Title: Explorations in Quantum Information-2

Date: Mar 17, 2015 09:00 AM

URL: http://pirsa.org/15030019

Abstract:

3 Weeks of Quantum Parlor Tricks in Small Hilbert Spaces

We will start the discussions with a week on Neutron Interferometry.
Monday - basics of NI, pure state
Tuesday - mixed state dynamics, density matrix, spin dependence
Wednesday - noise in NI
Thursday -SU(2) open systems dynamics
Friday - wave packets

Tutorials
I will assign problems for the tutorials and I hope to get a write up back from the class outlining their findings.

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Tue 9:05 AM dcory

QE Lec 1.nb

He-3 detector

We use a gas filled detector to measure neutrons. The gas is helium-3 which has a high absorption cross section of 5333 barns for 2200 m/s neutrons. 1 barn is 10^{-28} m^2 or 100 square femtometers (fm^2). Since the absorption cross-section is so high the stopping power is large. In a well designed detector the conversion of neutrons to charge is very probable and the quantum efficiency of detecting a neutron is close to unity.

The neutron is converted through the reaction

$$n + {}^3He \rightarrow {}^3H + {}^1H + 0.764 \text{ MeV}$$

into charged particles tritium and protium. These are detected by creating a charge cloud in the detector.

Spin Filter

The absorption process is spin-dependent, so we can use a spin polarized He-3 target as a spin filter. The spin-polarized helium-3 transmits neutrons with the same spin component while absorbing the other.

Cross-Section

The cross section from above is the shadow of the object from the beam's flux.

flux = # particles/(unit area x time)

event rate = cross section x flux

Neutron Properties

I just copied these from Wikipedia, http://en.wikipedia.org/wiki/Neutron

Here we need the mass, spin and magnetic moment.

Classification:	Baryon
Composition:	1 up quark, 2 down quarks
Family:	Fermion
Group:	Hadron
Interaction:	Gravity, Weak, Strong
Antiparticle:	Antineutron
Theorized:	Ernest Rutherford[1] (1920)

150%

For convenience, we define variables to hold commonly-used properties of the neutron.

```
mass = 1.67492729 × 10^-27; (* kg *)
```

Neutron Source

Nearly all neutron interferometry is performed with a reactor outfitted with a cold moderator as the neutron source. The above picture is on the reactor at NIST in Maryland. The reactor is in the square building in the upper left. The building to its right is the guide hall


Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help
Tue 9:06 AM
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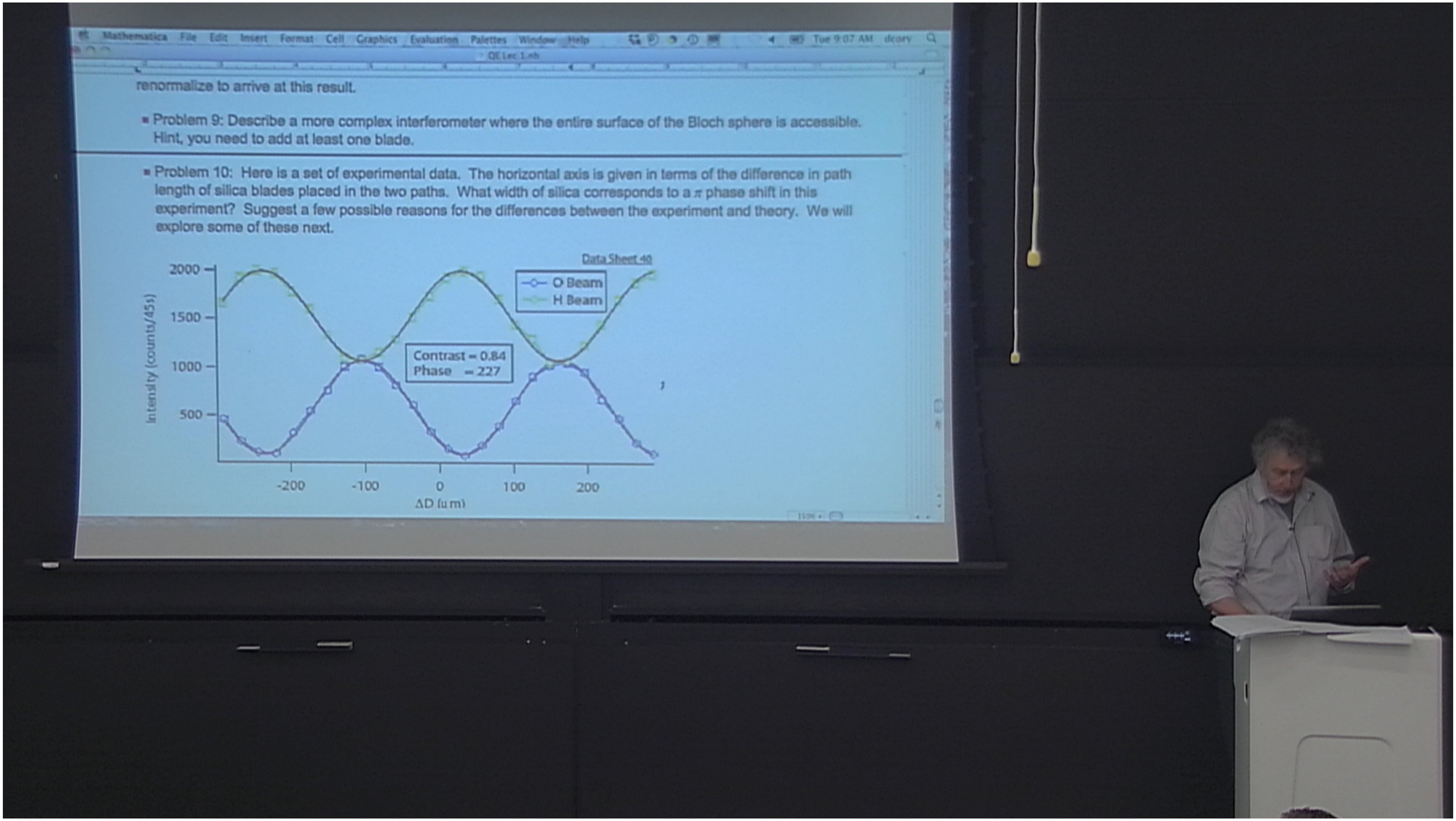
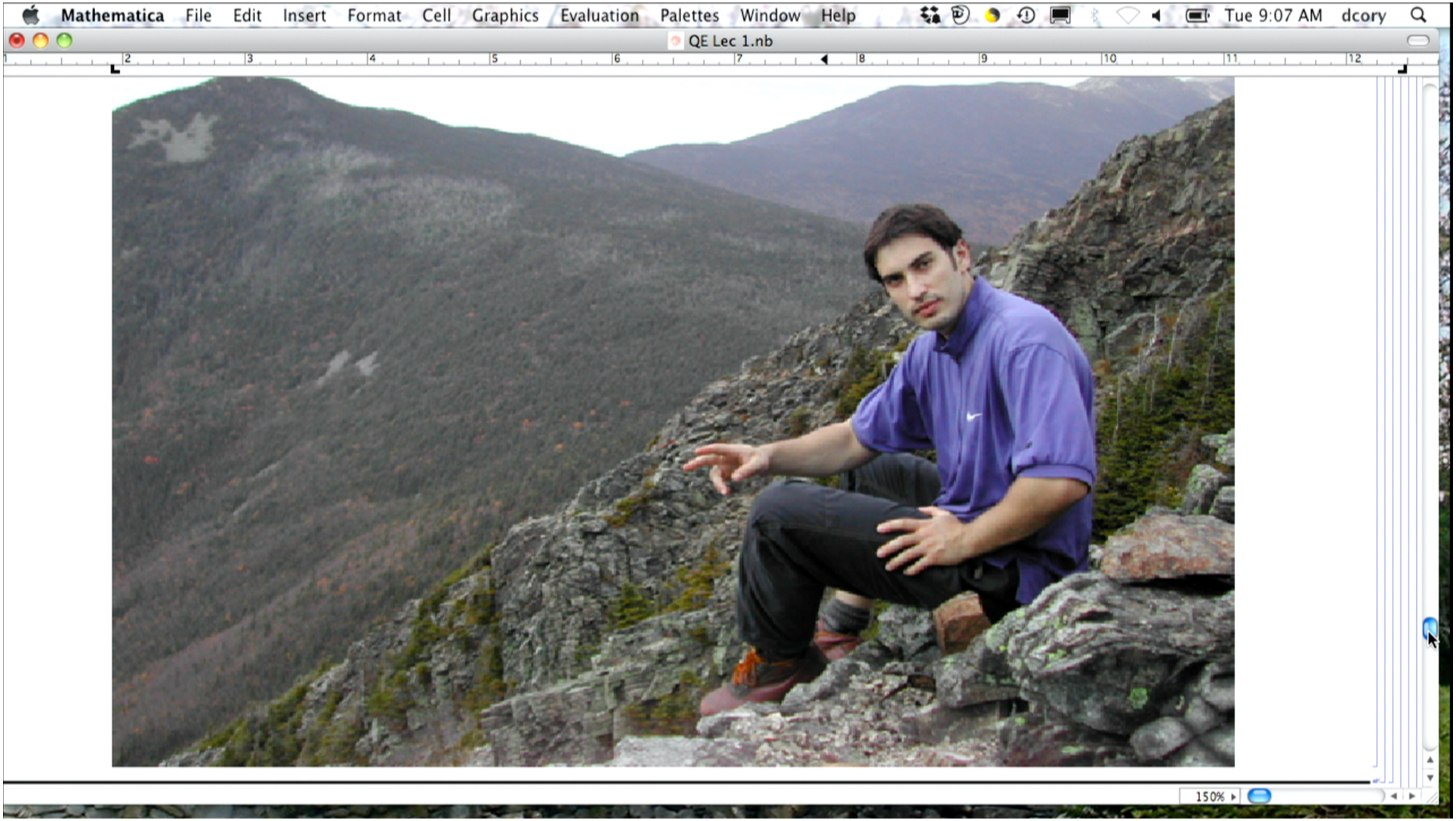
wavelength.
The guide hall at the NIST reactor in Gaithersburg MD currently has the following configuration of measurement end stations.


renormalize to arrive at this result.
Problem 9: Describe a more complex interferometer where the entire surface of the Bloch sphere is accessible. Hint, you need to add at least one blade.
Problem 10: Here is a set of experimental data. The horizontal axis is given in terms of the difference in path length of silica blades placed in the two paths. What width of silica corresponds to a π phase shift in this experiment? Suggest a few possible reasons for the differences between the experiment and theory. We will explore some of these next.
Data Sheet 40
O Beam
H Beam
Contrast = 0.84
Phase = 227
Intensity (counts/45s)
2000
1500
1000
500
-200
-100
0
100
200
ΔD (μm)



