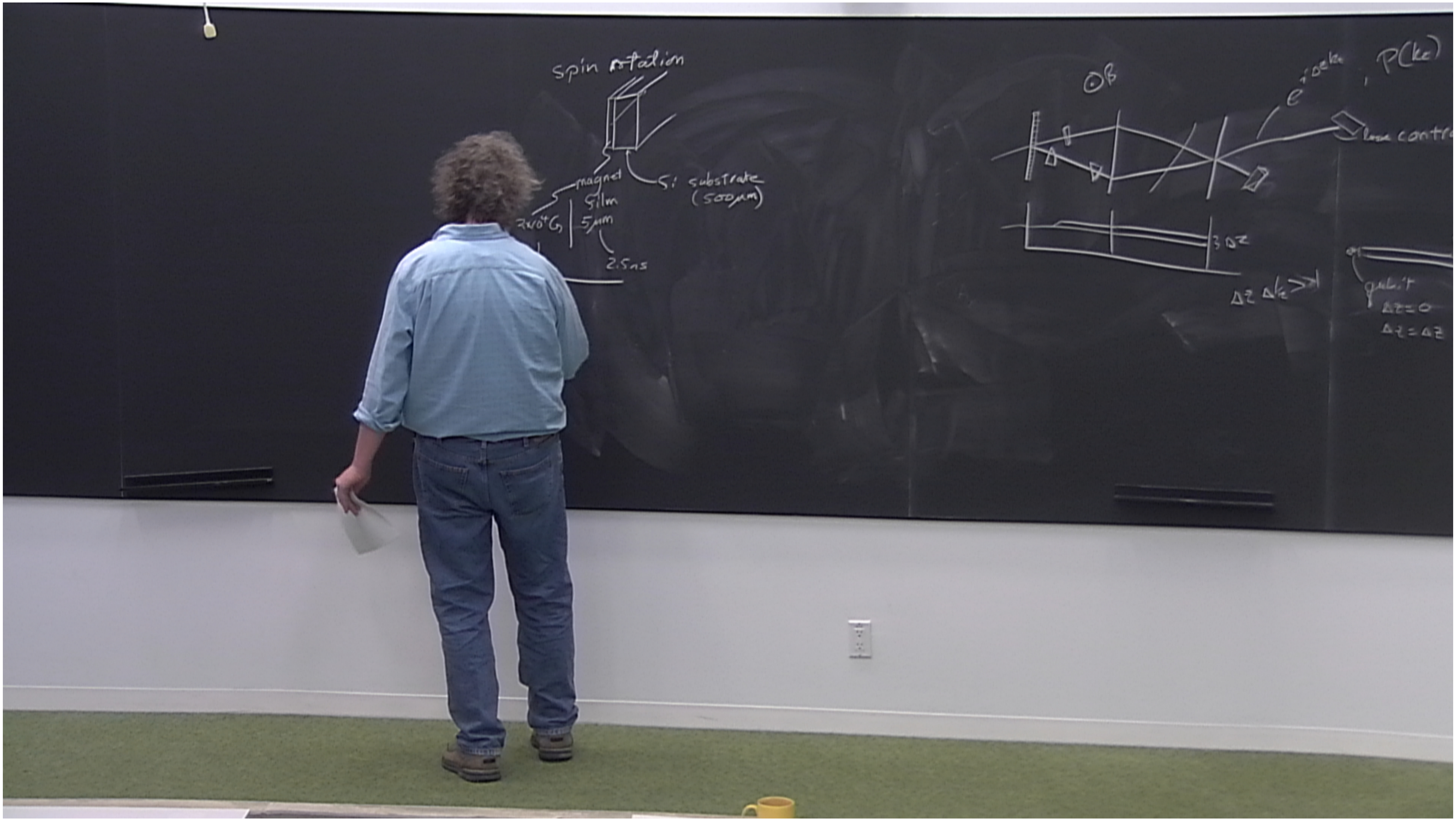

spin rotation
magnet
film
5μm
Si substrate
qubit

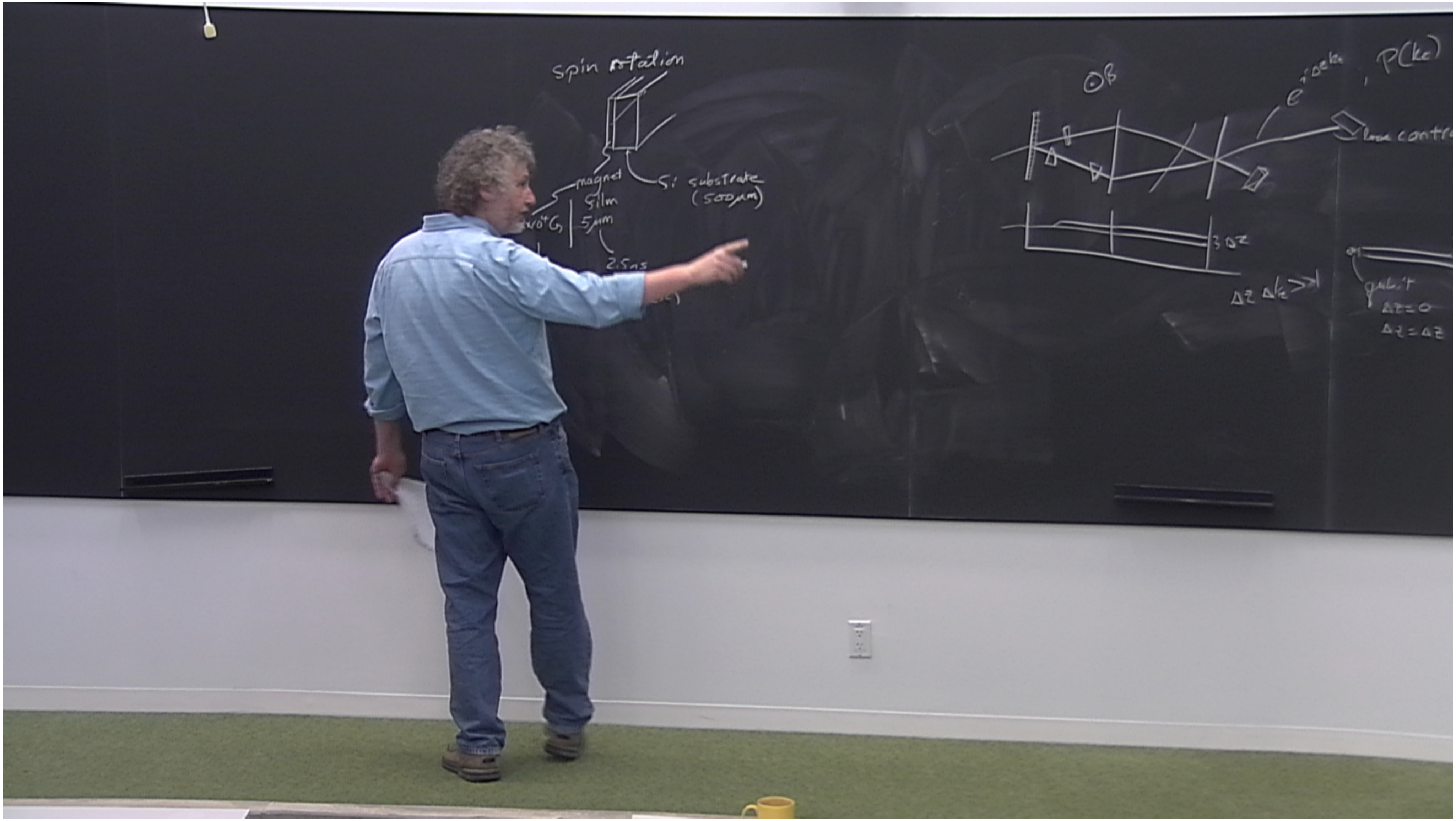

spin rotation
magnet
film
5μm
Si substrate
(500μm)