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Tue 9:07 AM dcory
QE Lec 1.nb
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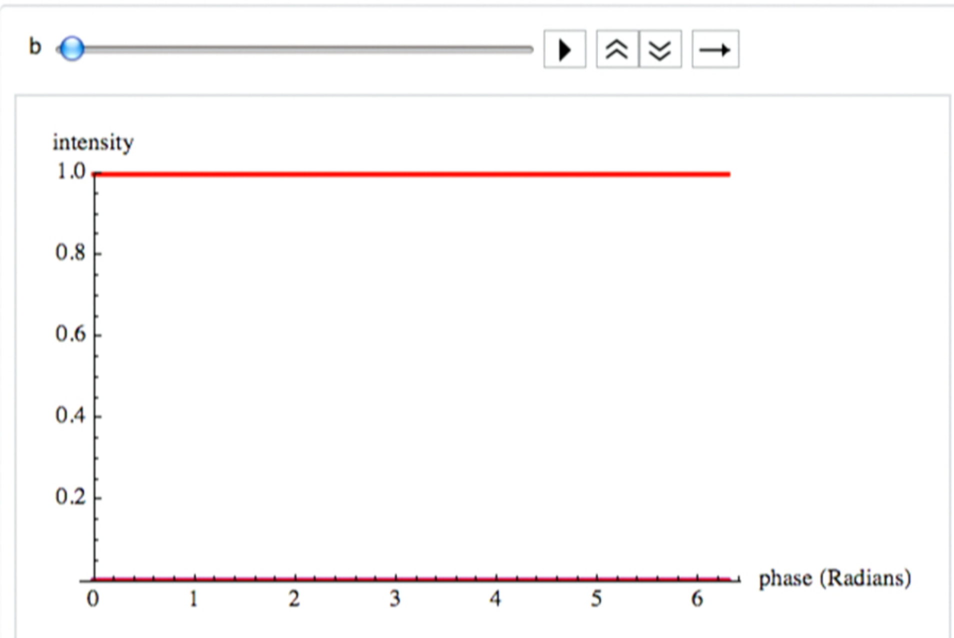
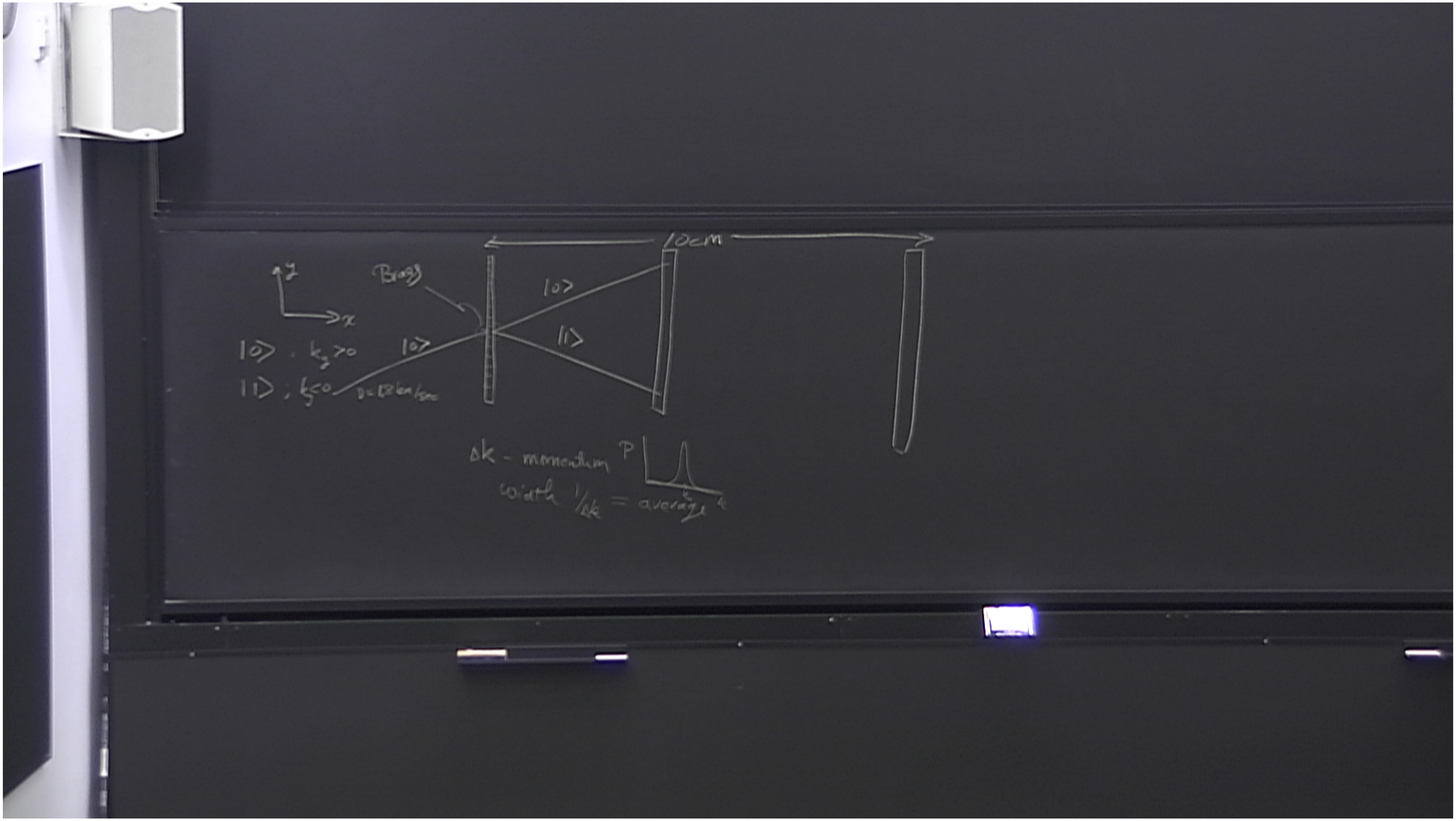
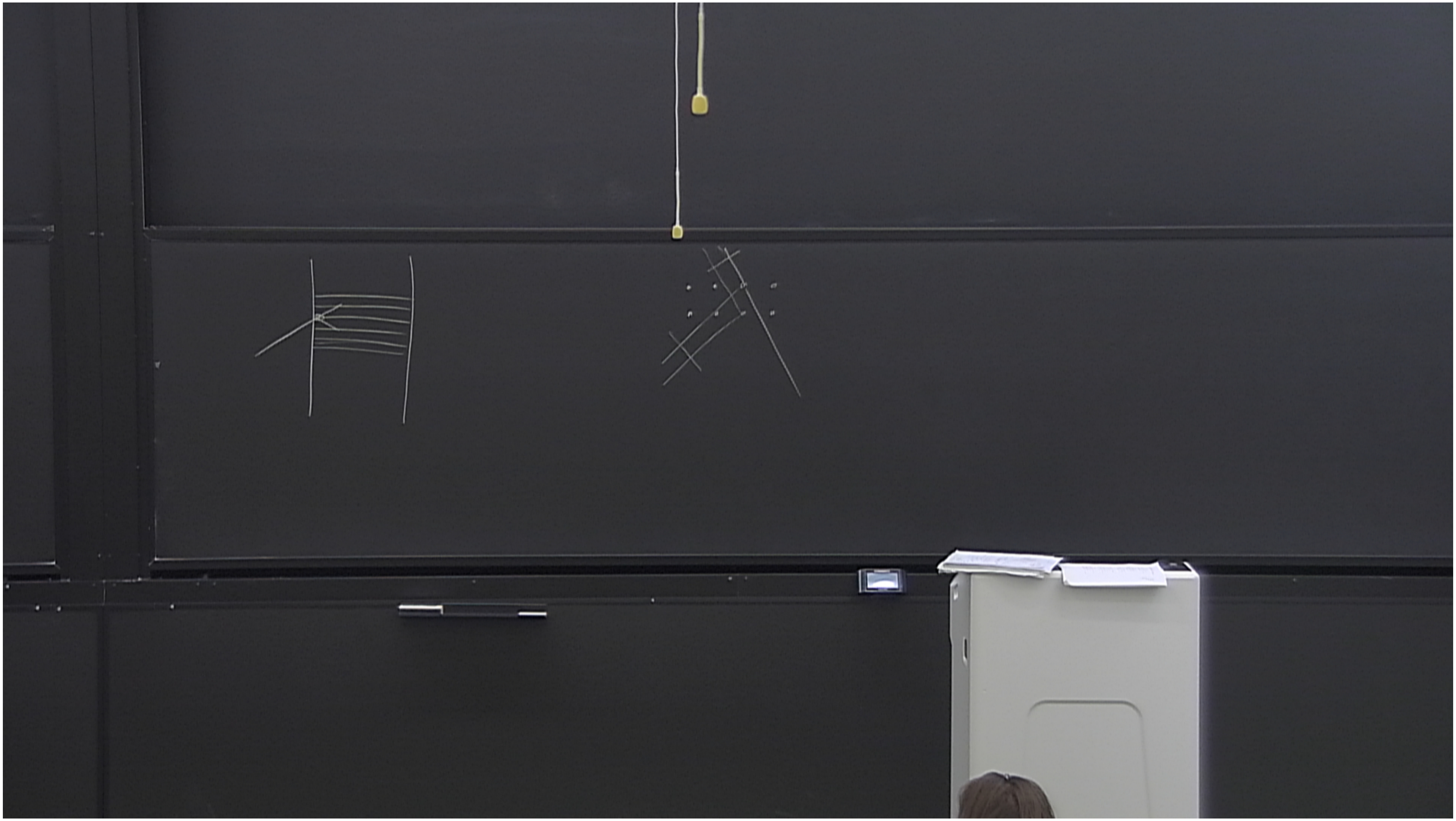
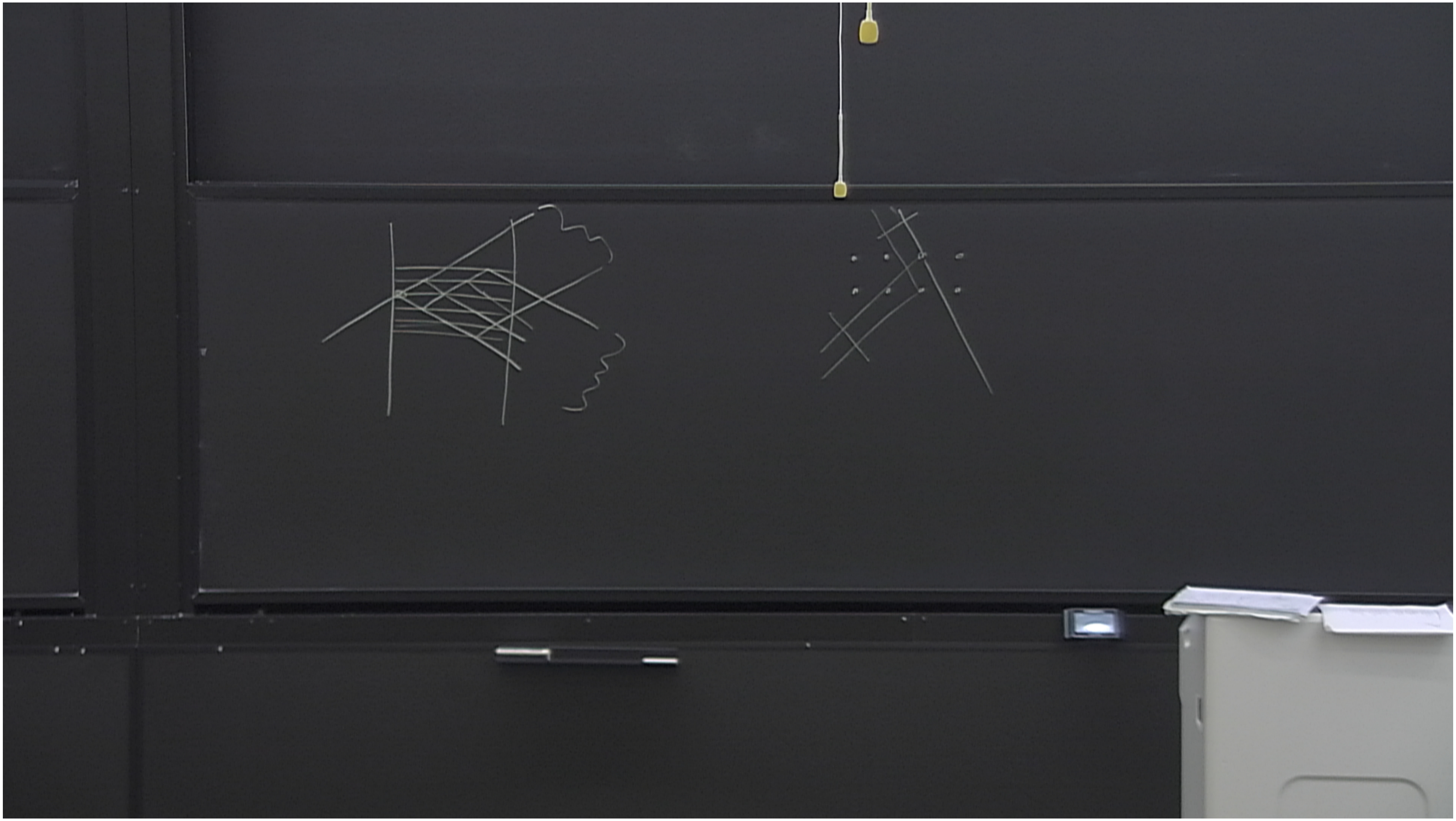
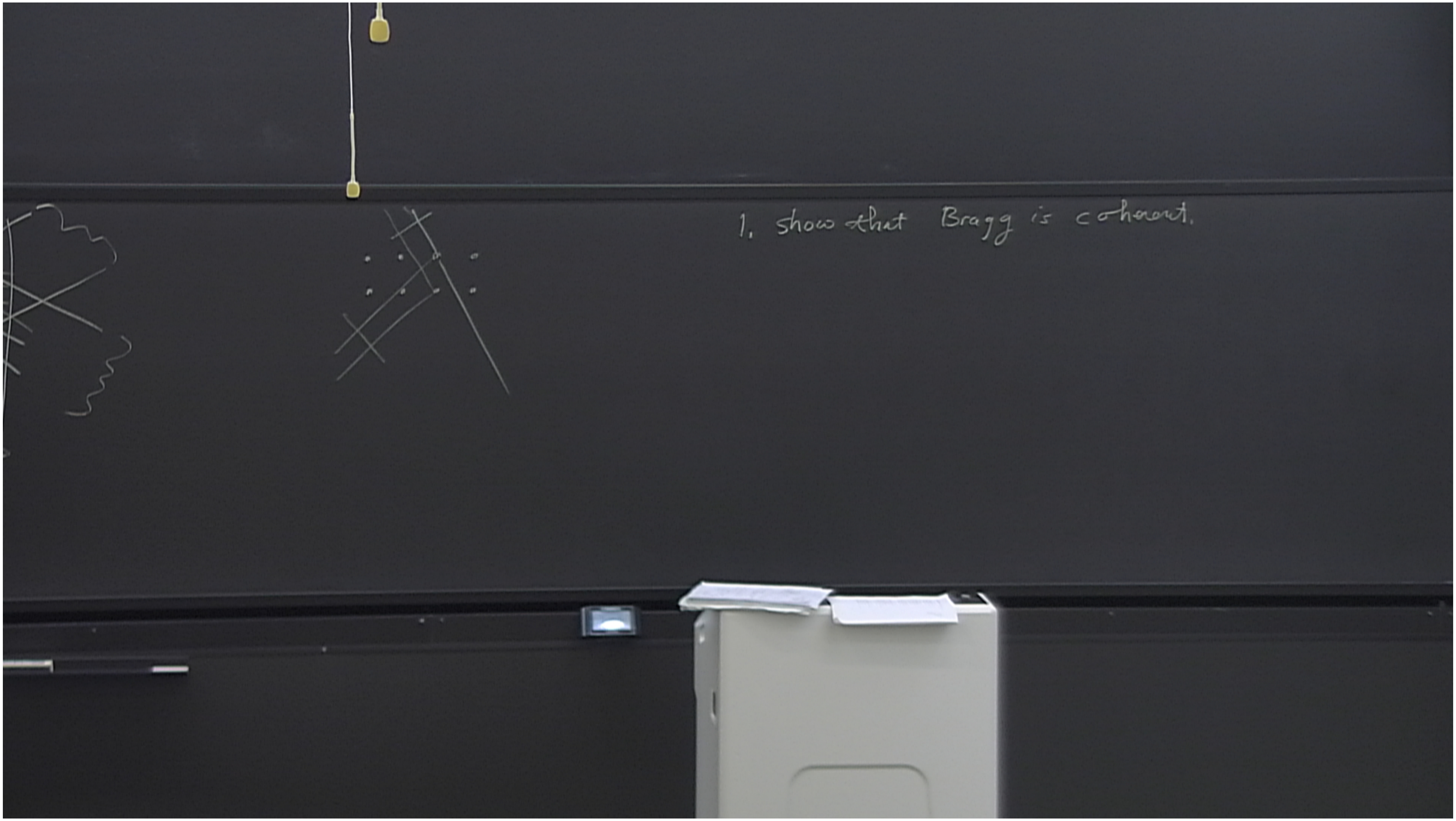
```
M3H[a_,b_]:= (Conjugate[res3[a,b]] res3[a,b])[[2]]

Animate[
 Show[Plot[M3O[a, b], {a, 0, 2 π}, {AxesLabel → {"phase (Radians)", "intensity"},
    PlotStyle → {RGBColor[0, 0, 1], Thickness[0.01]}, PlotRange → {0, 1}}],
  Plot[M3H[a, b], {a, 0, 2 π}, {AxesLabel → {"phase (Radians)", "intensity"},
    PlotStyle → {RGBColor[1, 0, 0], Thickness[0.01]}, PlotRange → {0, 1}}]],
 {b, 0, 2 π}, AnimationRunning → False, SaveDefinitions → True]
```