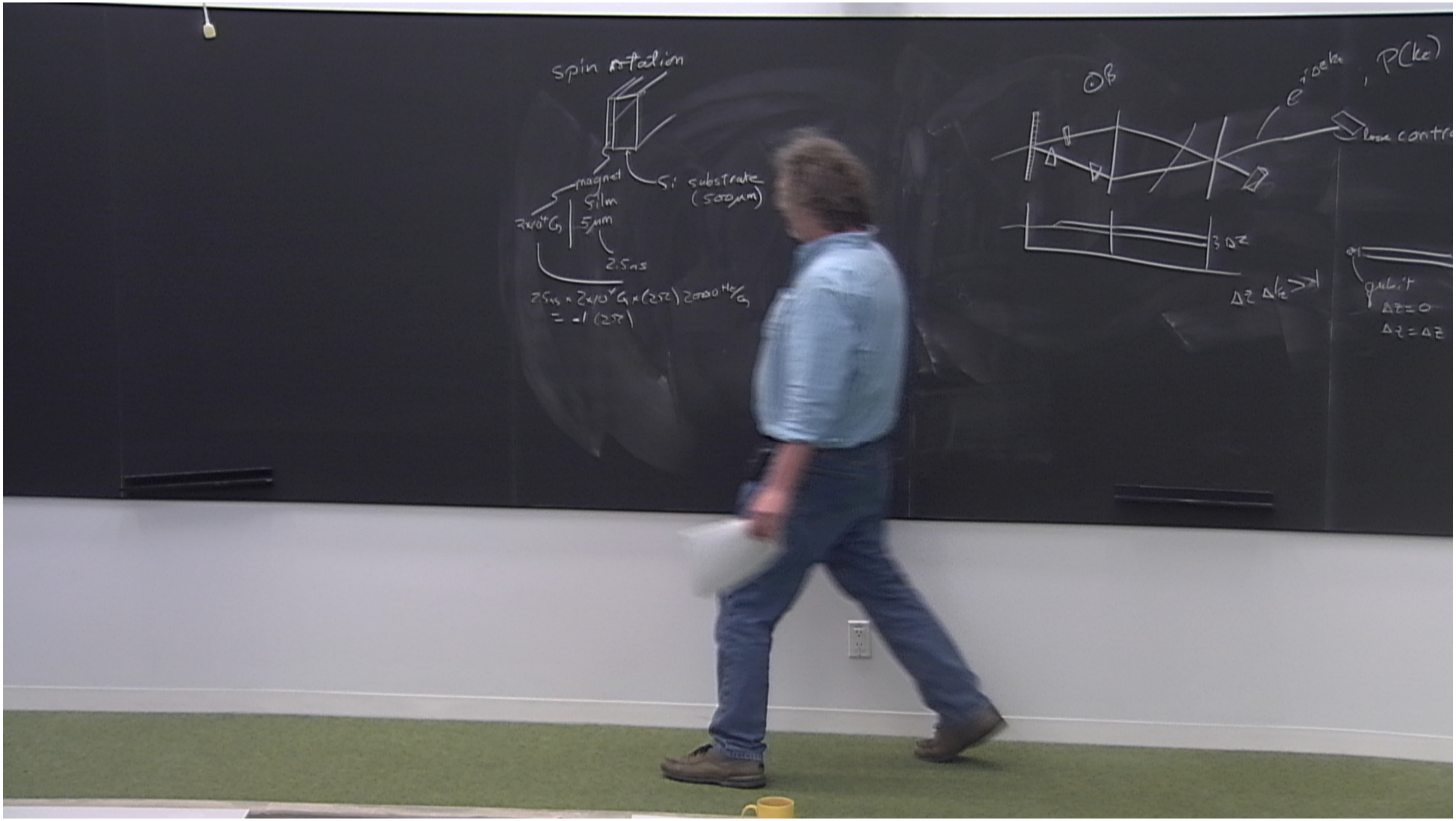

spin rotation
magnet film
5μm
Si substrate
(500μm)
P(kz)
qubit
Δz=0
Δz=Δz

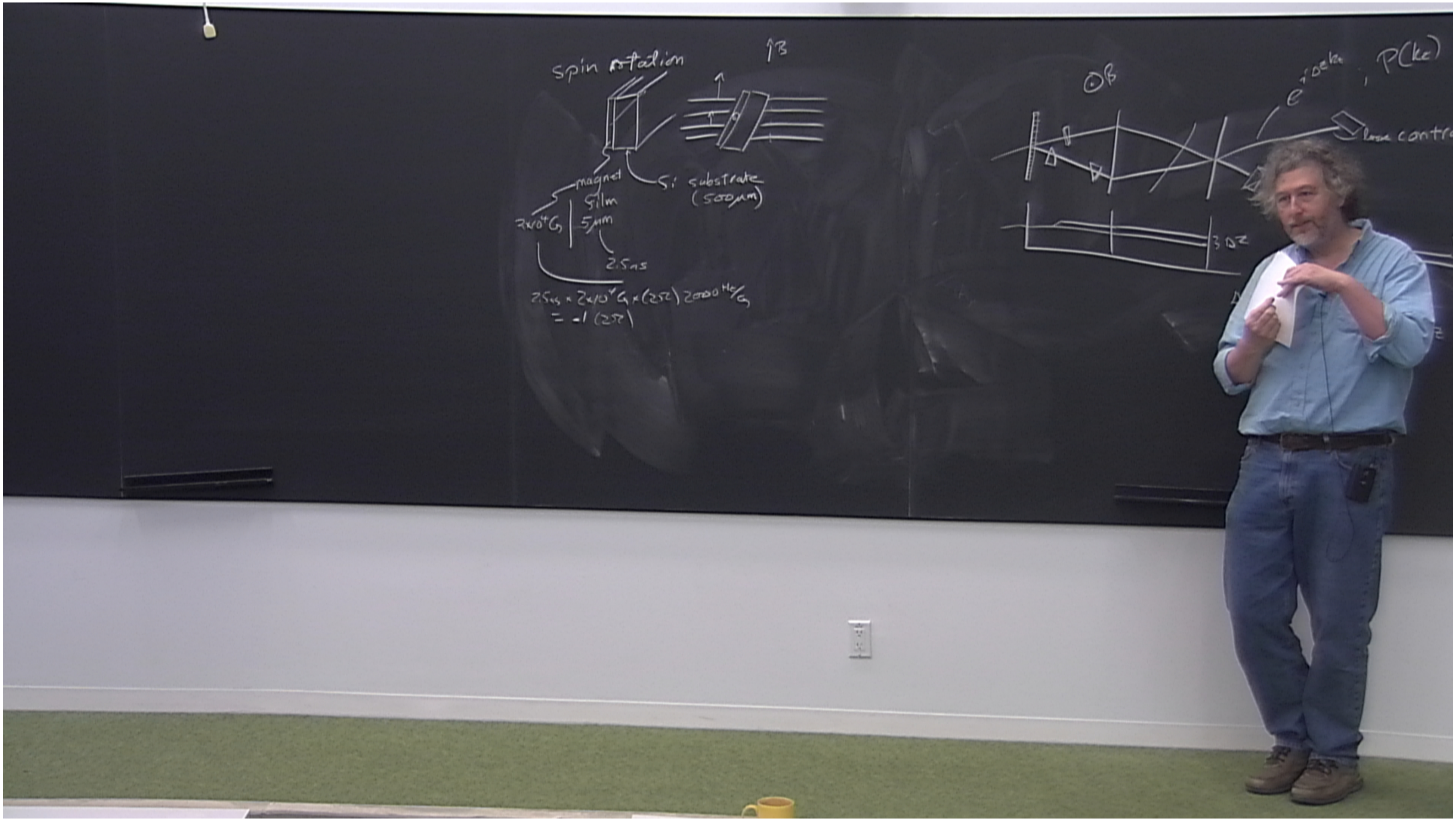

spin rotation
Si substrate
(500μm)
film
5μm
P(kz)
qubit
Δz=0
Δz=Δz

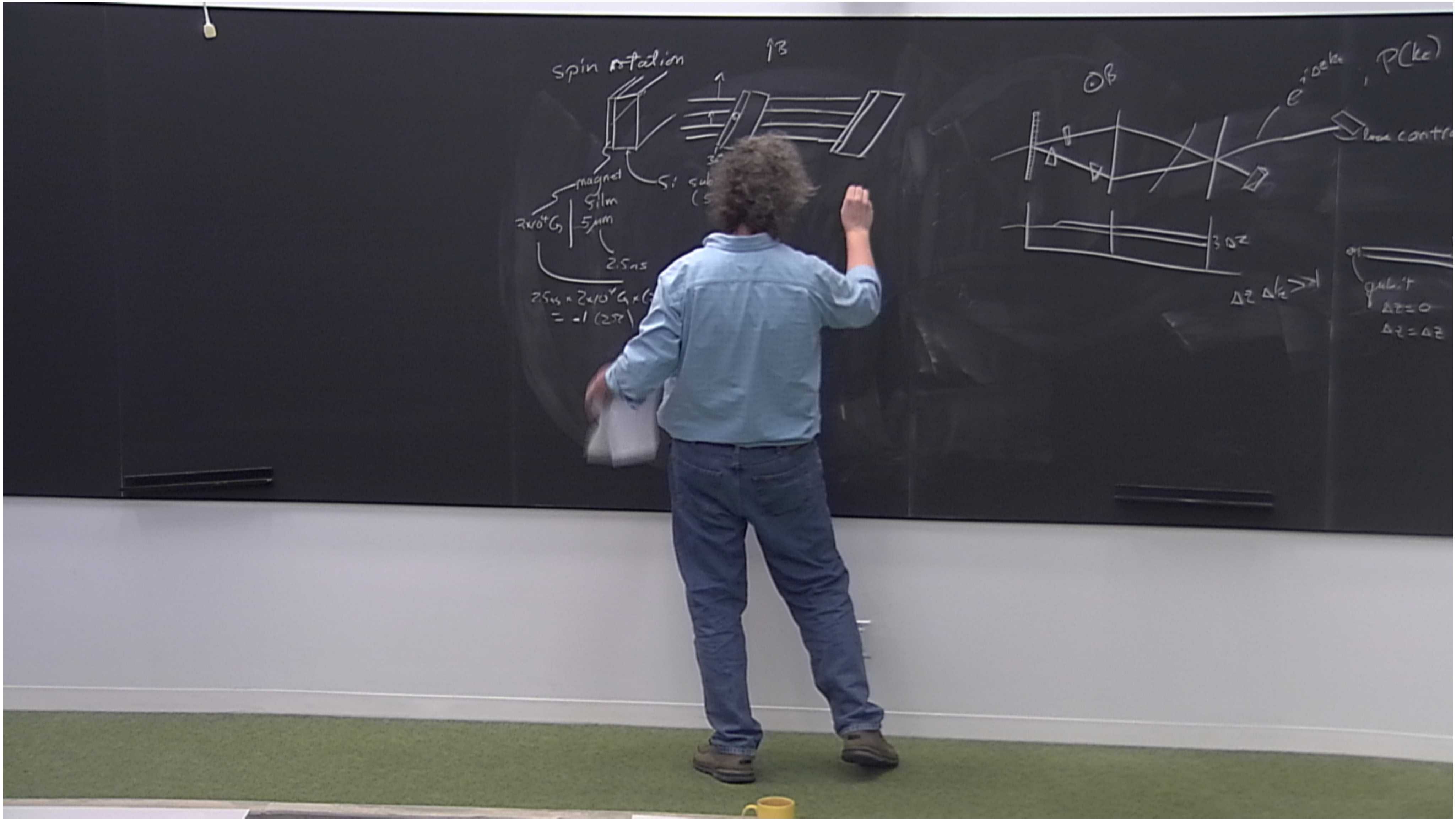

spin rotation
magnet film
Si substrate
(500μm)
5μm
2.5ns
P(kz)
3Δz

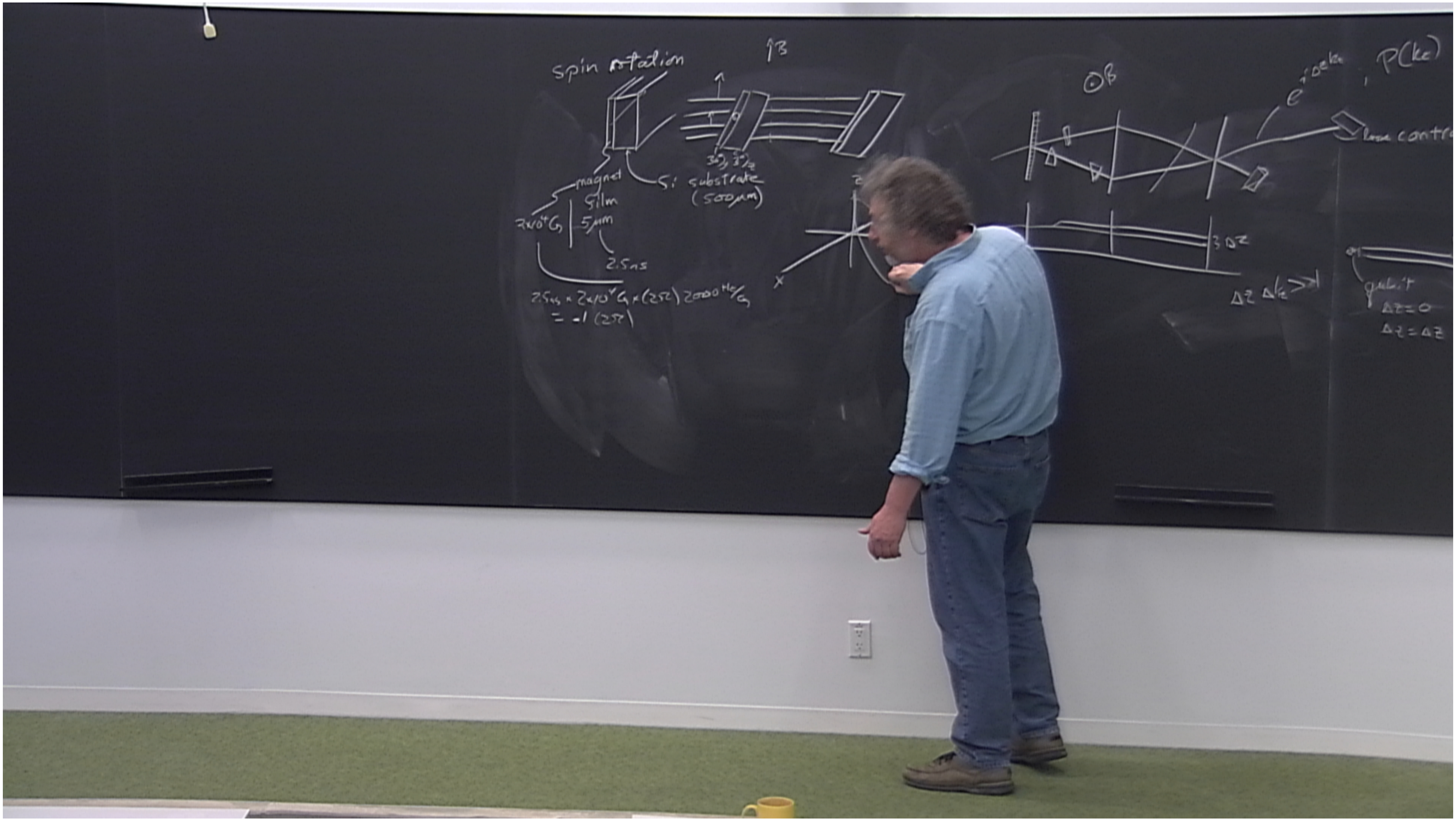

spin rotation
magnet
film
5μm
Si substrate
(500μm)
2.5ns
qubit

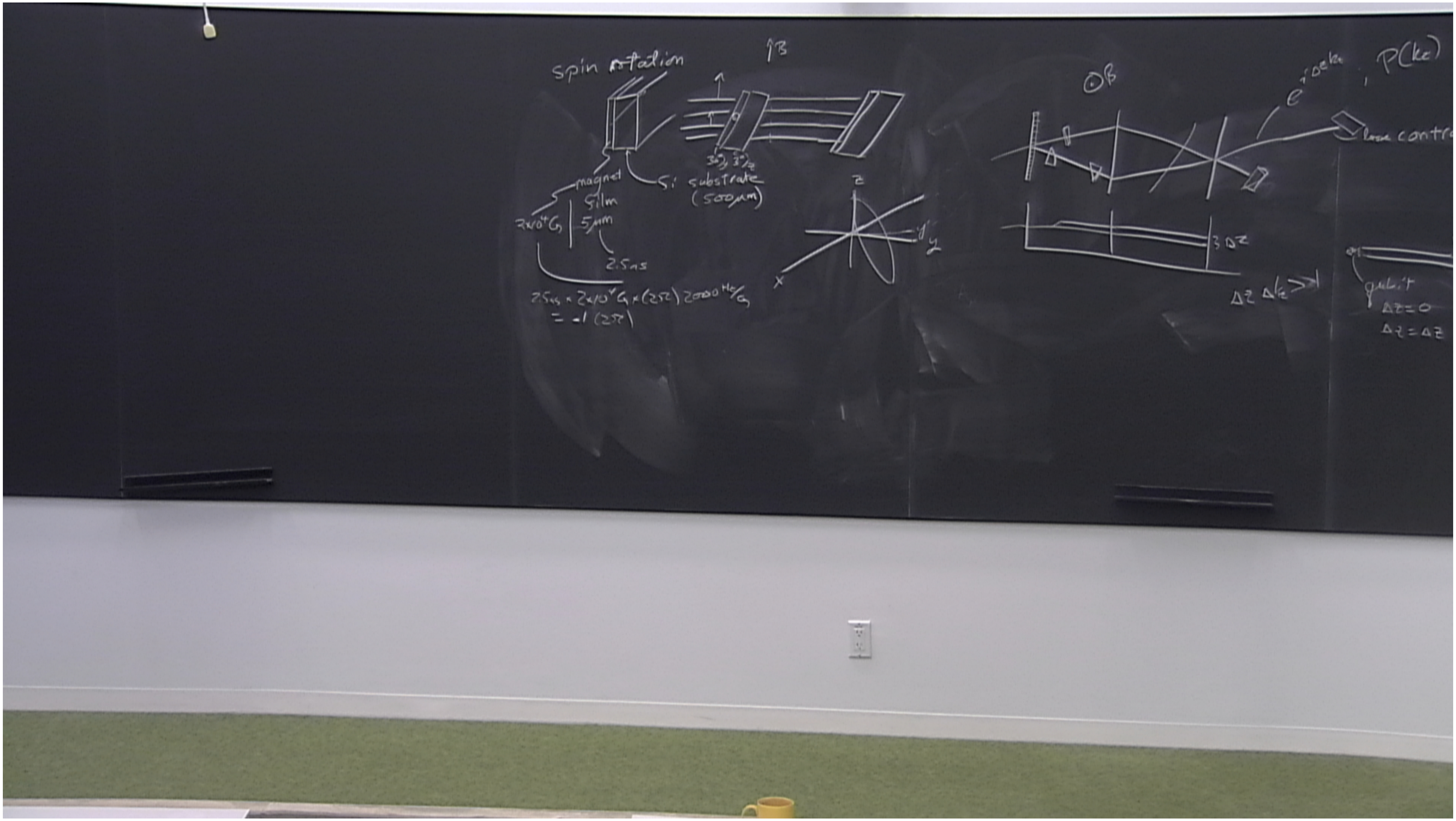

spin rotation
magnet
film
Si substrate
(500μm)
5μm
2.5ns
qubit

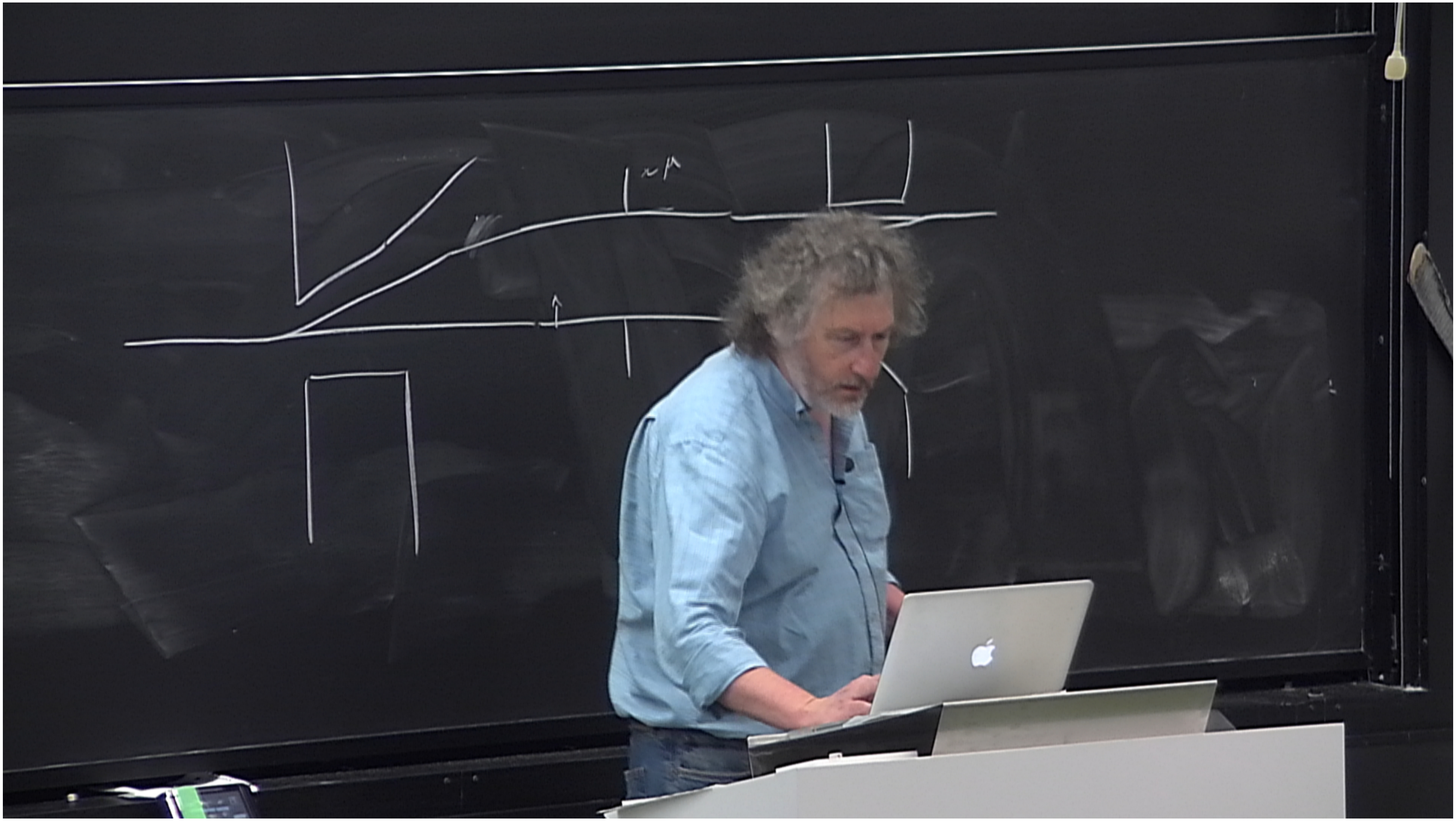

spin rotation
magnet
film
5μm
2.5ns
Si substrate
(500μm)
qubit


spin rotation
magnet
film
5 μm
Si substrate
(500 μm)
2.5 ns
P(kc)
laser control

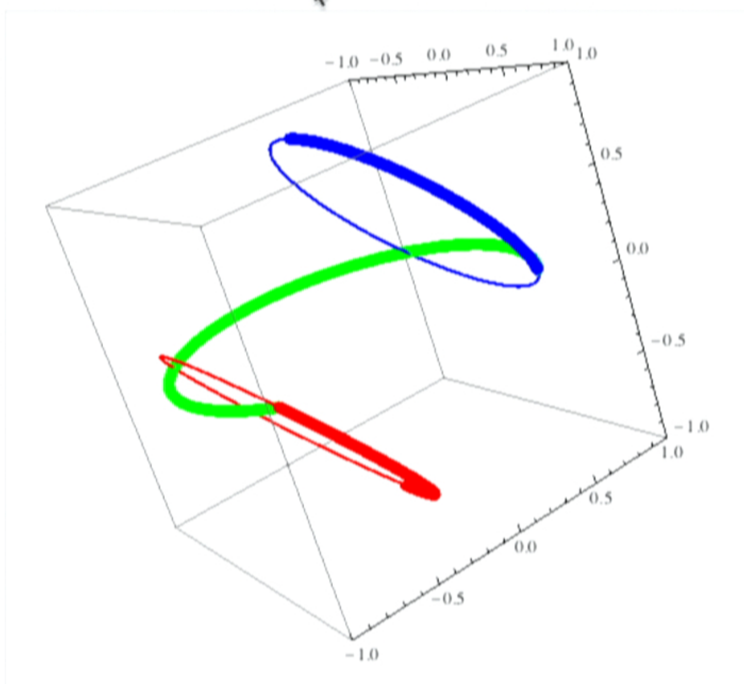

spin rotation
magnet
film
2.5ns
= .1 (2π)


spin rotation
magnet
film
5μm
2.5ns
Si substrate
(500μm)
$2.5ns \times 2\times10^4 G \times (2\pi)\, 2000\, Hz/G$
$= .1\, (2\pi)$
⊙B
P(kz)
qubit

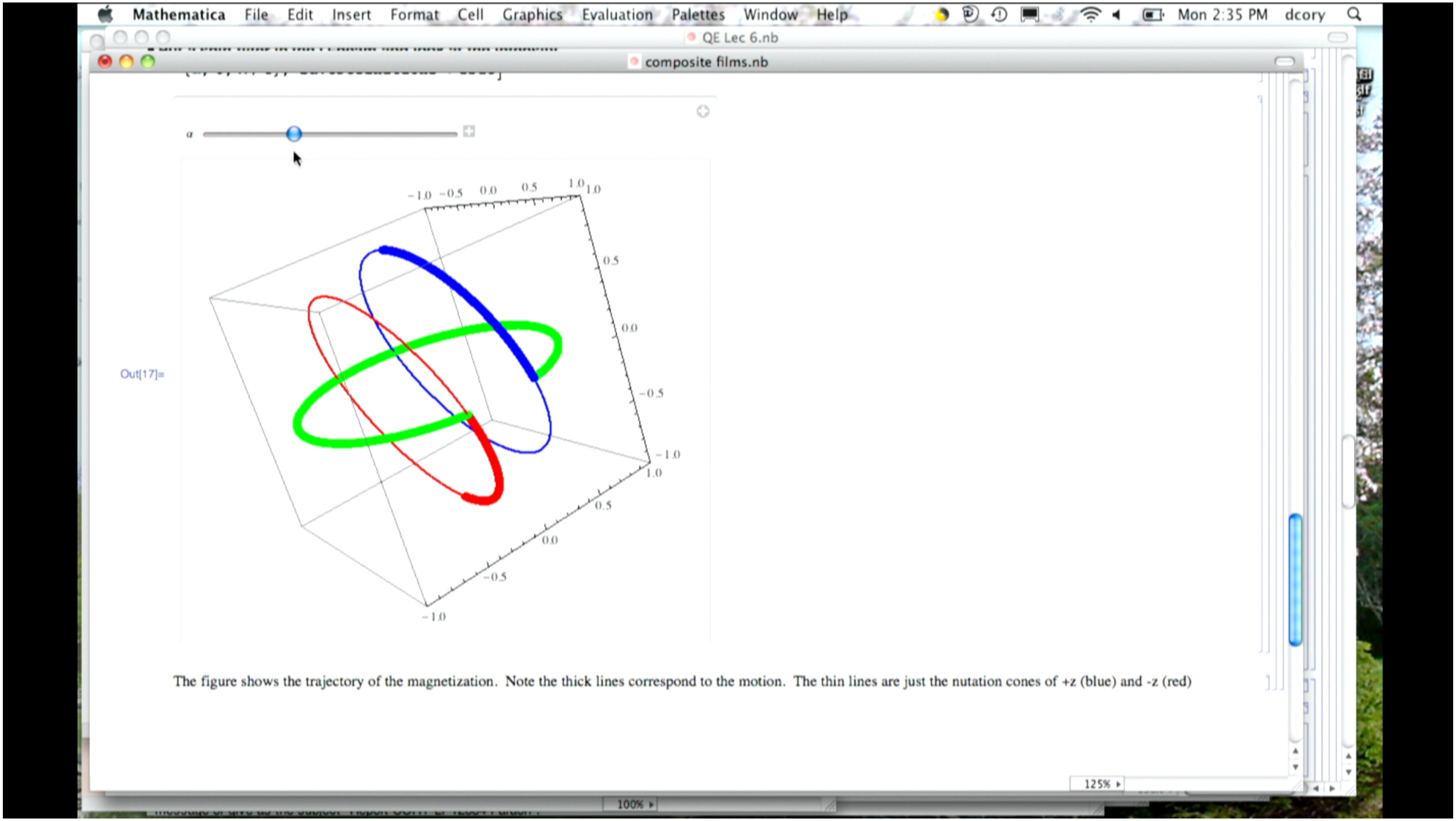

spin rotation
magnet film
Si substrate
(500μm)
2.5ns
⊙B
qubit
Δz=0
Δz=Δz

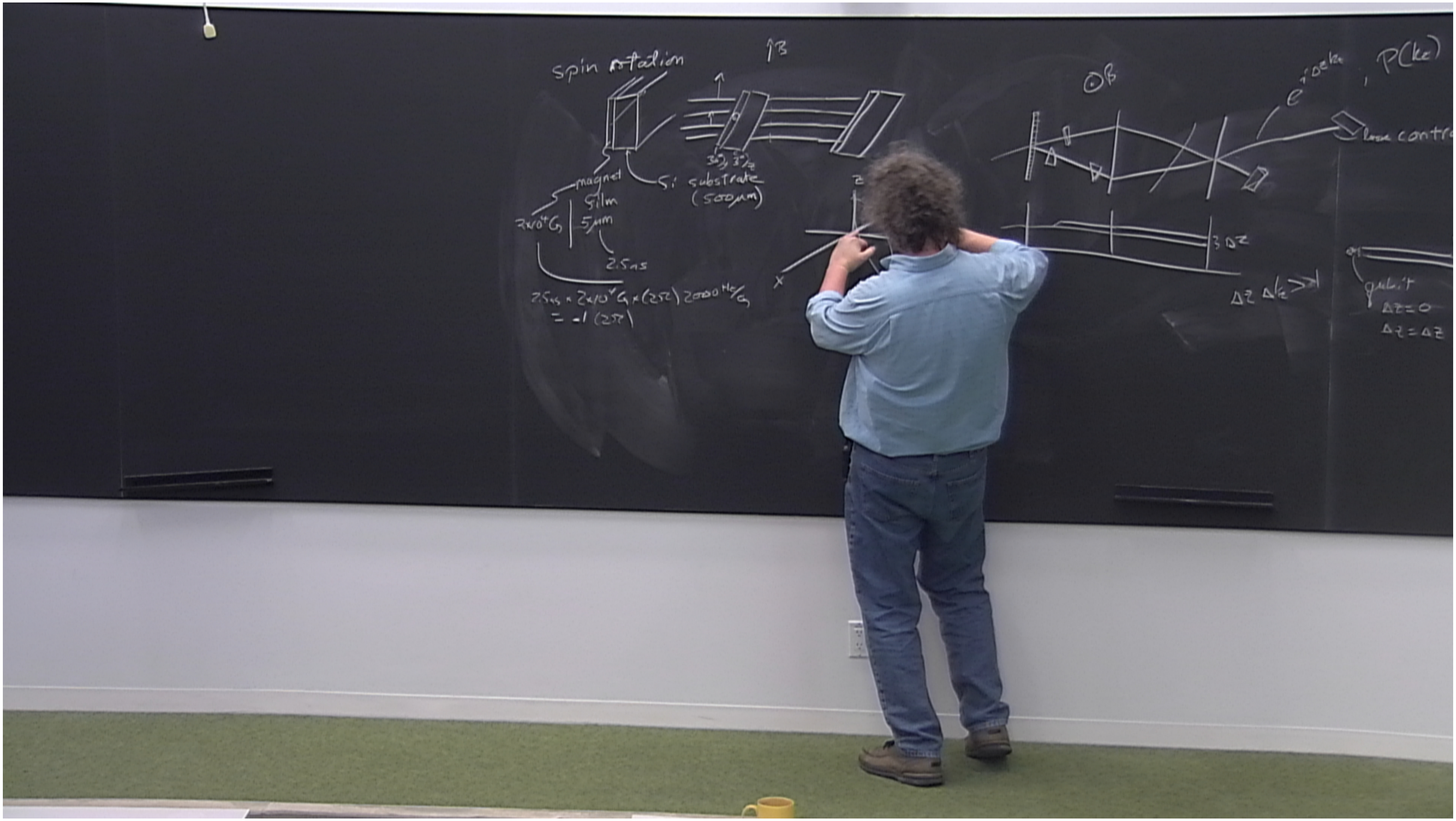


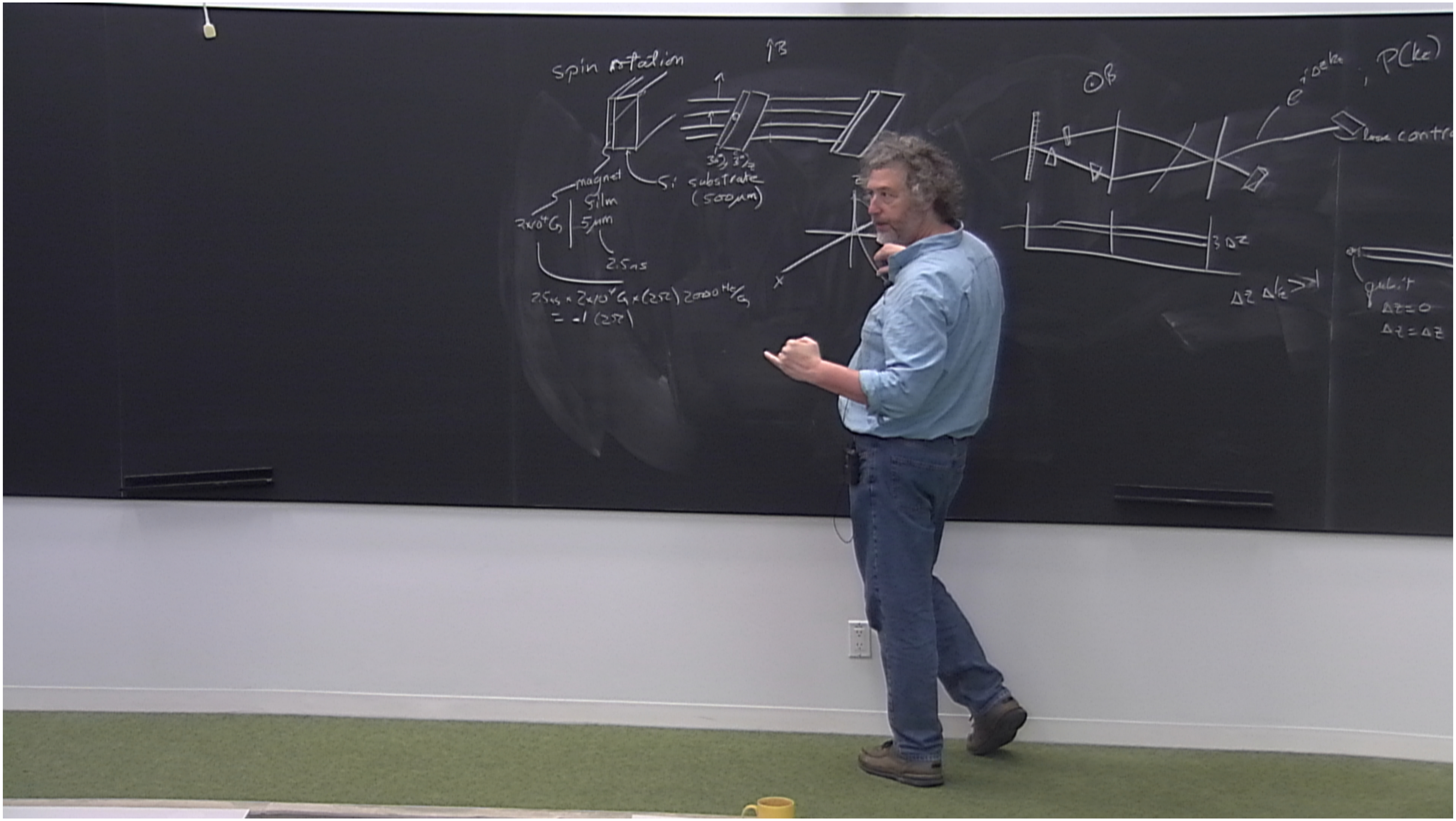
Out[17]=

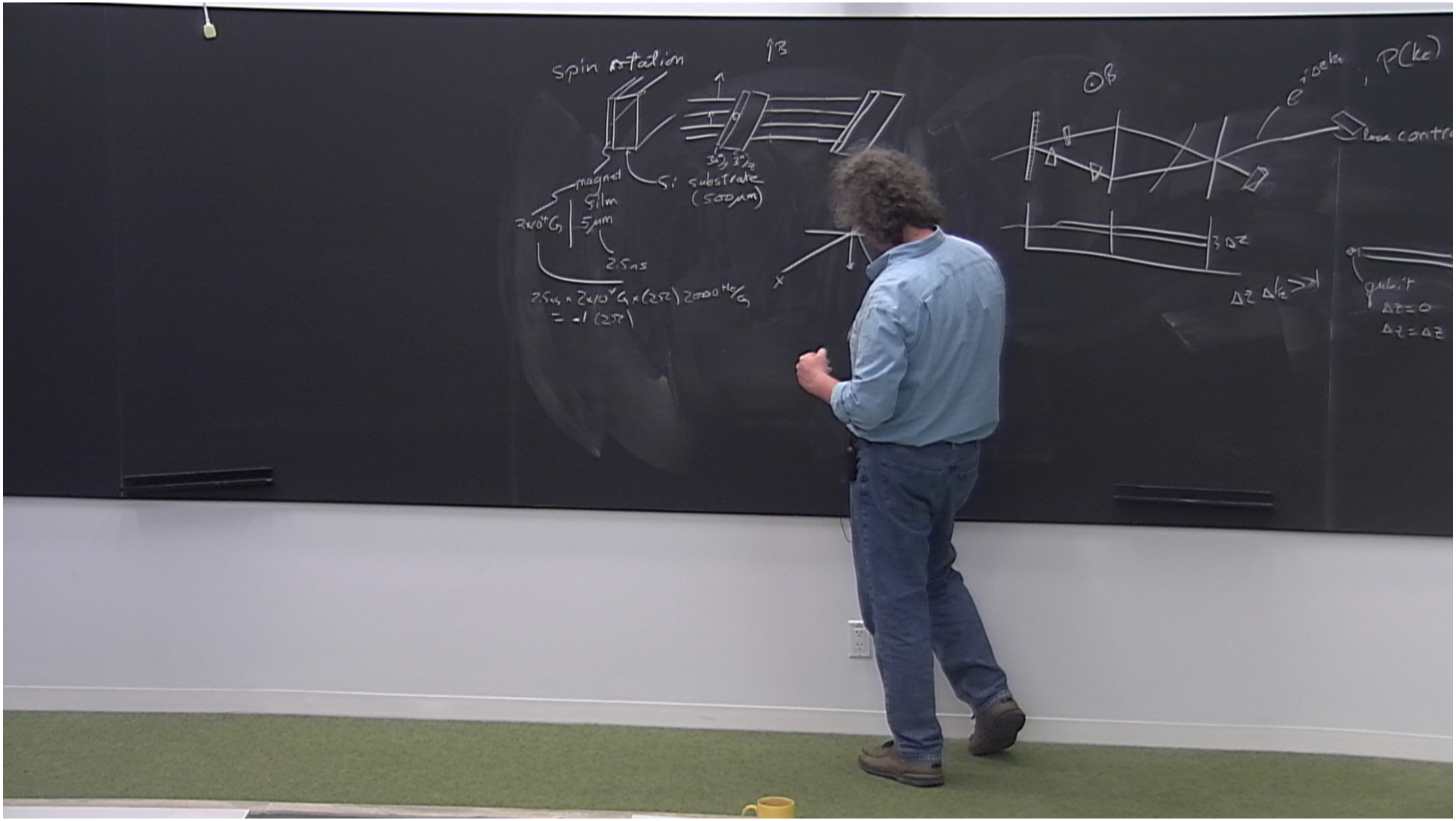


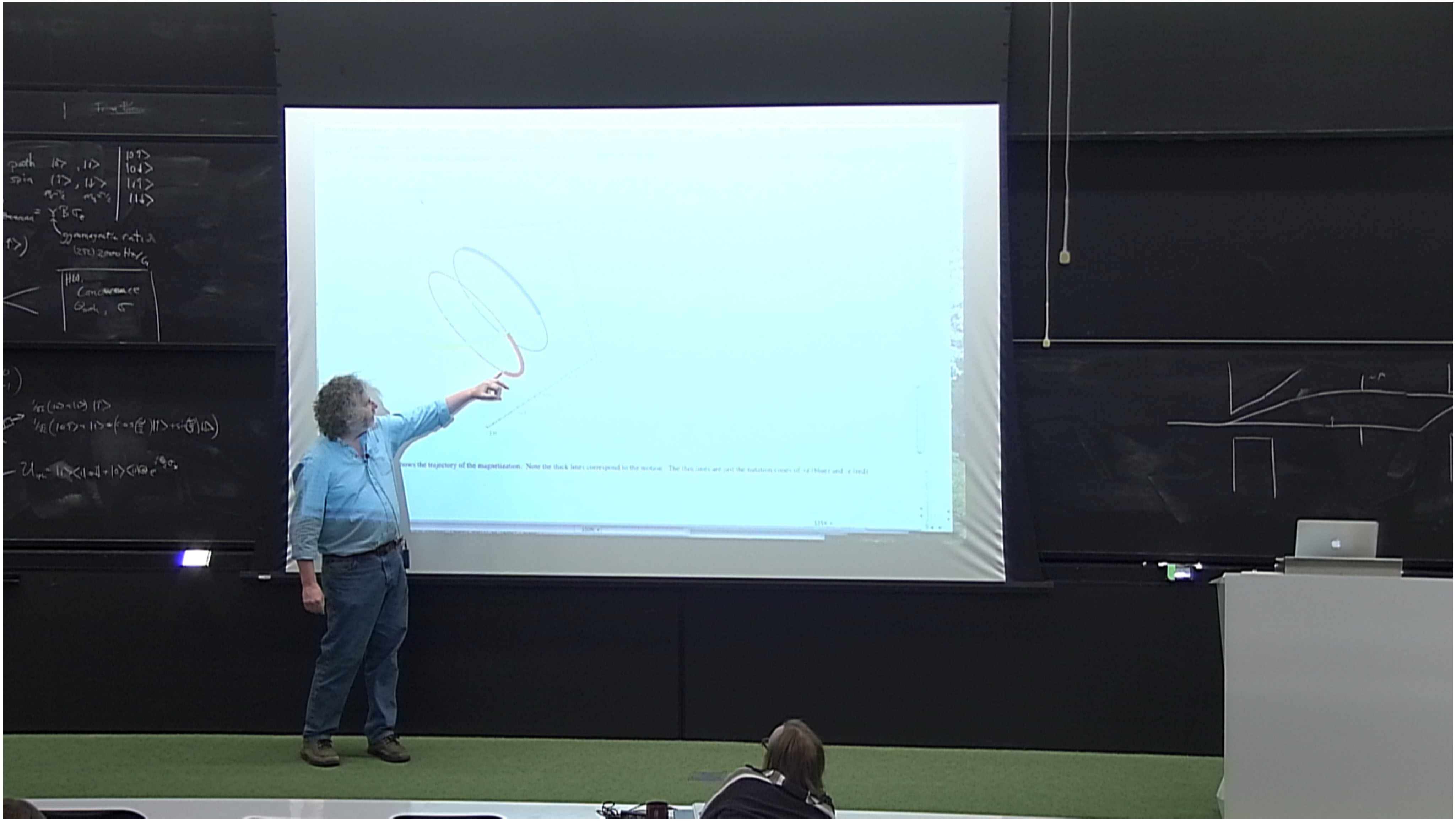
The figure shows the trajectory of the magnetization. Note the thick lines correspond to the motion. The thin lines are just the nutation cones of +z (blue) and -z (red)