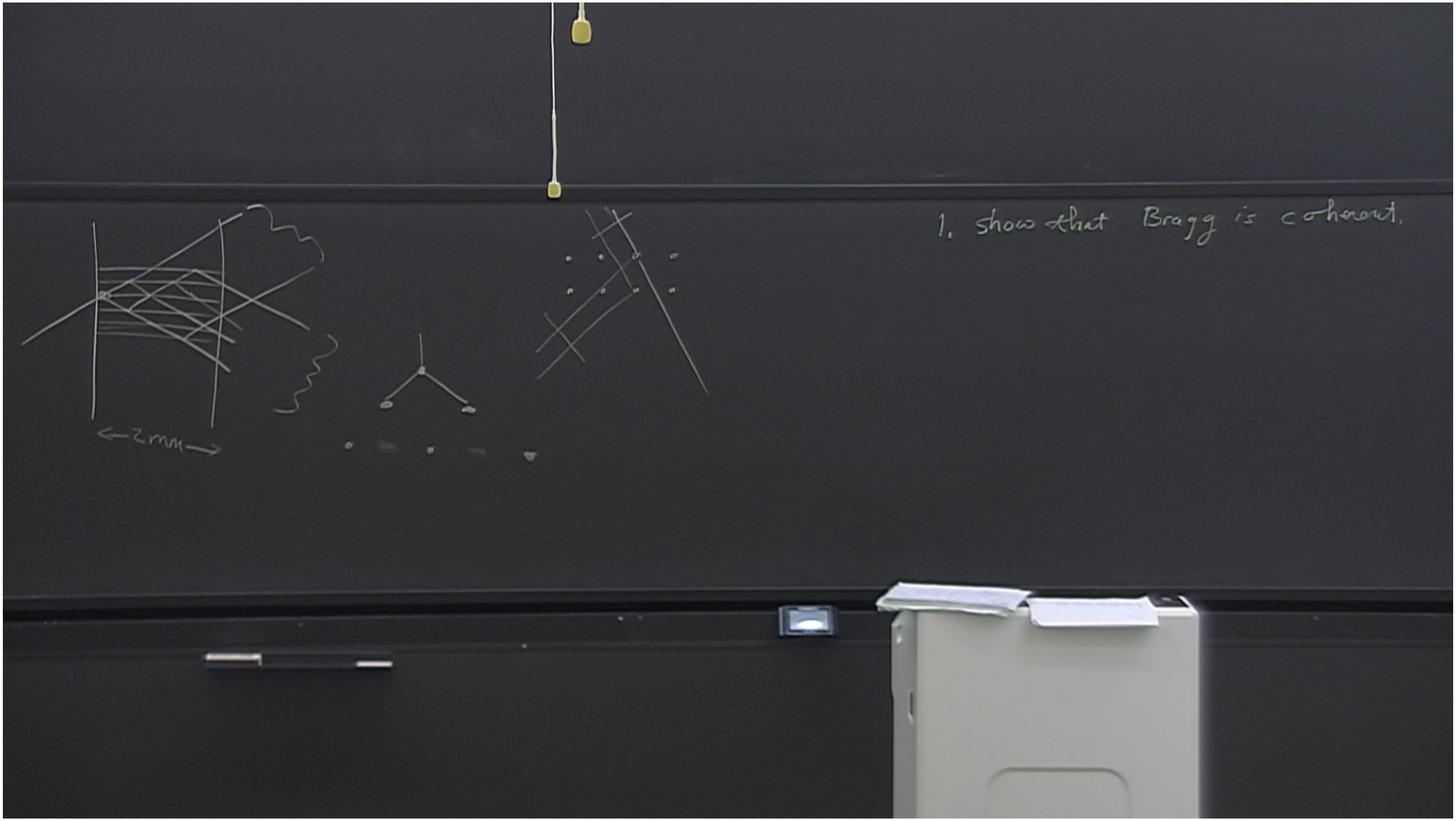


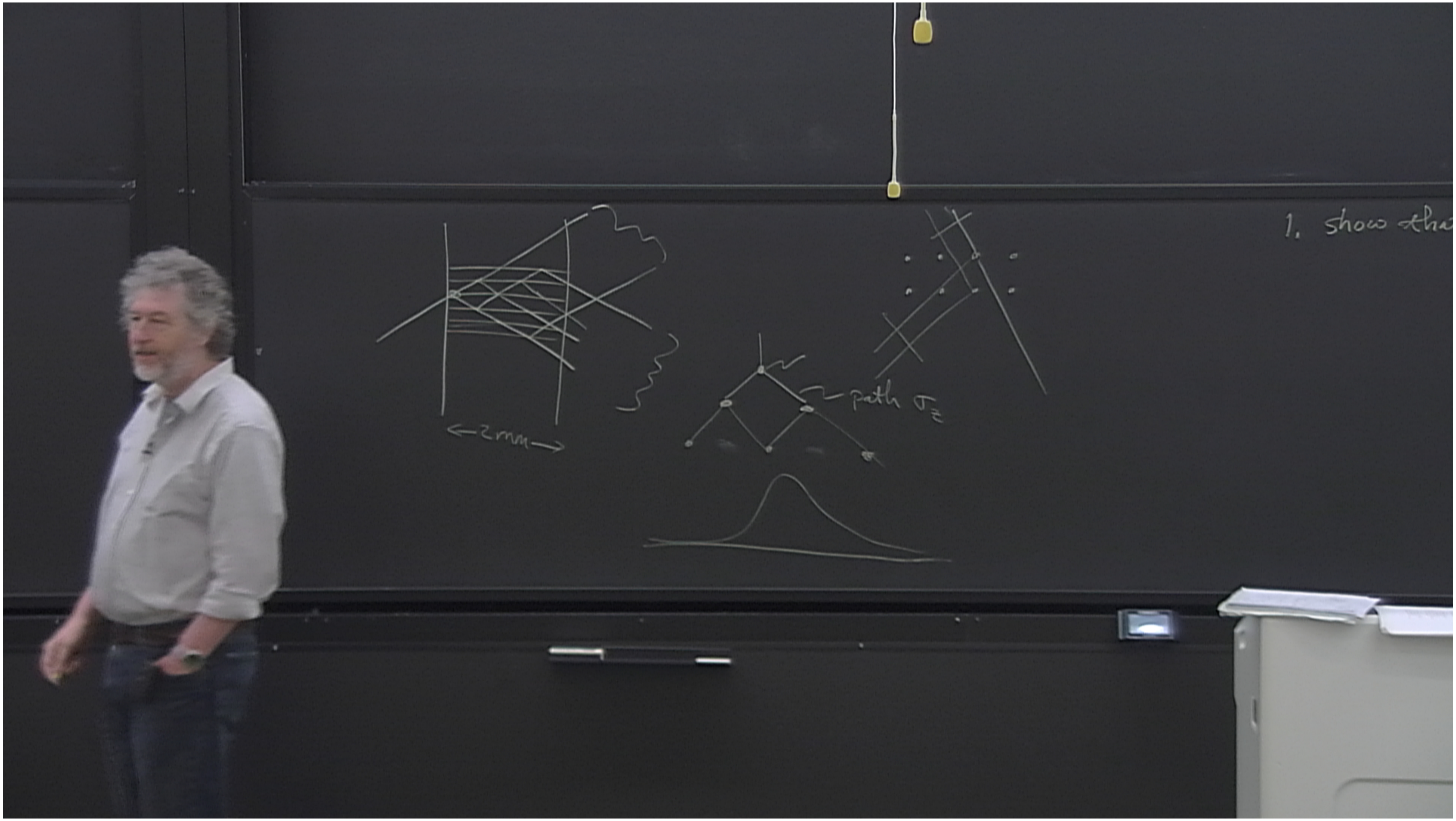

10cm
Bragg
|0⟩
|1⟩
|0⟩ : k_z > 0
|1⟩ ; k_z < 0
Δk - momentum
width 1/Δk = average



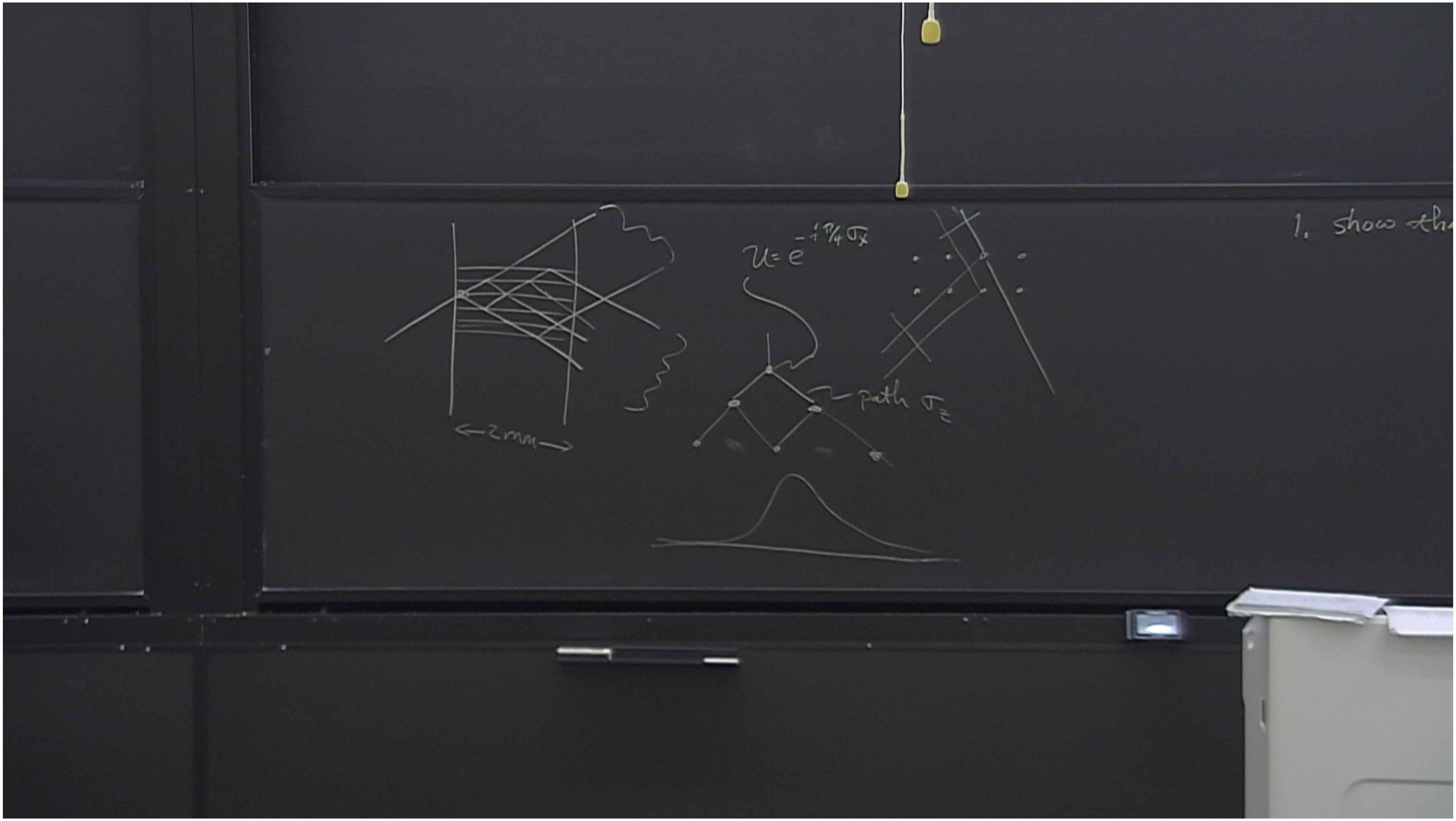



1. show that Bragg is coherent.