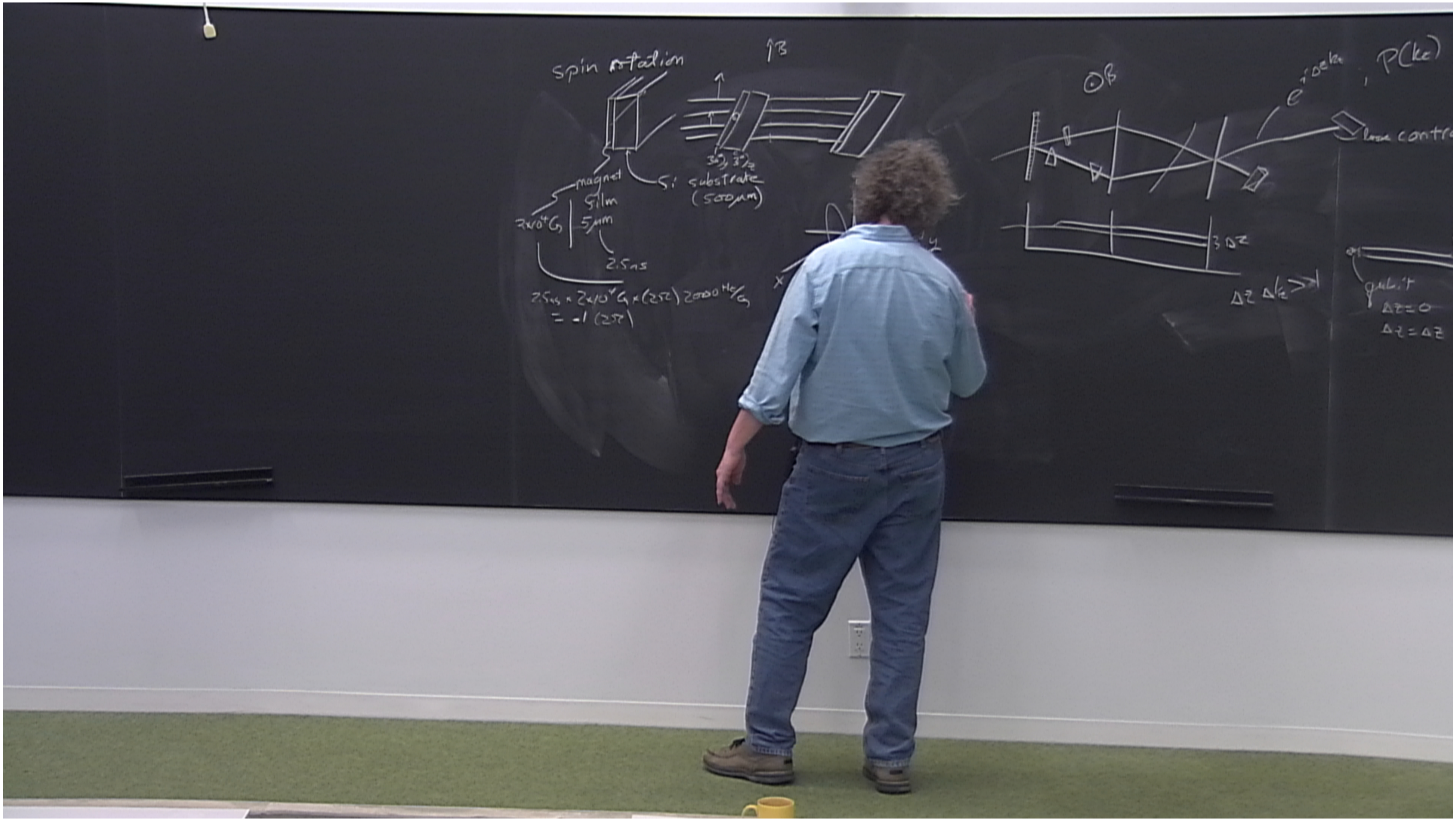

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help
Mon 2:35 PM dcory
QE Lec 6.nb
composite films.nb
a
Out[17]=
−1.0 −0.5 0.0 0.5 1.0
1.0
0.5
0.0
−0.5
−1.0
1.0
0.5
0.0
−0.5
−1.0
The figure shows the trajectory of the magnetization. Note the thick lines correspond to the motion. The thin lines are just the nutation cones of +z (blue) and -z (red)
125%
100%

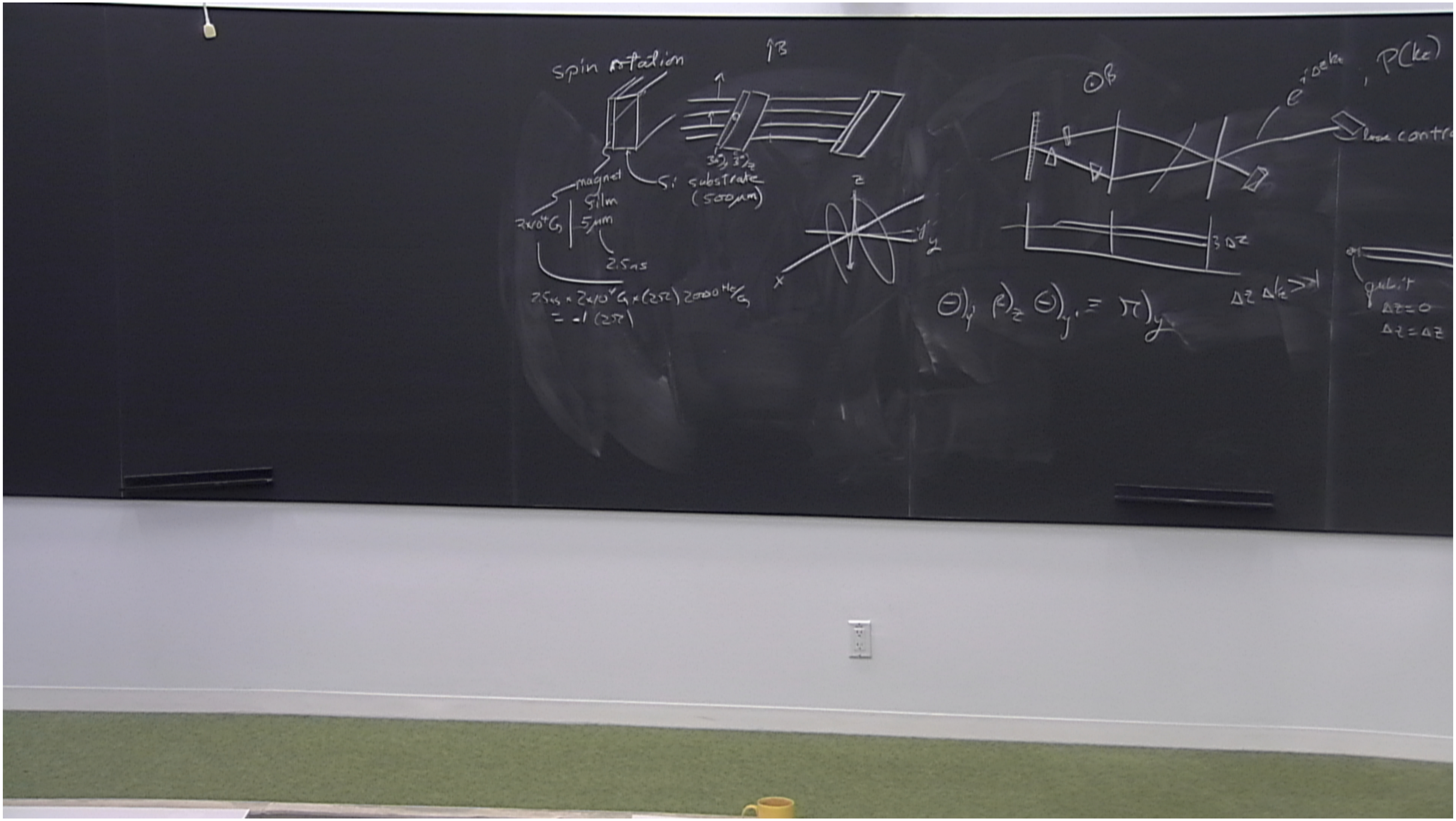

spin rotation
magnet
film
5μm
2.5ns
Si substrate
(500μm)
2.5ns × 2×10⁴ G × (2π) 2000 Hz/G
= .1 (2π)
qubit
Δz = 0
Δz = Δz

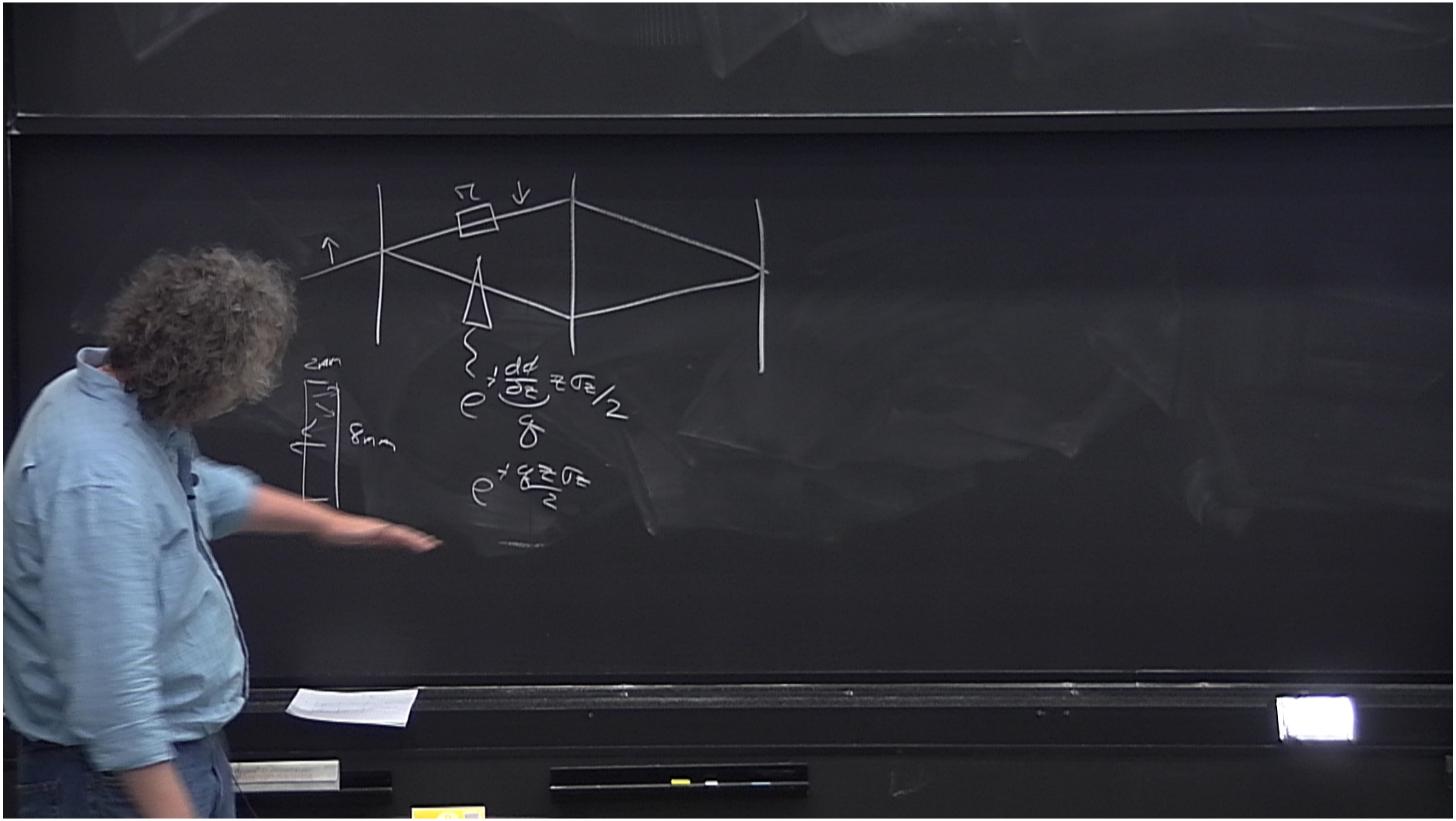

spin rotation
magnet
film
5μm
Si substrate
(500μm)
2.5ns
qubit


spin rotation
magnet
film
5μm
2.5ns
Si substrate
(500μm)
qubit

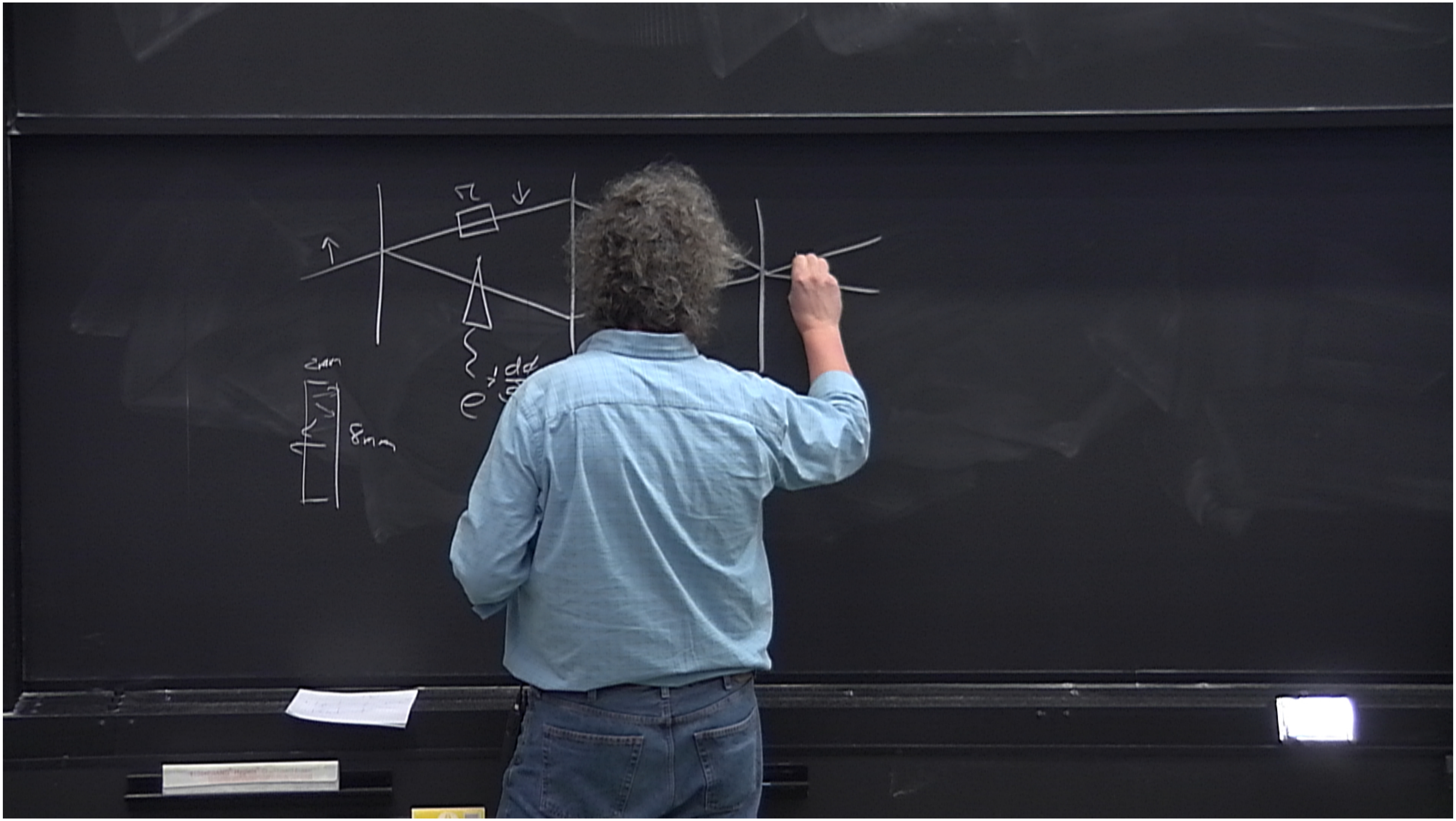

ows the trajectory of the magnetization. Note the thick lines correspond to the motion.

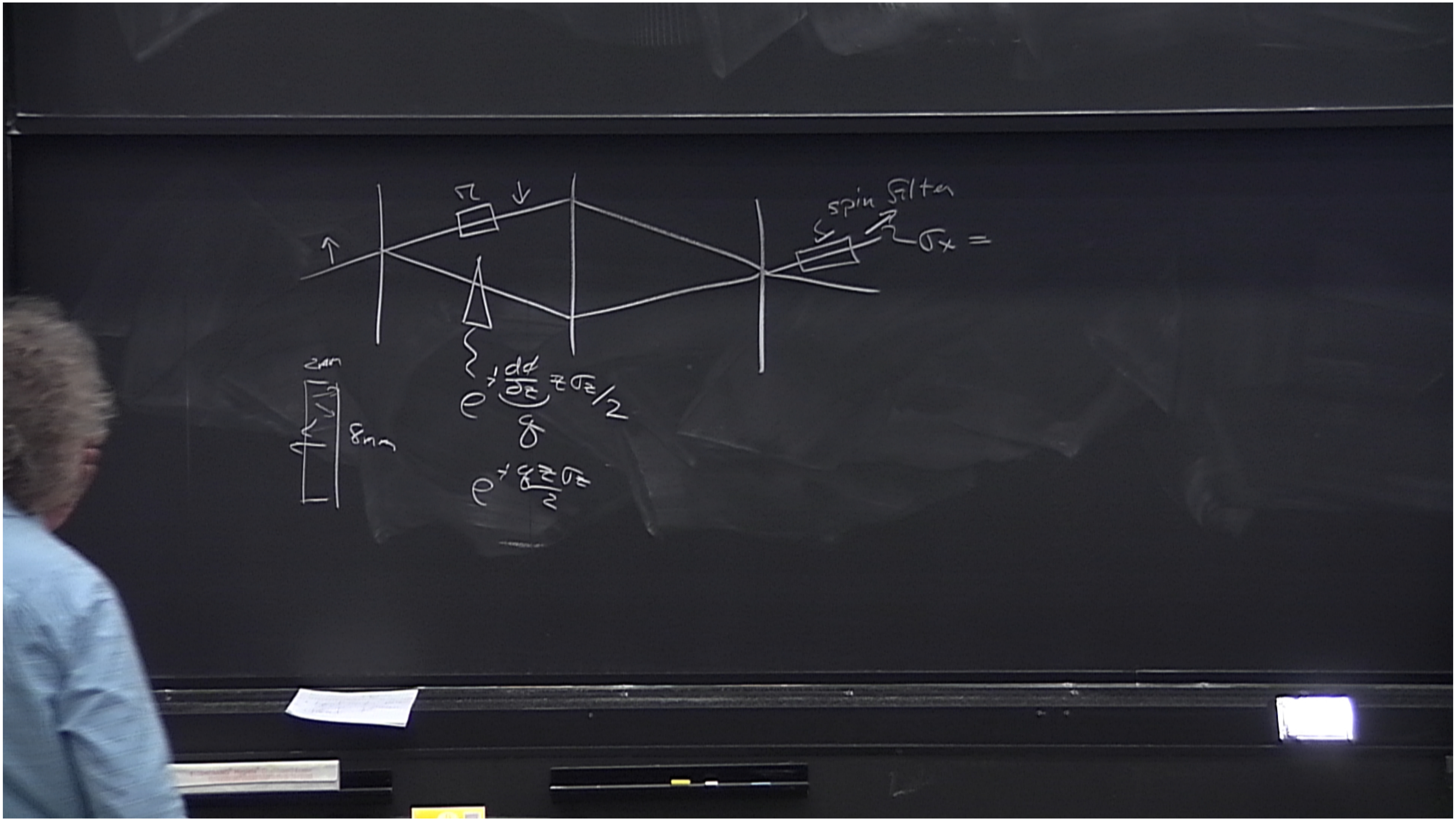

spin rotation
magnet
film
5μm
Si substrate
(500μm)
2.5ns
qubit


spin rotation
magnet
Si substrate
(500μm)
film
5μm
2.5ns
P(kc)
qubit
Δz=0
Δz=Δz



2mm
8mm





spin filter
σ_x =
2mm
8mm

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entanglement filter.nb

```
Out[21]= {{1/√2, 0, -1/√2, 0}, {0, 1, 0, 0}, {1/√2, 0, 1/√2, 0}, {0, 0, 0, 1}}

In[23]:= Uspin = MatrixExp[I (π / 2) KroneckerProduct[Ep, PauliMatrix[1]]]

Out[23]= {{0, i, 0, 0}, {i, 0, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}

In[24]:= Uspini = MatrixExp[-I (π / 2) KroneckerProduct[Ep, PauliMatrix[1]]]

Out[24]= {{0, -i, 0, 0}, {-i, 0, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}

Uphase[a_] := MatrixExp[I (a / 2) KroneckerProduct[PauliMatrix[1], Ep]]

In[26]:= Uphasei[a_] := MatrixExp[-I (a / 2) KroneckerProduct[PauliMatrix[1], Ep]]

In[28]:= Umir = MatrixExp[I (π / 2) KroneckerProduct[PauliMatrix[1], Ep]]

Out[28]= {{0, 0, i, 0}, {0, 1, 0, 0}, {i, 0, 0, 0}, {0, 0, 0, 1}}

In[29]:= Umiri = MatrixExp[-I (π / 2) KroneckerProduct[PauliMatrix[1], Ep]]

Out[29]= {{0, 0, -i, 0}, {0, 1, 0, 0}, {-i, 0, 0, 0}, {0, 0, 0, 1}}

In[30]:= rout[a_] := Ub . Umir . Uspin . Uphase[a] . Ub . rin . Ubi . Uphasei[a] . Uspin . Umir . Ub

In[32]:= Simplify[rout[a]] // MatrixForm

Out[32]//MatrixForm=
```

$$\begin{pmatrix} -\frac{1}{4} & \frac{1}{2\sqrt{2}} & -\frac{1}{4} & 0 \\ \frac{1}{2\sqrt{2}} & -\frac{1}{2} & \frac{1}{2\sqrt{2}} & 0 \\ 1 & 1 & 1 & 0 \end{pmatrix}$$

150%

-z (red)

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entanglement filter.nb

```
In[29]:= Umiri = MatrixExp[-I (π / 2) KroneckerProduct[PauliMatrix[1], Ep]]

Out[29]= {{0, 0, -i, 0}, {0, 1, 0, 0}, {-i, 0, 0, 0}, {0, 0, 0, 1}}

In[30]:= rout[a_] := Ub . Umir . Uspin . Uphase[a] . Ub . rin . Ubi . Uphasei[a] . Uspin . Umir . Ub

In[32]:= Simplify[rout[a]] // MatrixForm
```

Out[32]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{4} & \frac{1}{2\sqrt{2}} & -\frac{1}{4} & 0 \\ \frac{1}{2\sqrt{2}} & -\frac{1}{2} & \frac{1}{2\sqrt{2}} & 0 \\ \frac{1}{4} & -\frac{1}{2\sqrt{2}} & \frac{1}{4} & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

```
In[34]:= Ub // MatrixForm
```

Out[34]//MatrixForm=

$$\begin{pmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & 0 \\ -\frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

150%

-z (red)

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entanglement filter.nb

In[29]:=
```
Umiri = MatrixExp[-I (π / 2) KroneckerProduct[PauliMatrix[1], Ep]]
```

Out[29]=
```
{{0, 0, -i, 0}, {0, 1, 0, 0}, {-i, 0, 0, 0}, {0, 0, 0, 1}}
```

In[30]:=
```
rout[a_] := Ub . Umir . Uspin . Uphase[a] . Ub . rin . Ubi . Uphasei[a] . Uspin . Umir . Ub
```

In[32]:=
```
Simplify[rout[a]] // MatrixForm
```

Out[32]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{4} & \frac{1}{2\sqrt{2}} & -\frac{1}{4} & 0 \\ \frac{1}{2\sqrt{2}} & -\frac{1}{2} & \frac{1}{2\sqrt{2}} & 0 \\ \frac{1}{4} & -\frac{1}{2\sqrt{2}} & \frac{1}{4} & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