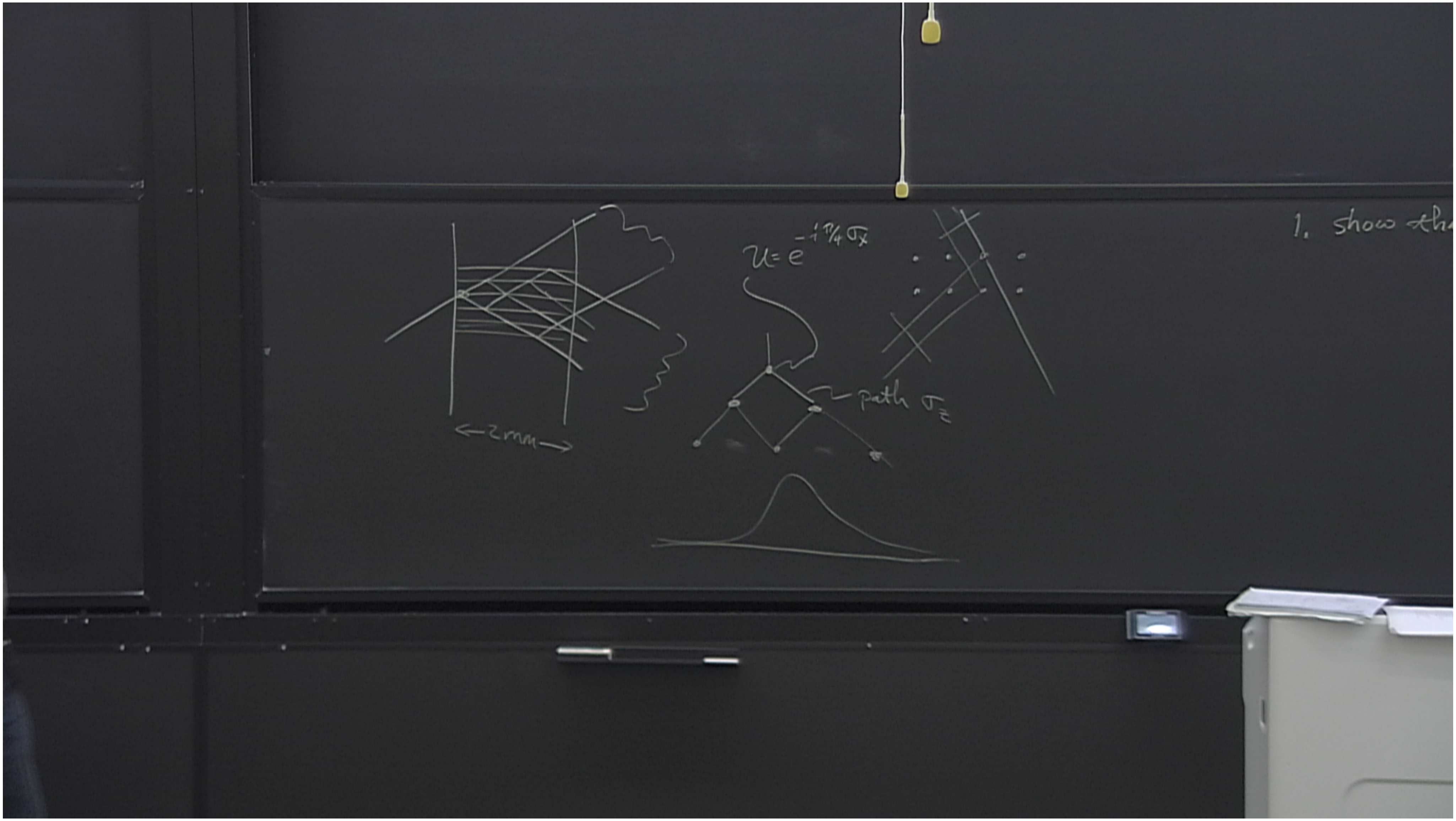

1. show that Bragg is coherent.
2mm



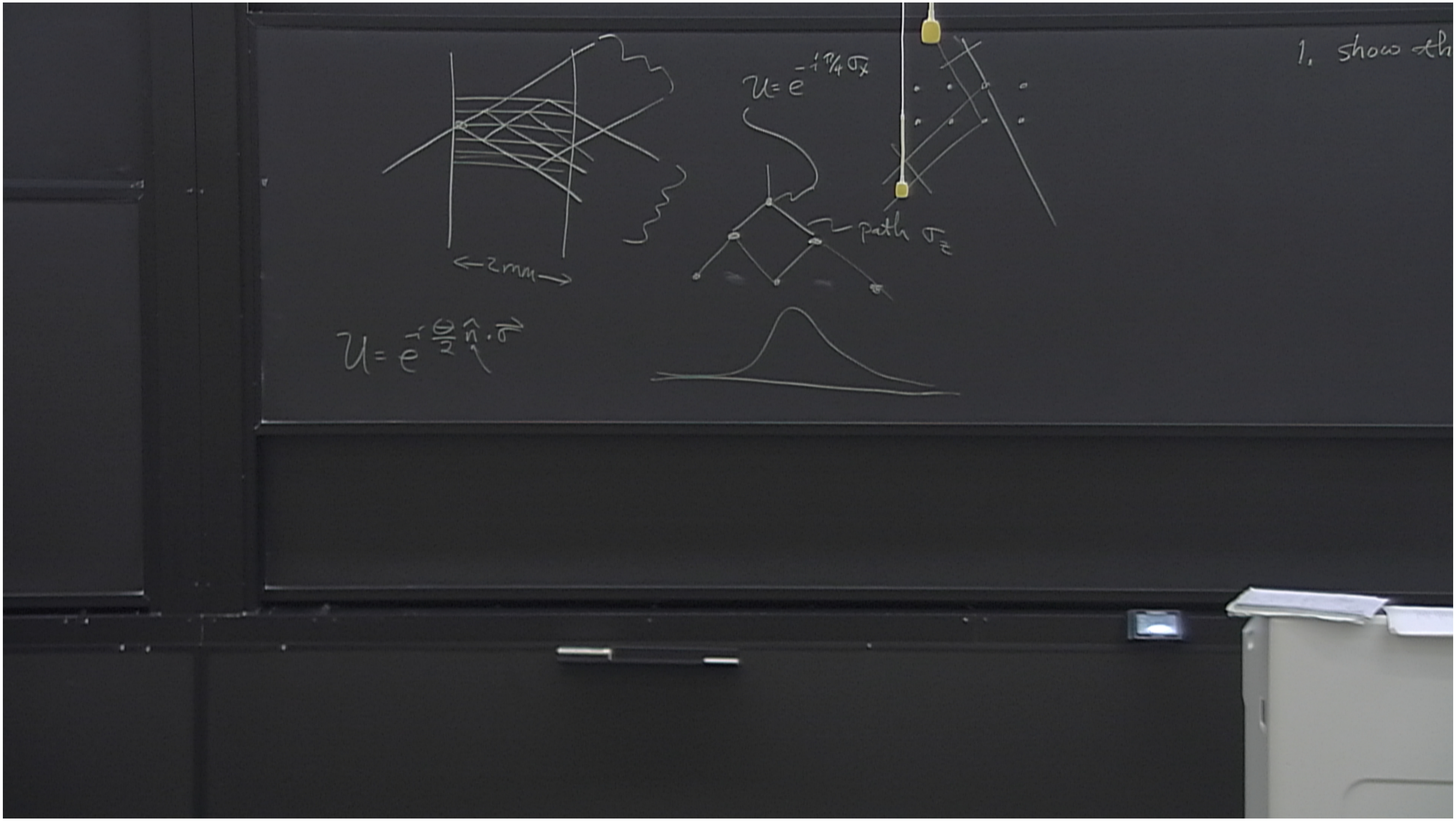
1. show tha
path σ_z
←2mm→

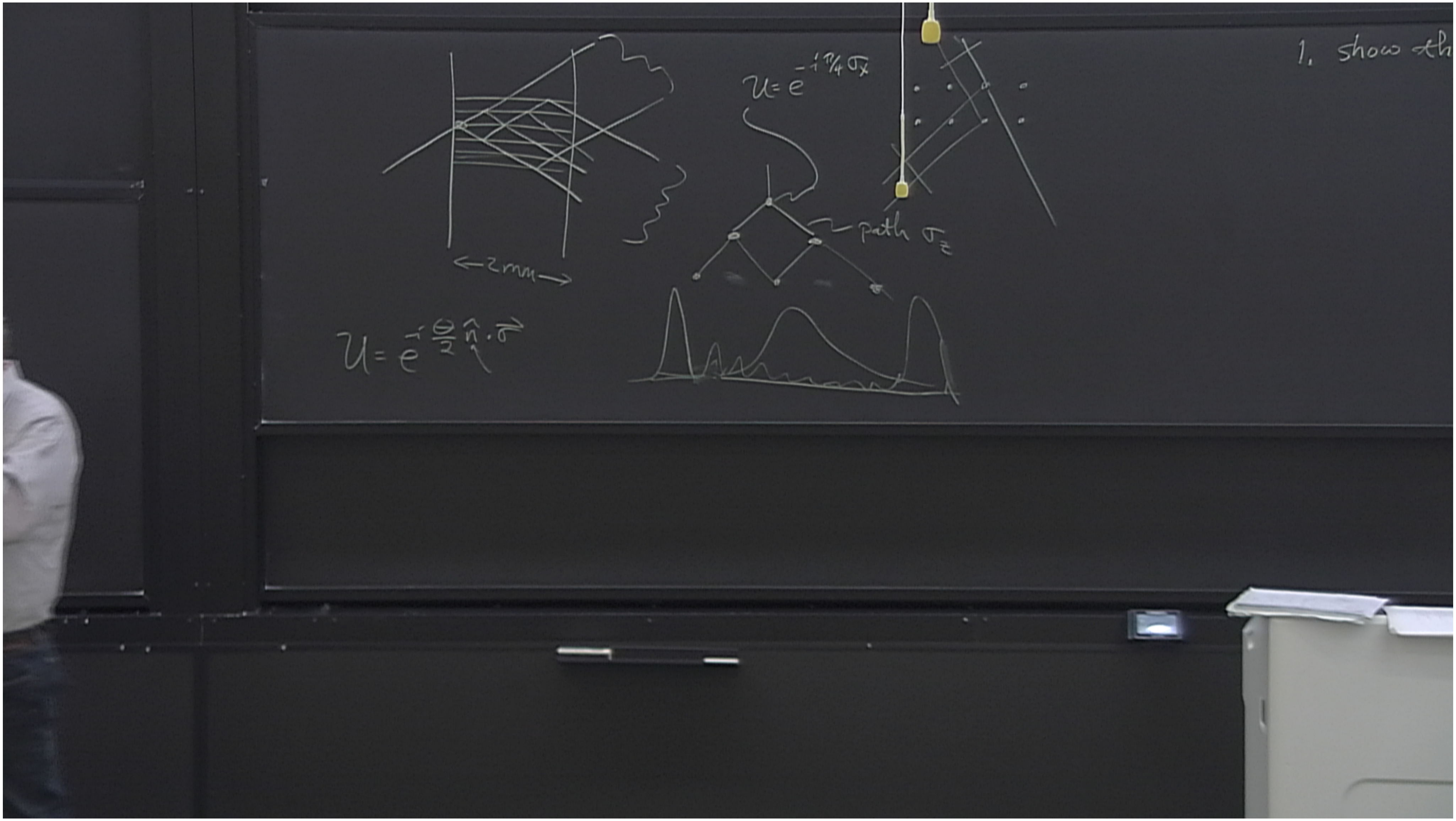


←2mm→
U= e^{-i π/4 σx}
path σz
1. show th

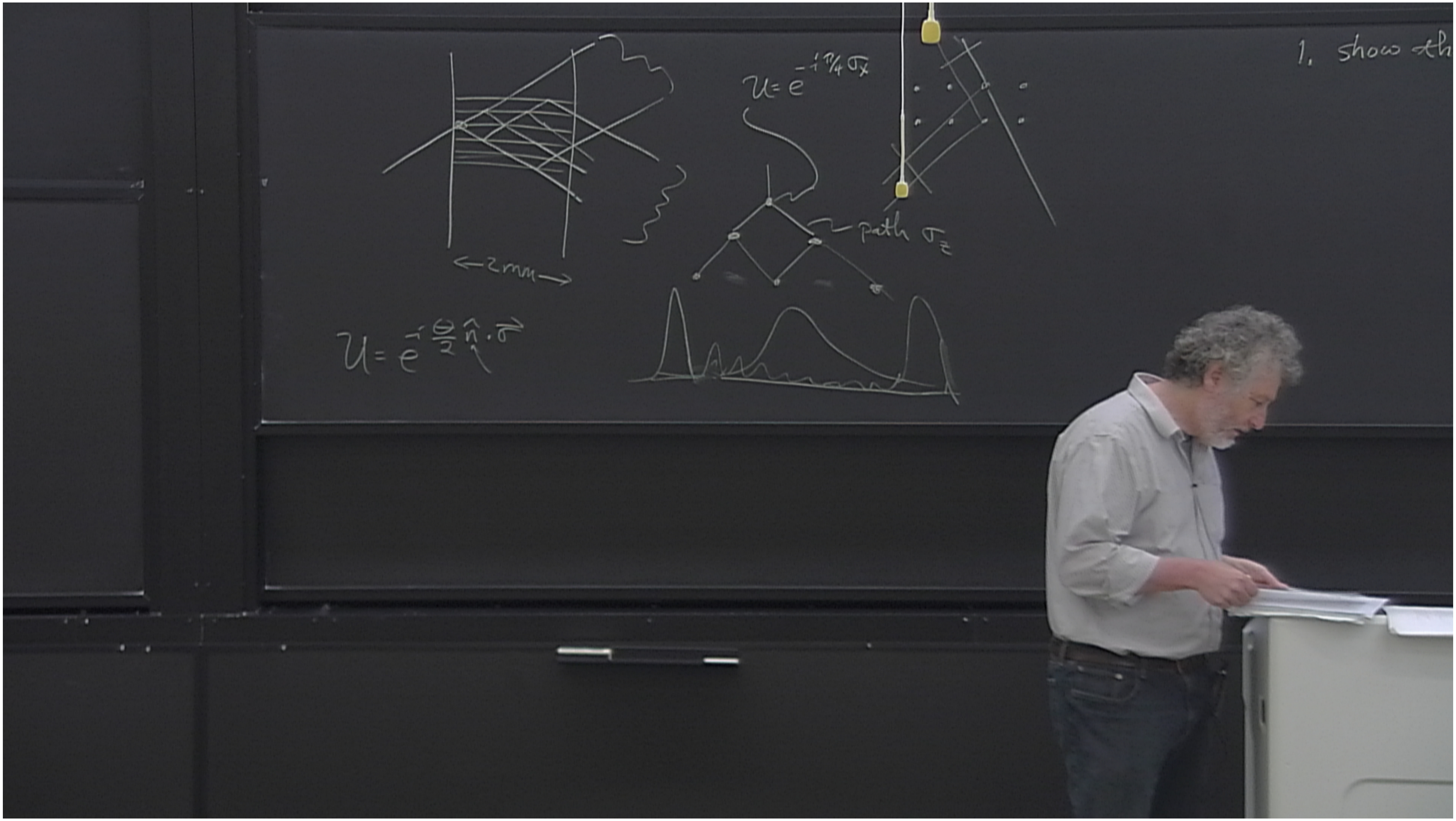


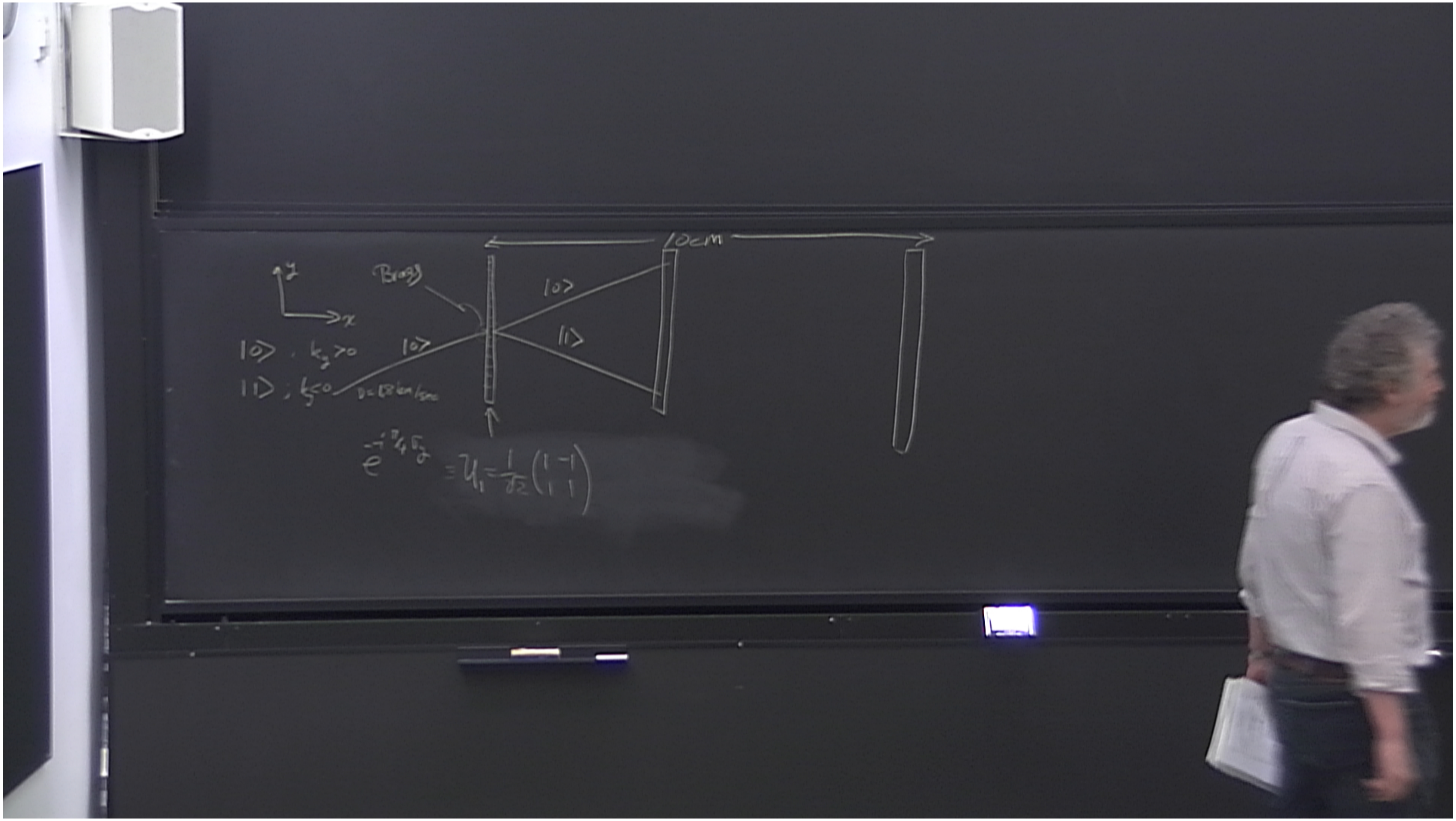
←2mm→
U = e^{-iπ/4 σx}
path σz
1. show th

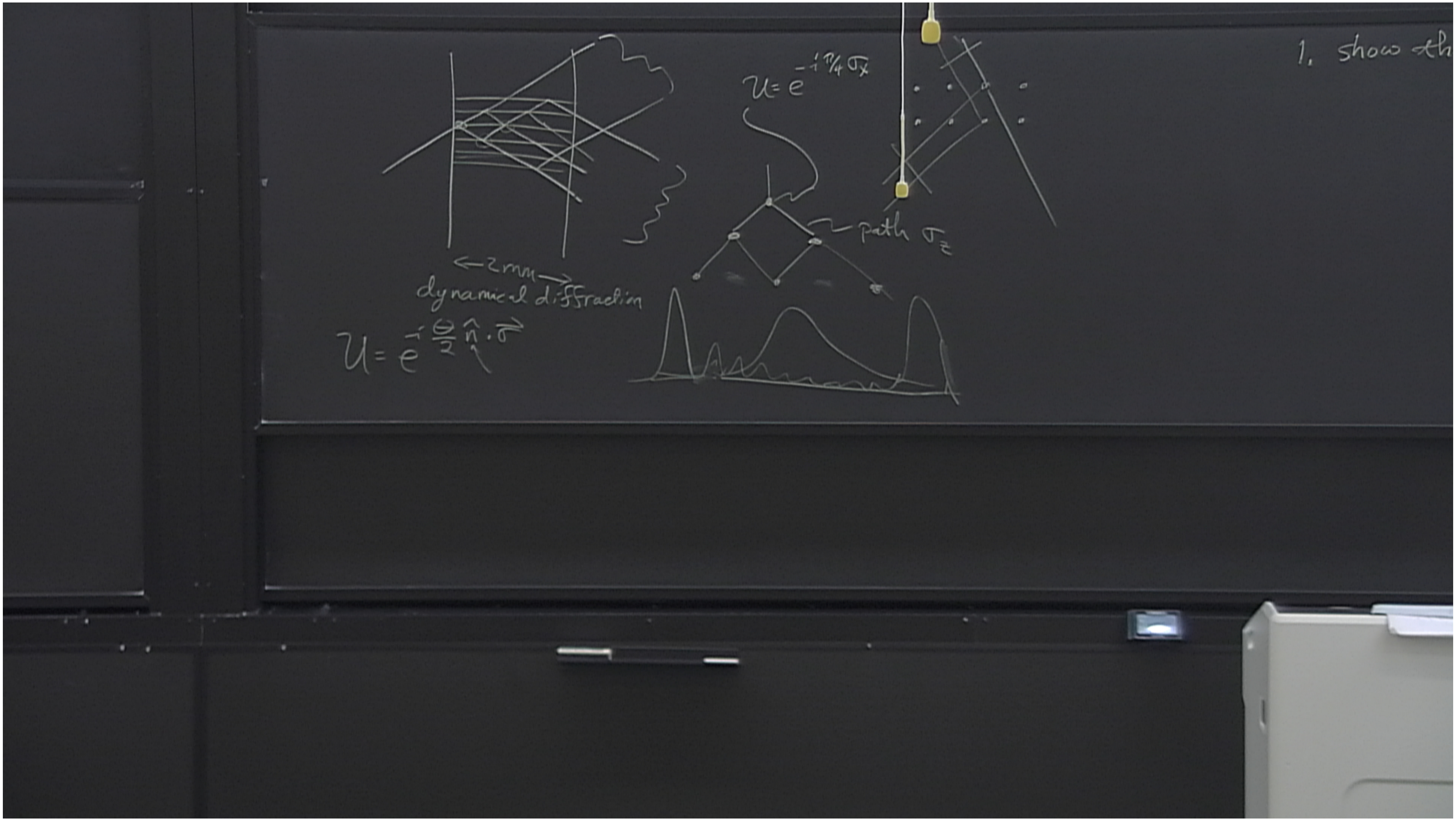

U = e^{-i π/4 σx}
path σz
←2mm→
U = e^{-i θ/2 n̂·σ⃗}
1. show th

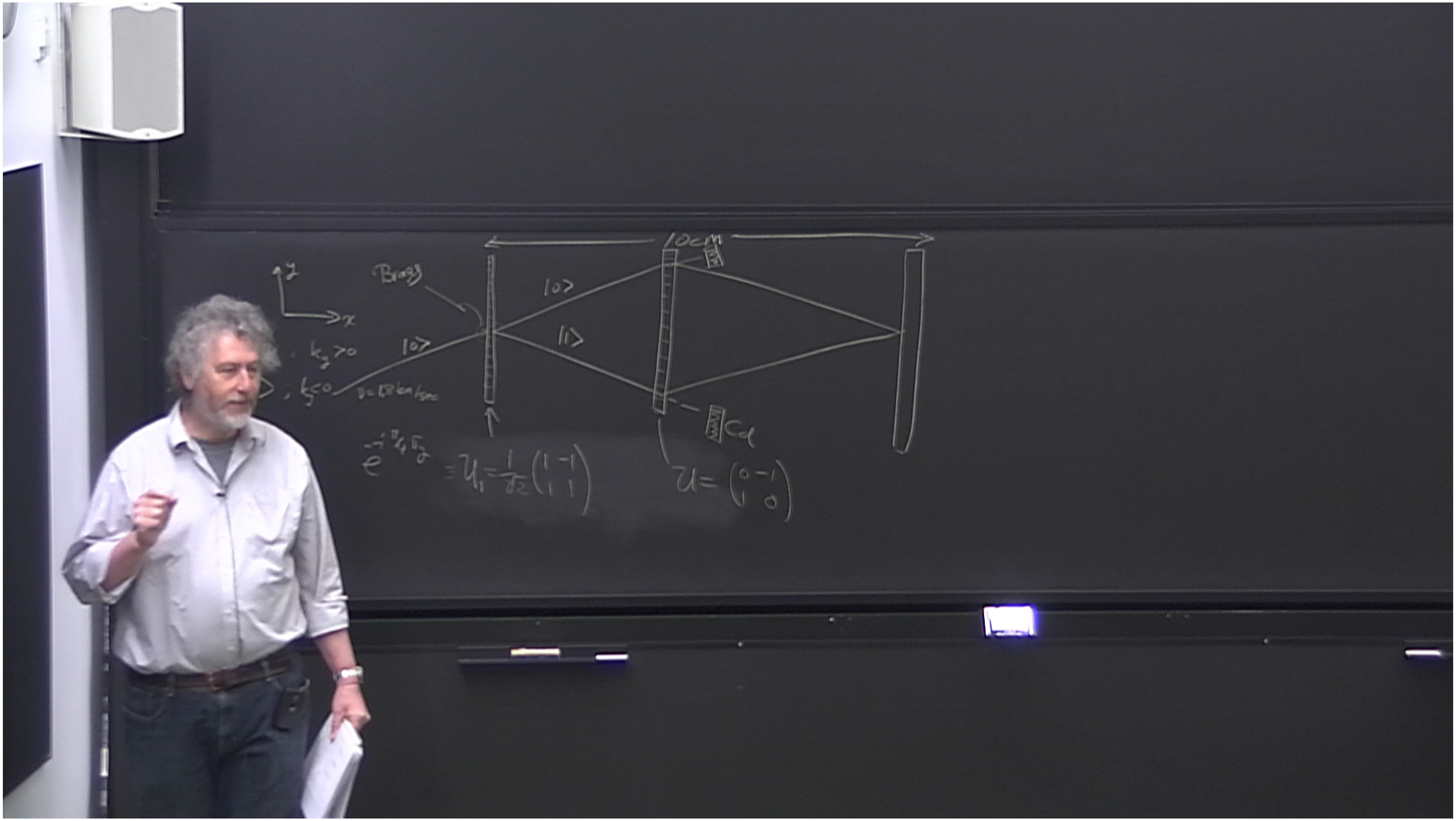


$\mathcal{U} = e^{-i\frac{\pi}{4}\sigma_x}$
path σ_z
←2mm→
$\mathcal{U} = e^{-i\frac{\theta}{2}\hat{n}\cdot\vec{\sigma}}$
1. show th