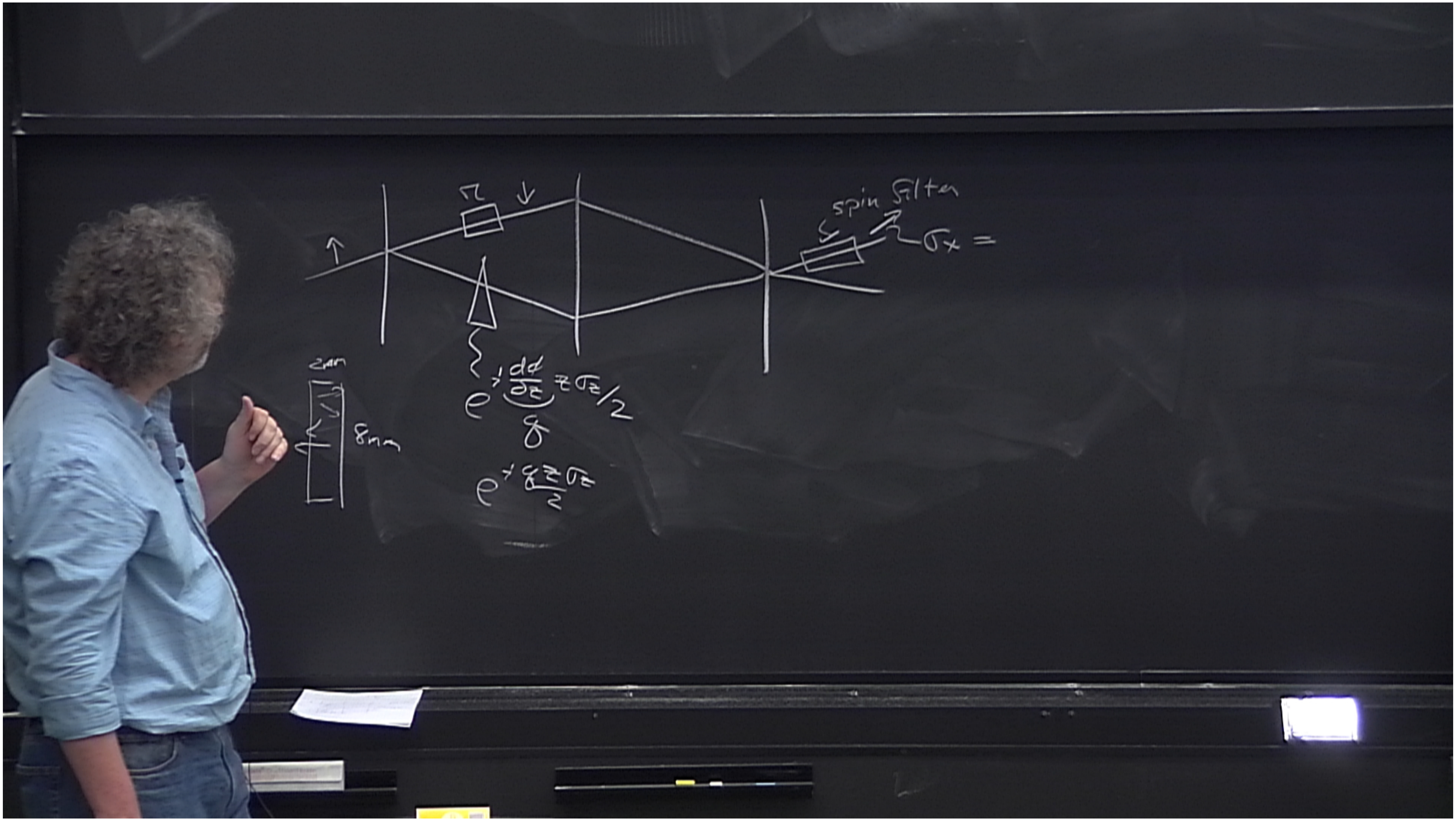
In[34]:=
```
Ub // MatrixForm
```

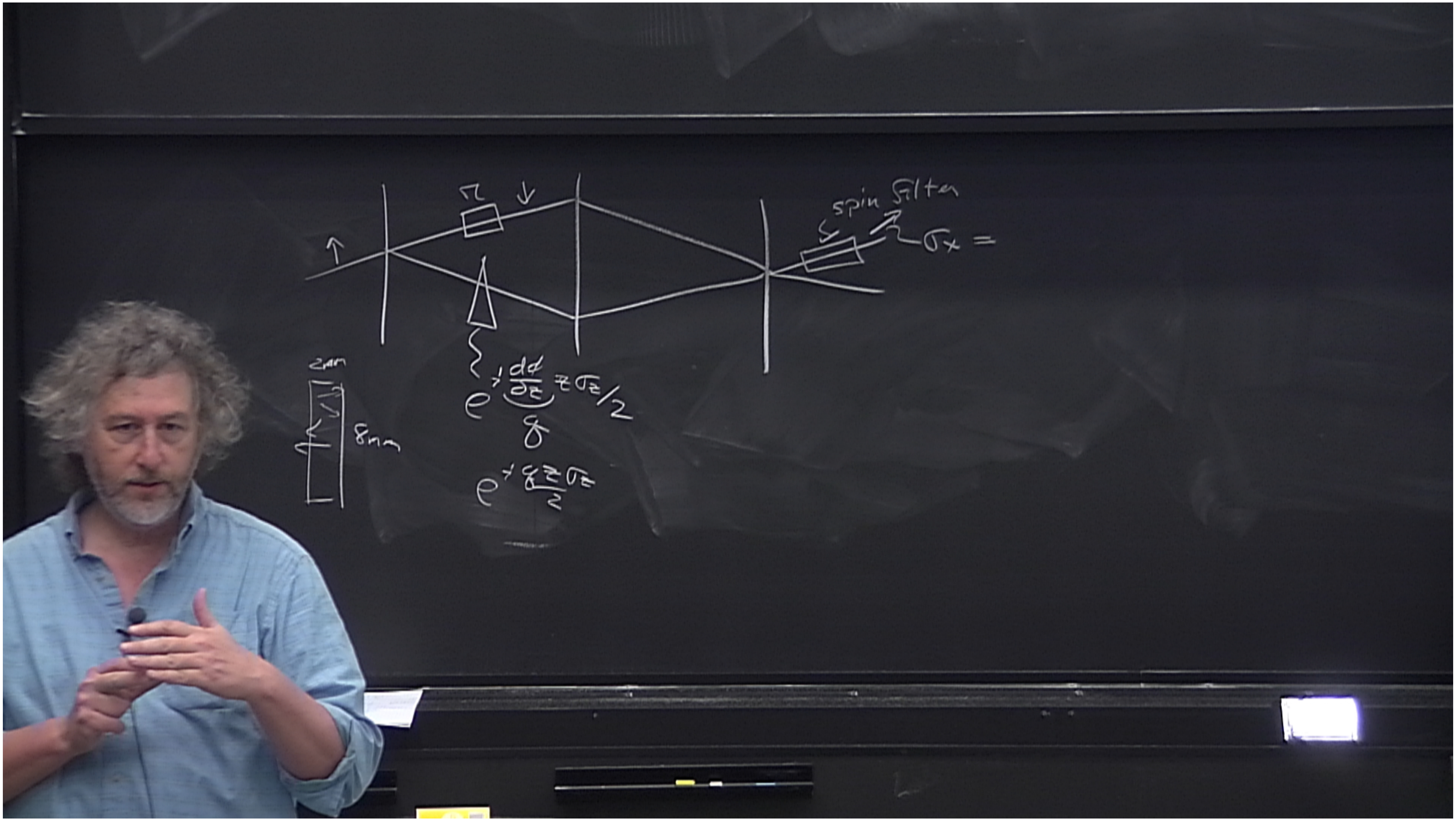
Out[34]//MatrixForm=

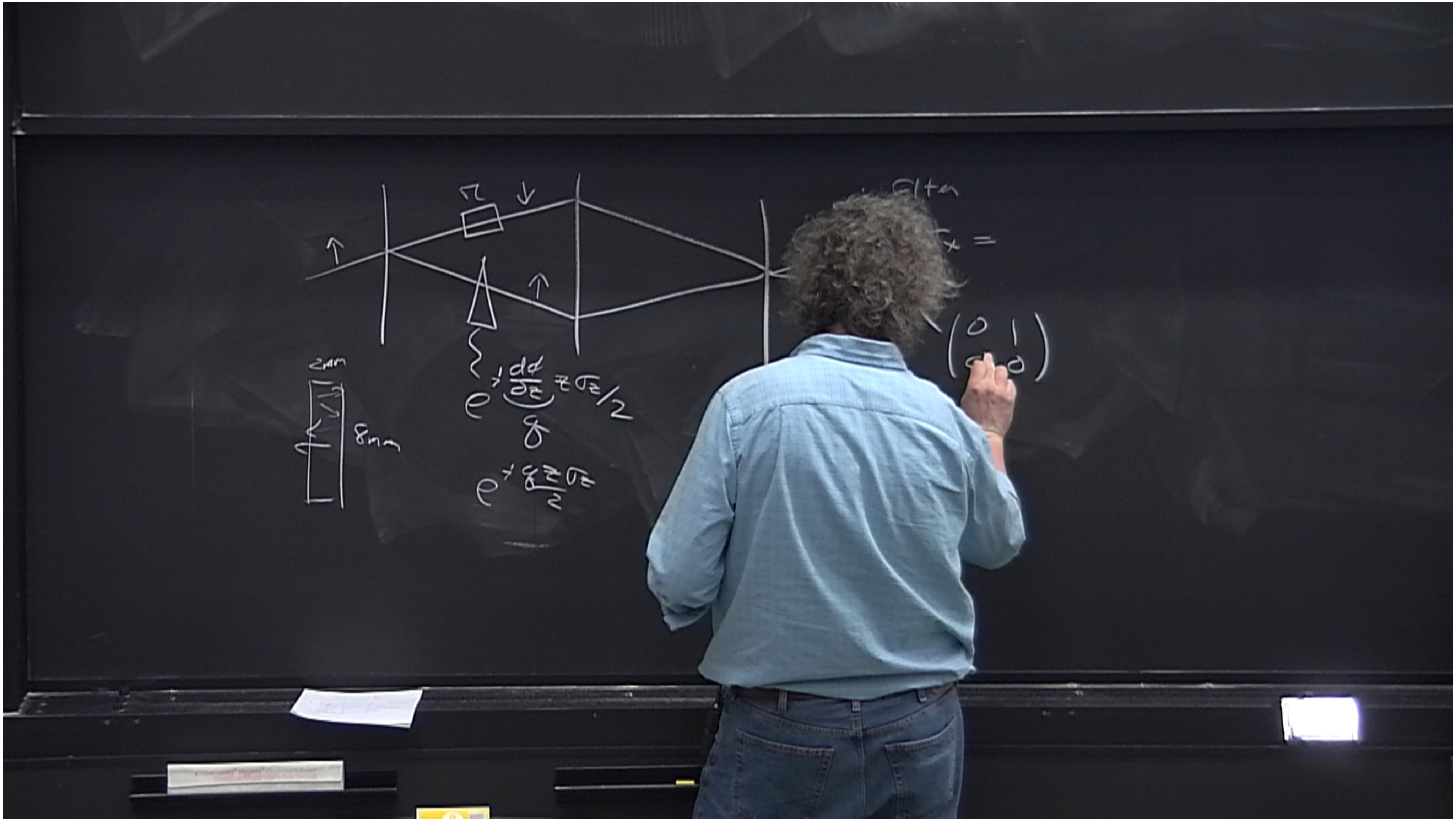
$$\begin{pmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & 0 \\ -\frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

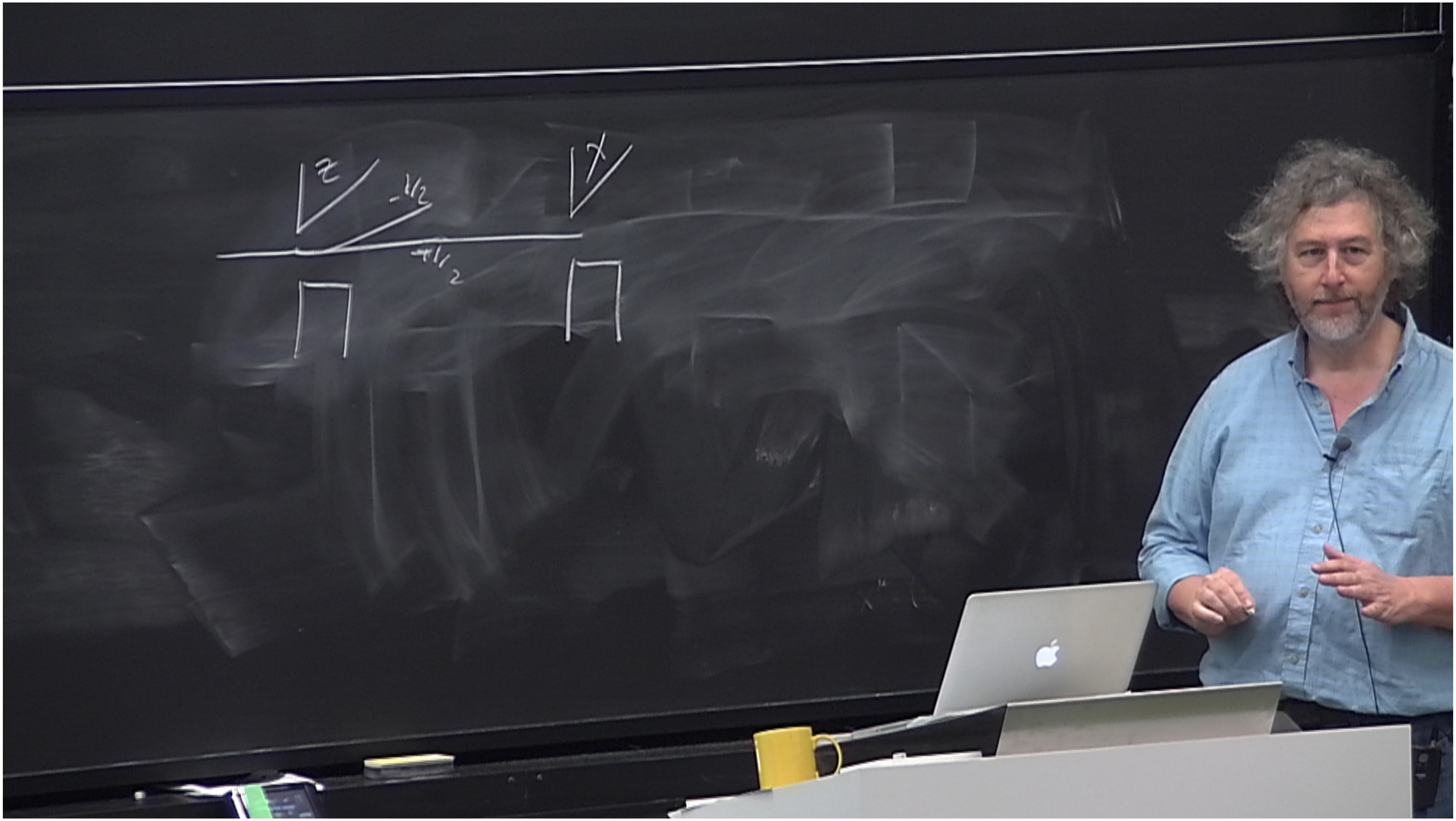
-z (red)