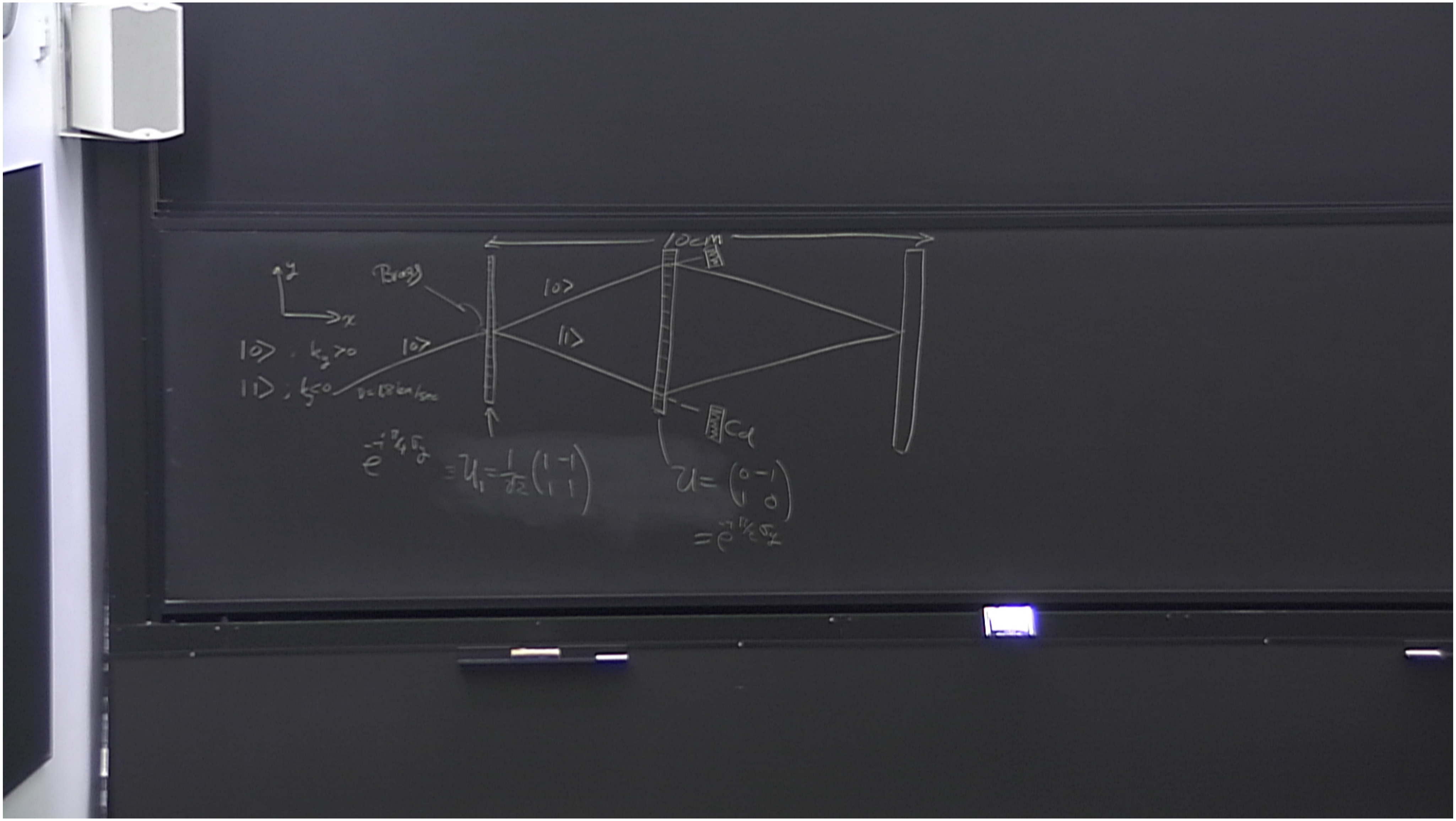

1. show th
U= e^{-iπ/4 σx}
path σz
2mm
U= e^{-i θ/2 n̂·σ}

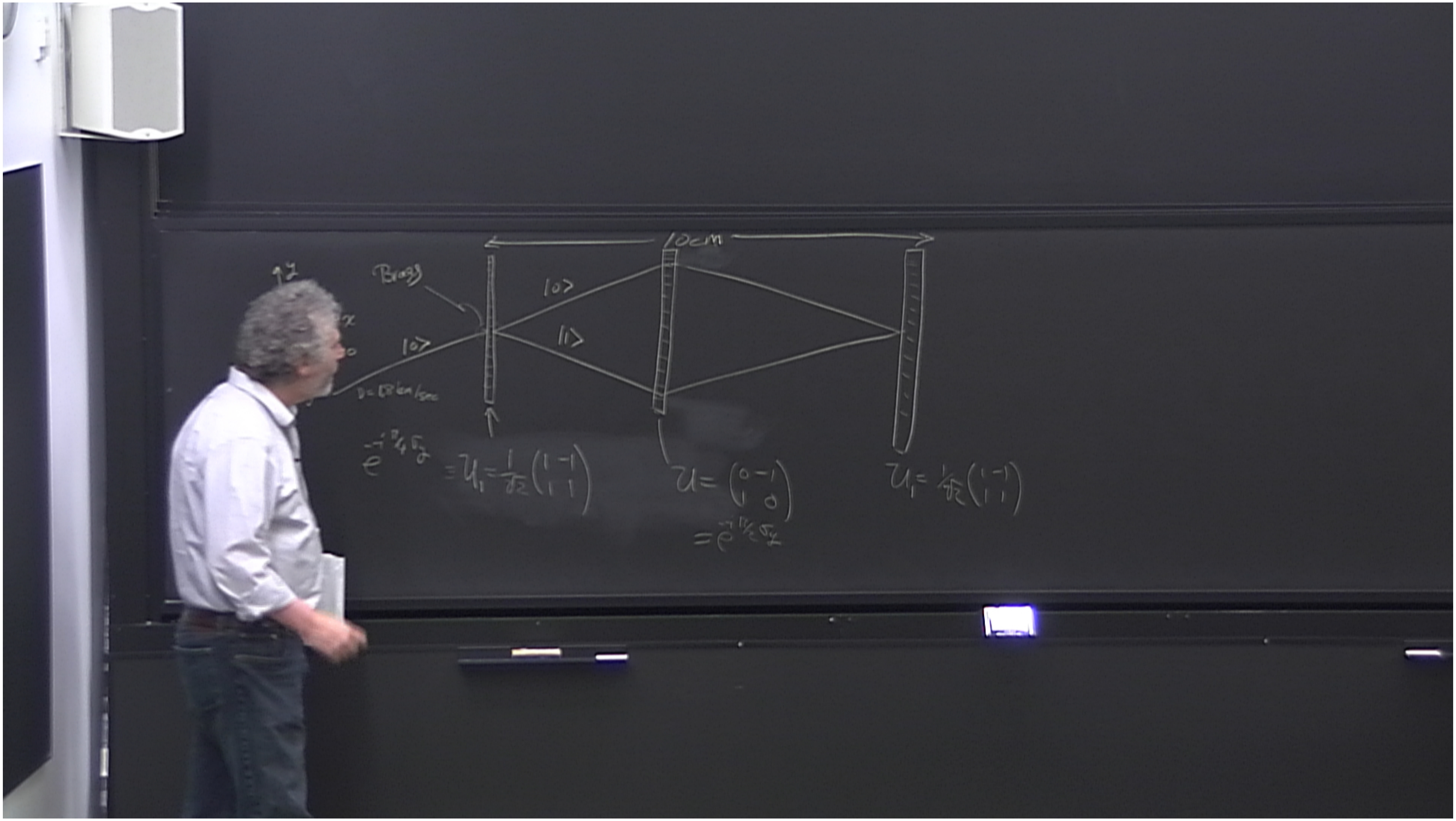

10cm
Bragg
|0>
|1>
|0> ; k_y>0
|1> ; k_y<0

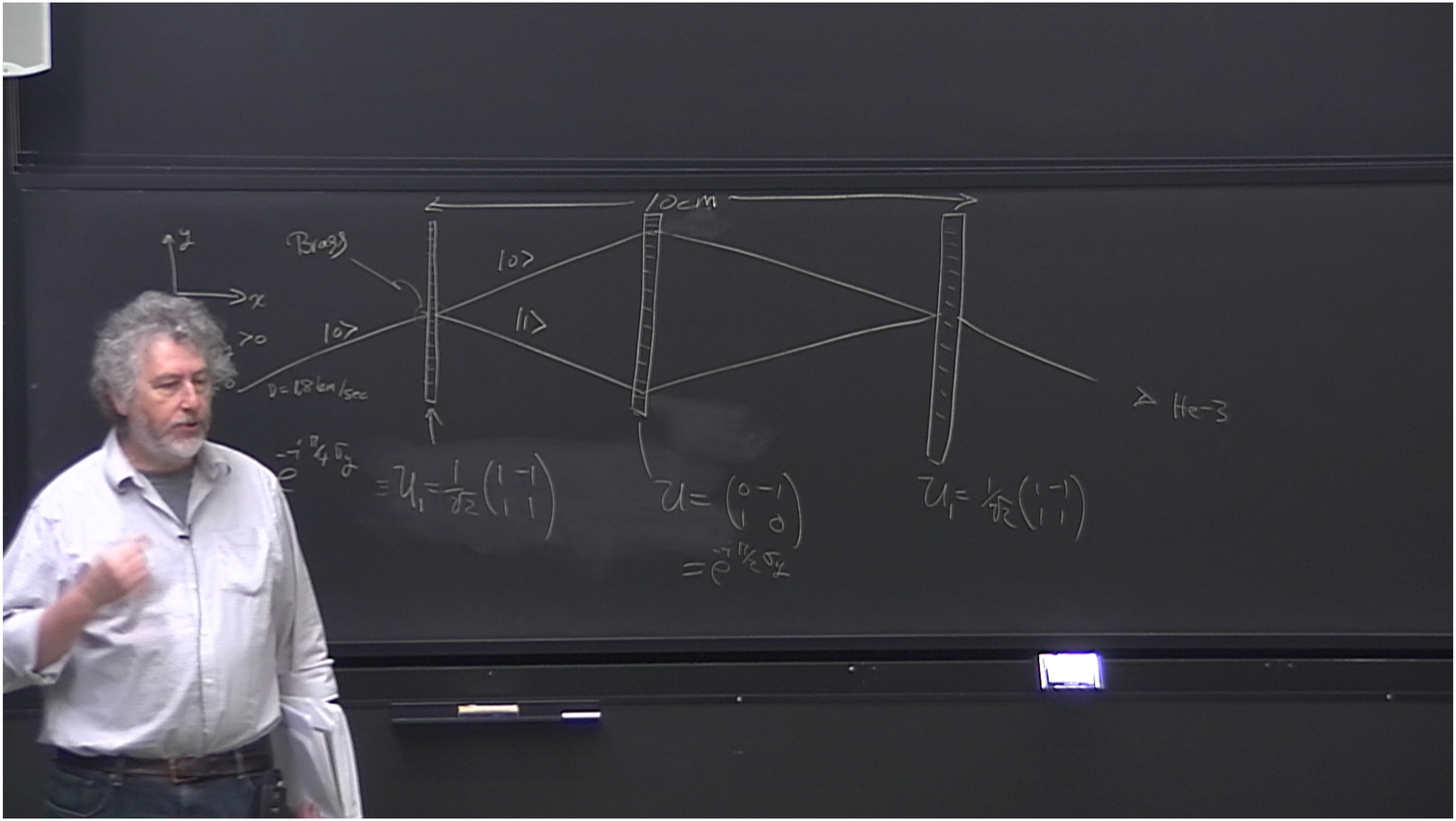

1. show th
U = e^{-i π/4 σx}
path σz
←2mm→
dynamical diffraction
U = e^{-i θ/2 n̂·σ⃗}