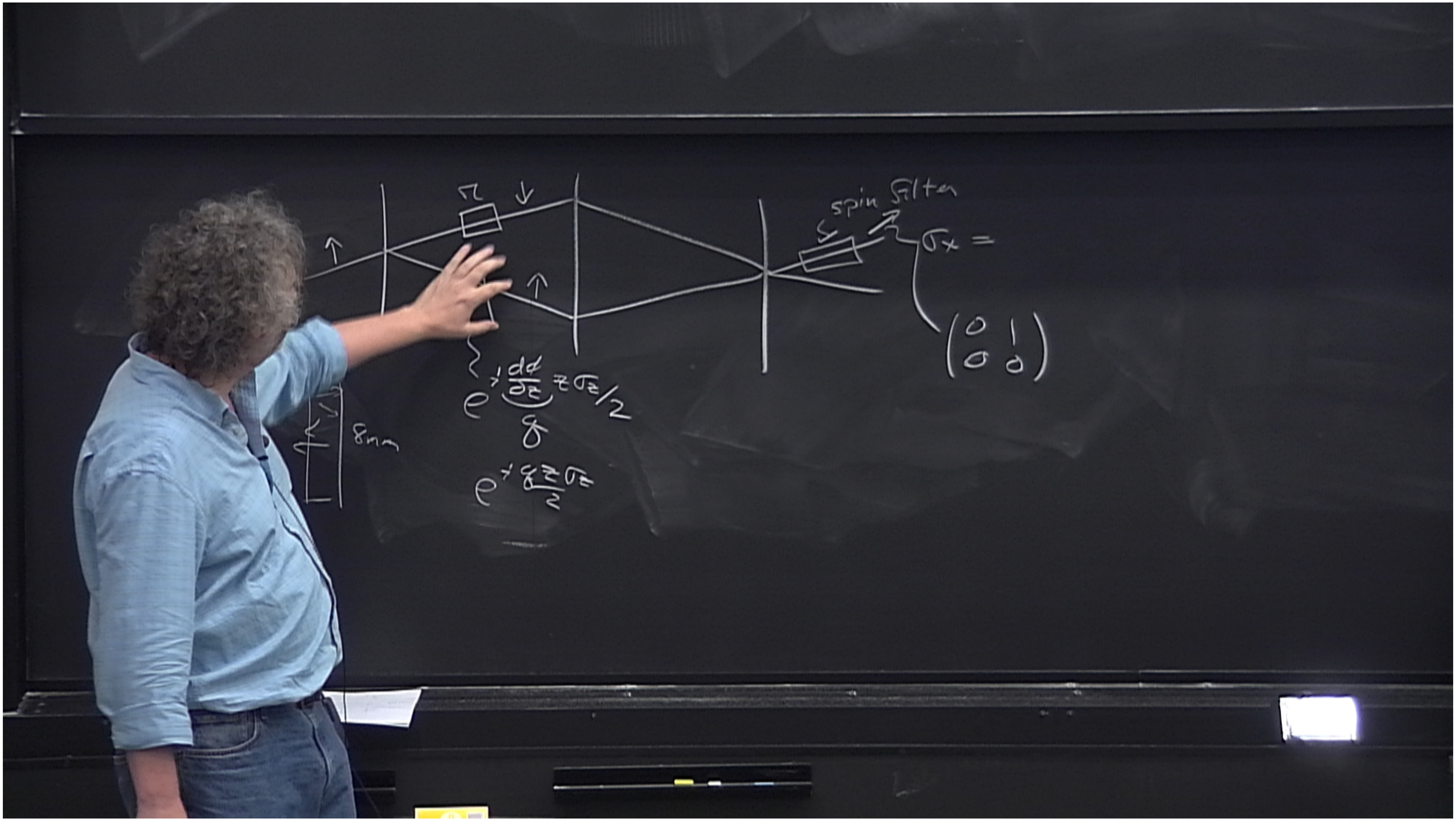
150%

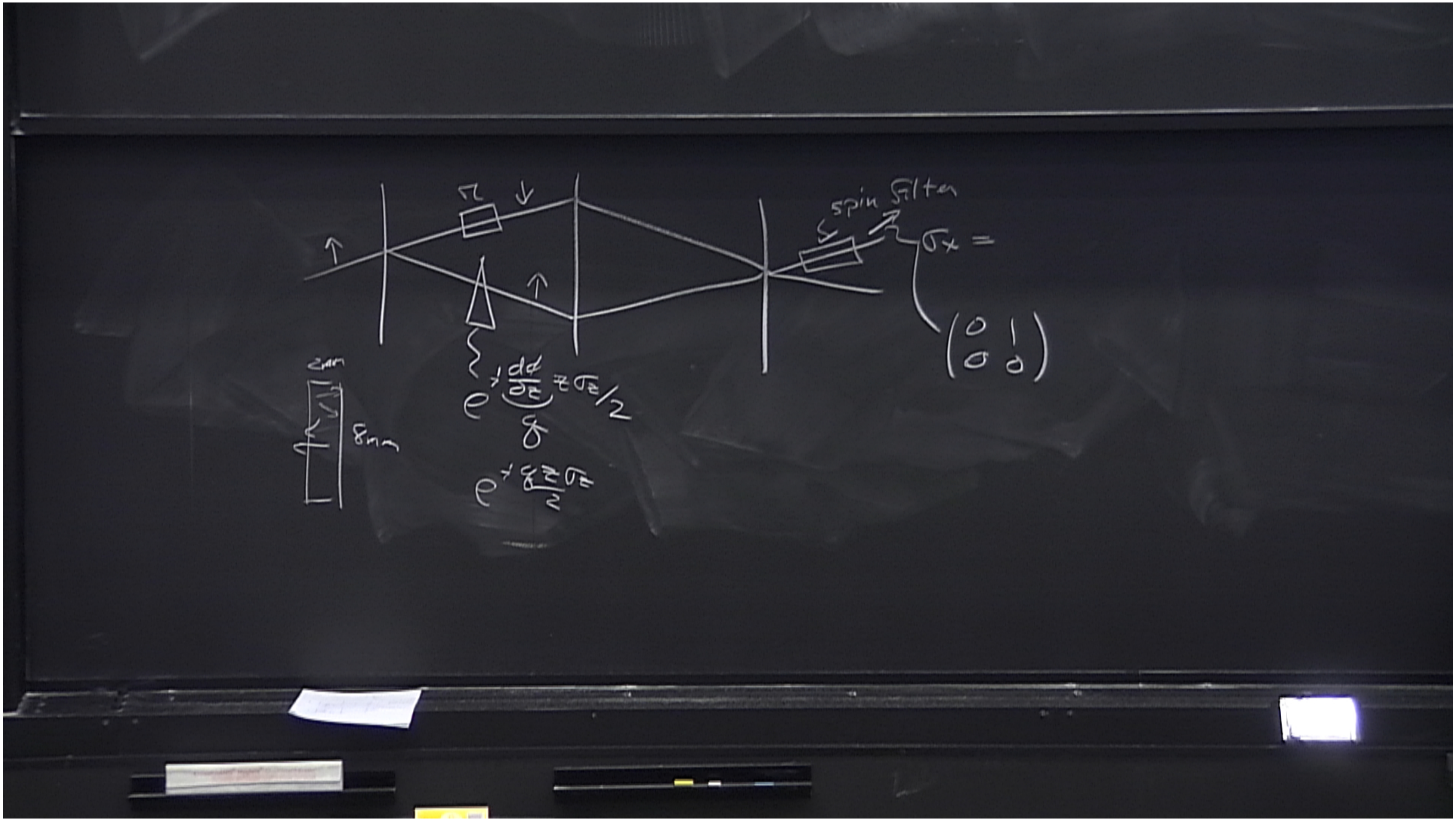

spin filter
σ_x =
2mm
8mm

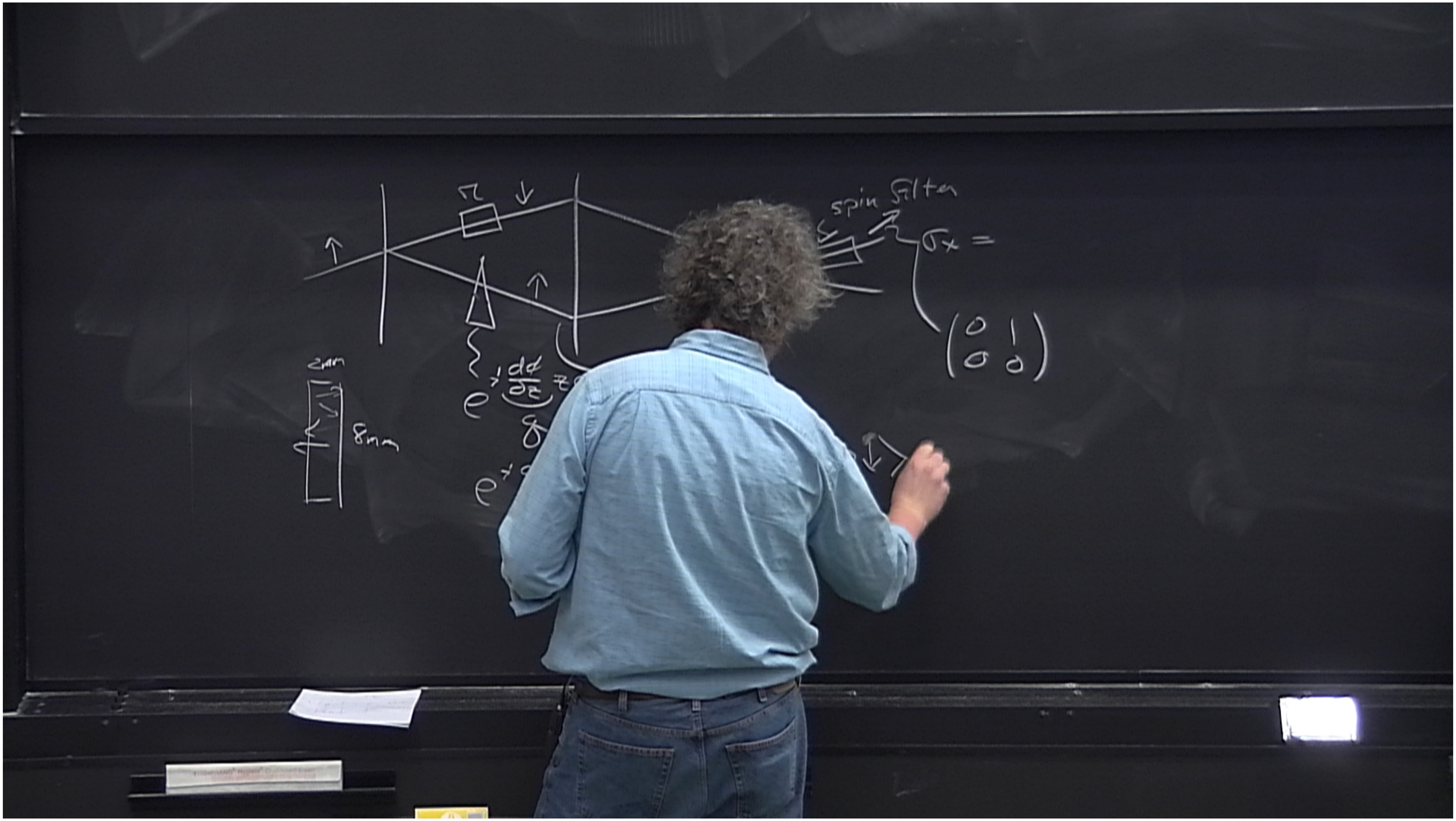

spin filter
2mm
8mm

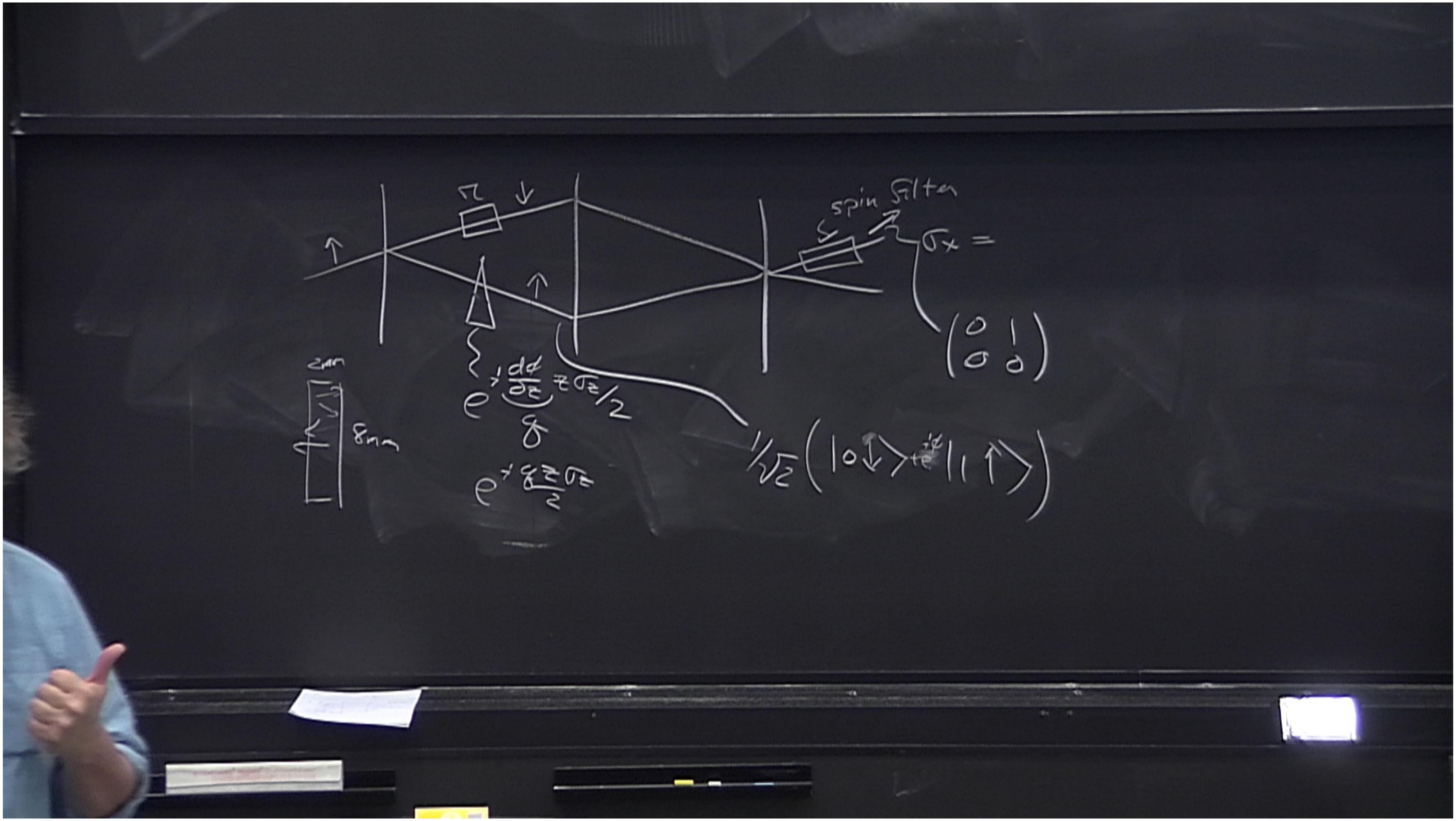

2mm
8mm

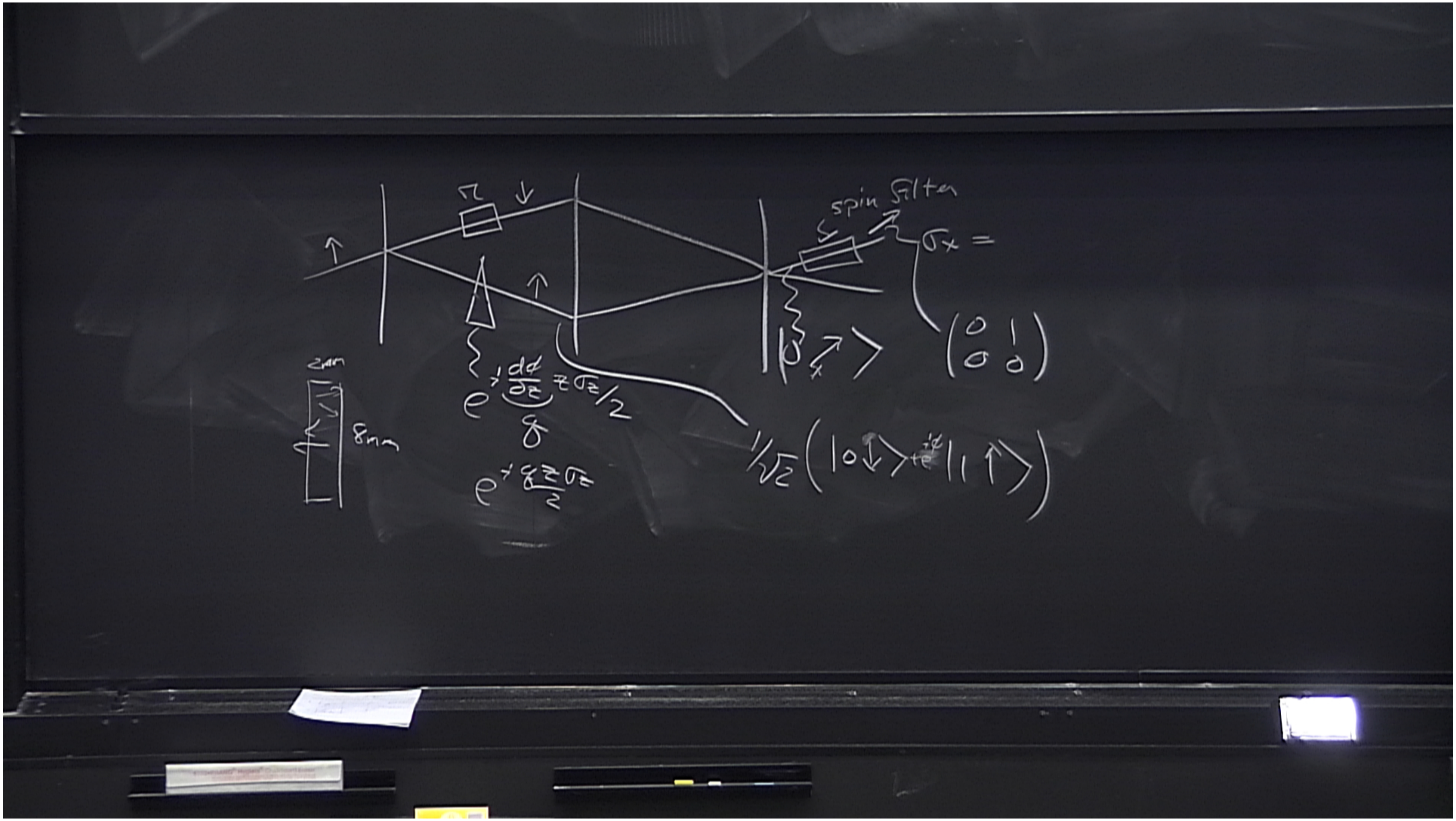

Z
-1/2
+1/2
X

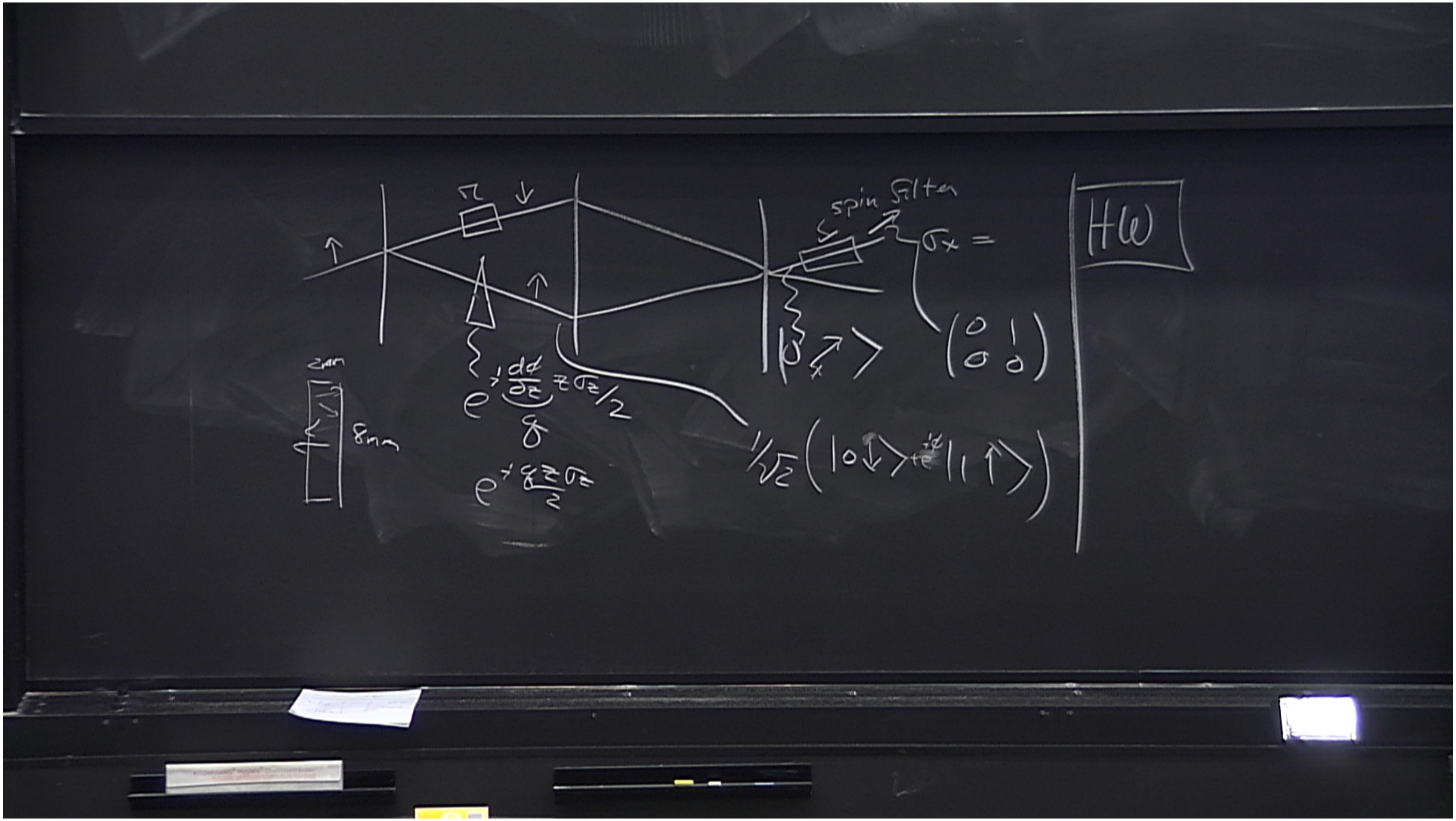

spin filter
8nm

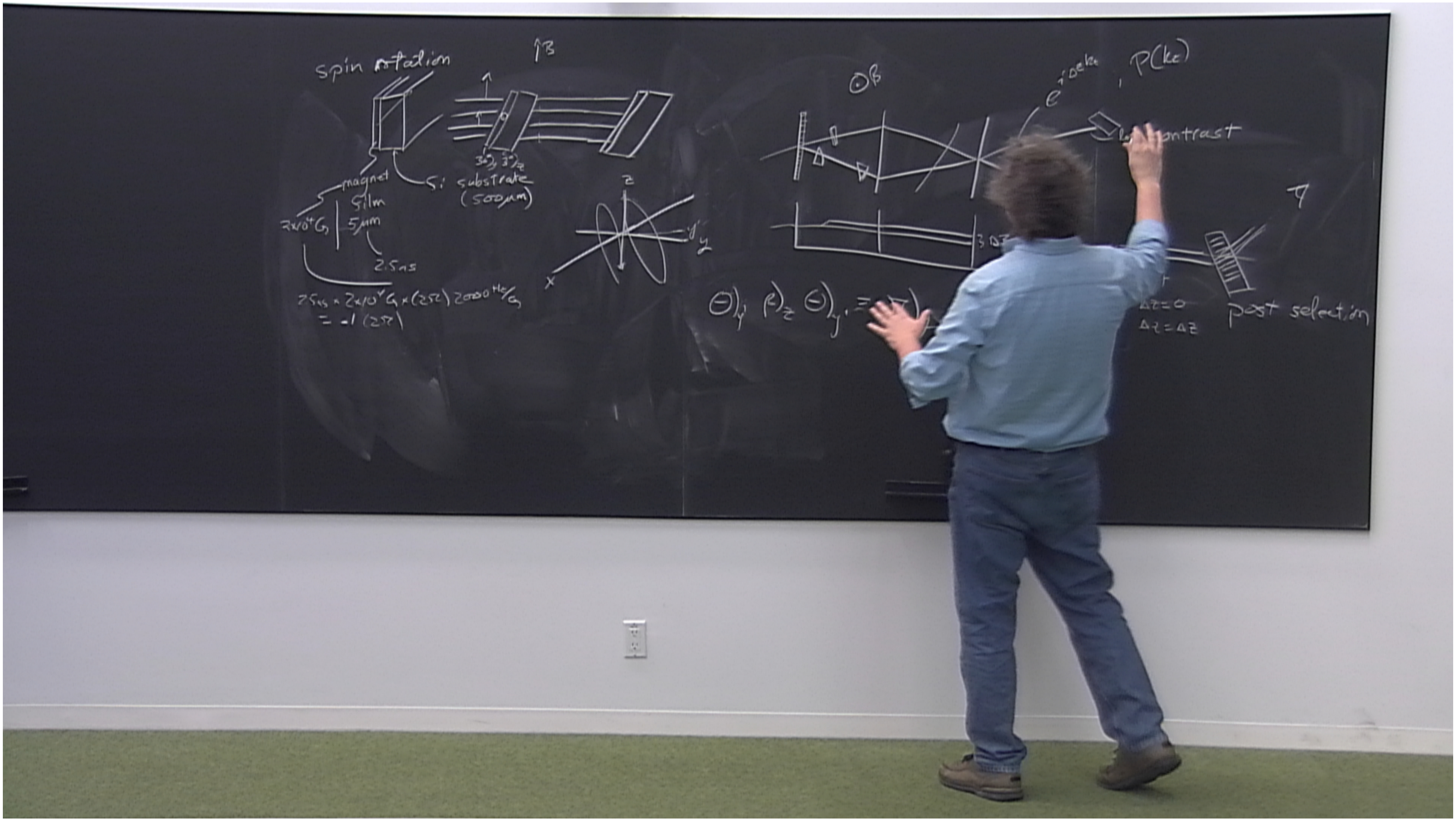

spin filter
σx =
2mm
8mm

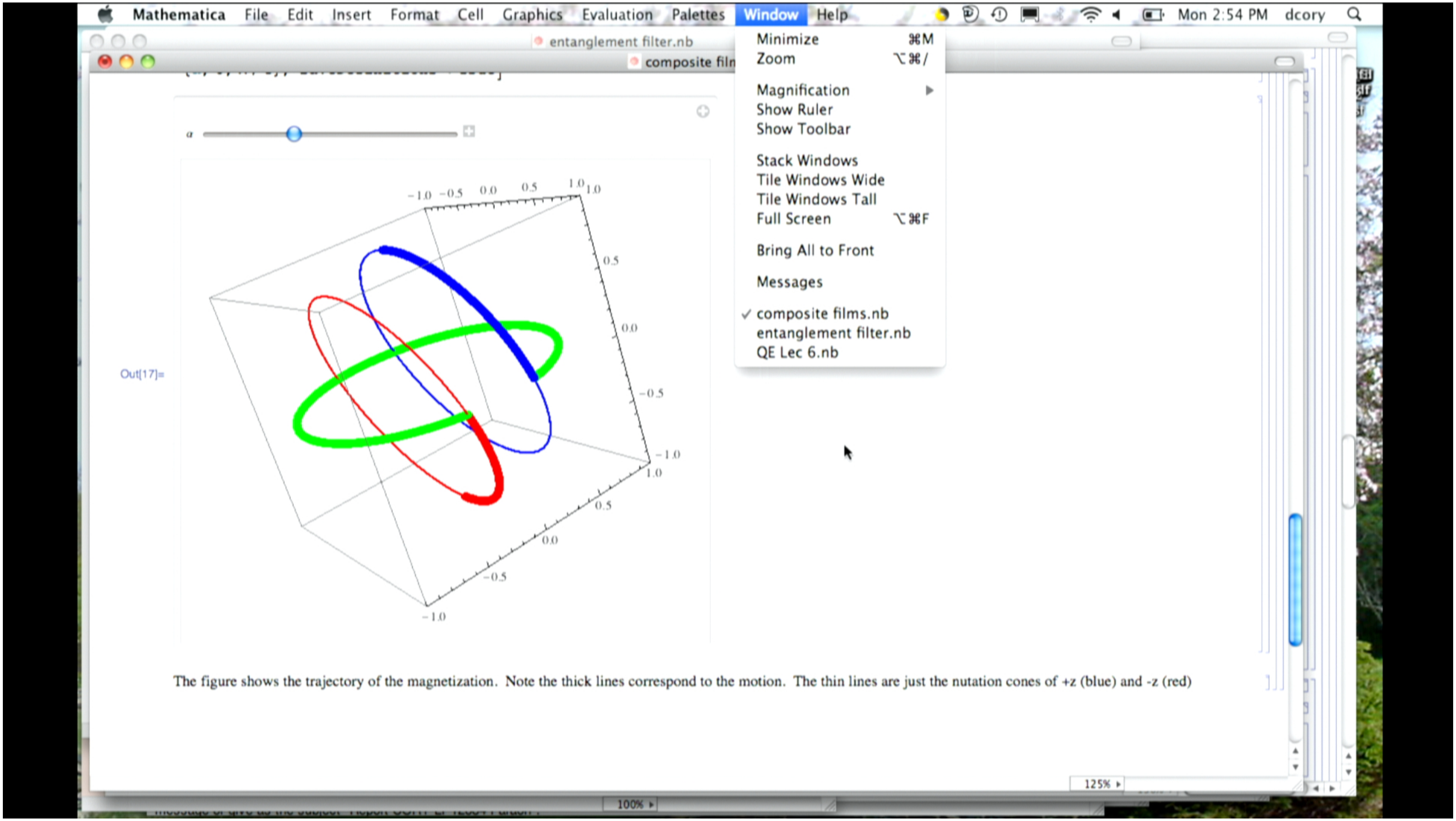

spin filter
2mm
8mm


spin filter
2nm
8nm


spin filter
2mm
8mm


spin filter
HW
8mm


spin rotation
magnet
Si substrate
(500μm)
film
5μm
2.5ns
contrast
post selection
Δz=0
Δz=ΔZ



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entanglement filter.nb
composite film
Minimize ⌘M
Zoom ⌥⌘/
Magnification
Show Ruler
Show Toolbar
Stack Windows
Tile Windows Wide
Tile Windows Tall
Full Screen ⌥⌘F
Bring All to Front
Messages
✓ composite films.nb
entanglement filter.nb
QE Lec 6.nb
a
Out[17]=
−1.0 −0.5 0.0 0.5 1.0
1.0 0.5 0.0 −0.5 −1.0
1.0 0.5 0.0 −0.5 −1.0
The figure shows the trajectory of the magnetization. Note the thick lines correspond to the motion. The thin lines are just the nutation cones of +z (blue) and -z (red)
125%
100%