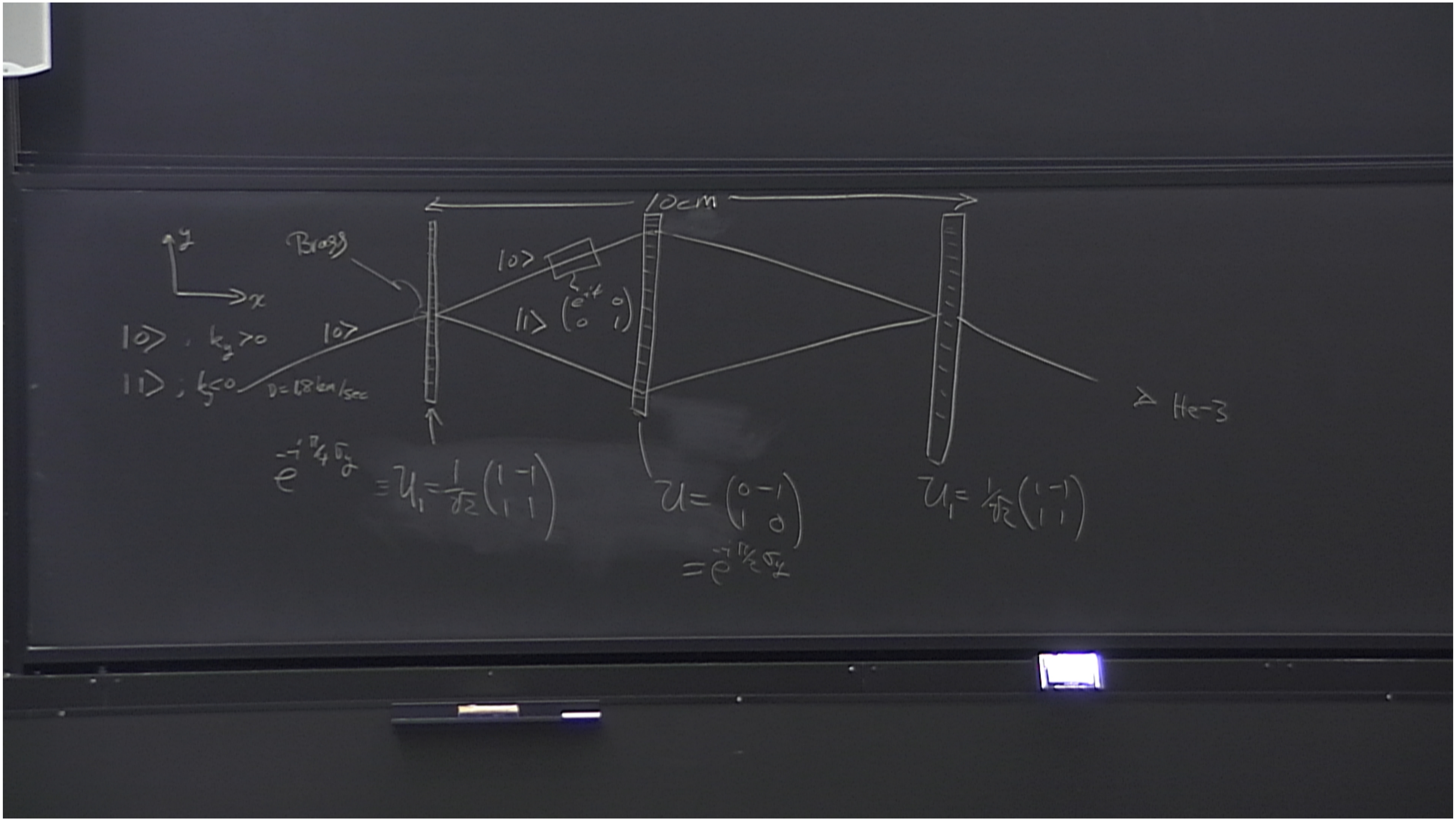
10cm
Bragg
|0>
|1>



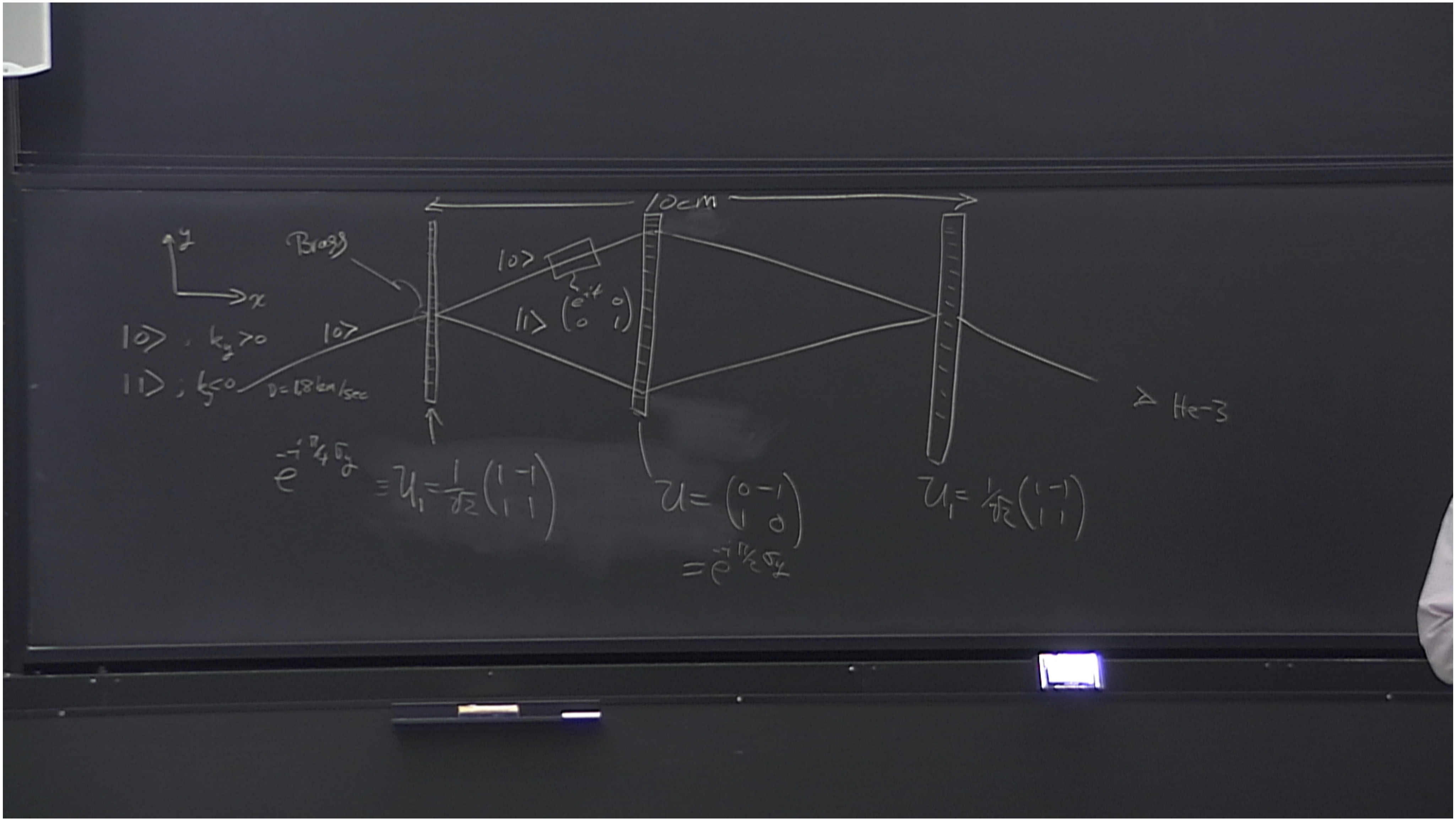


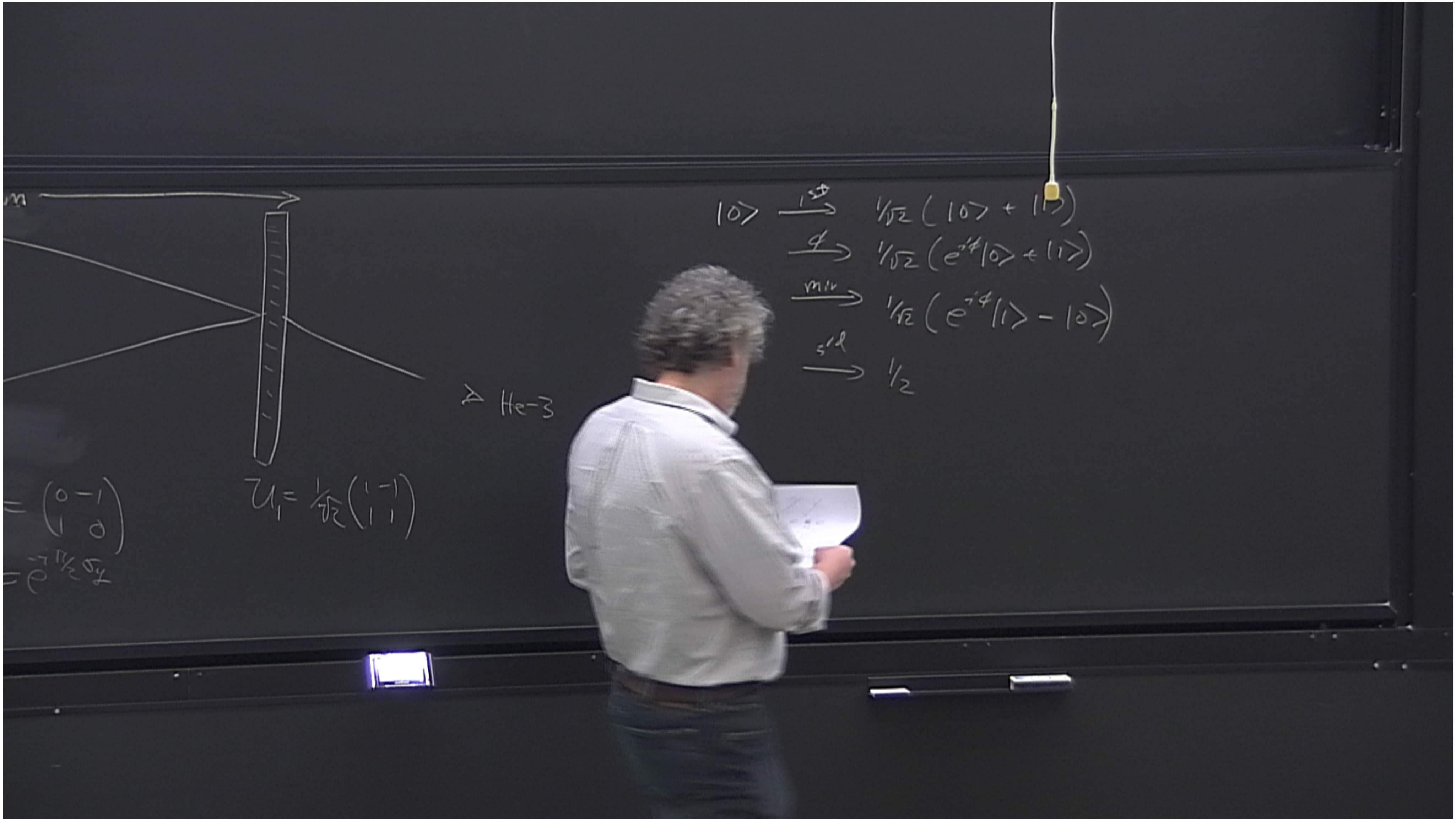


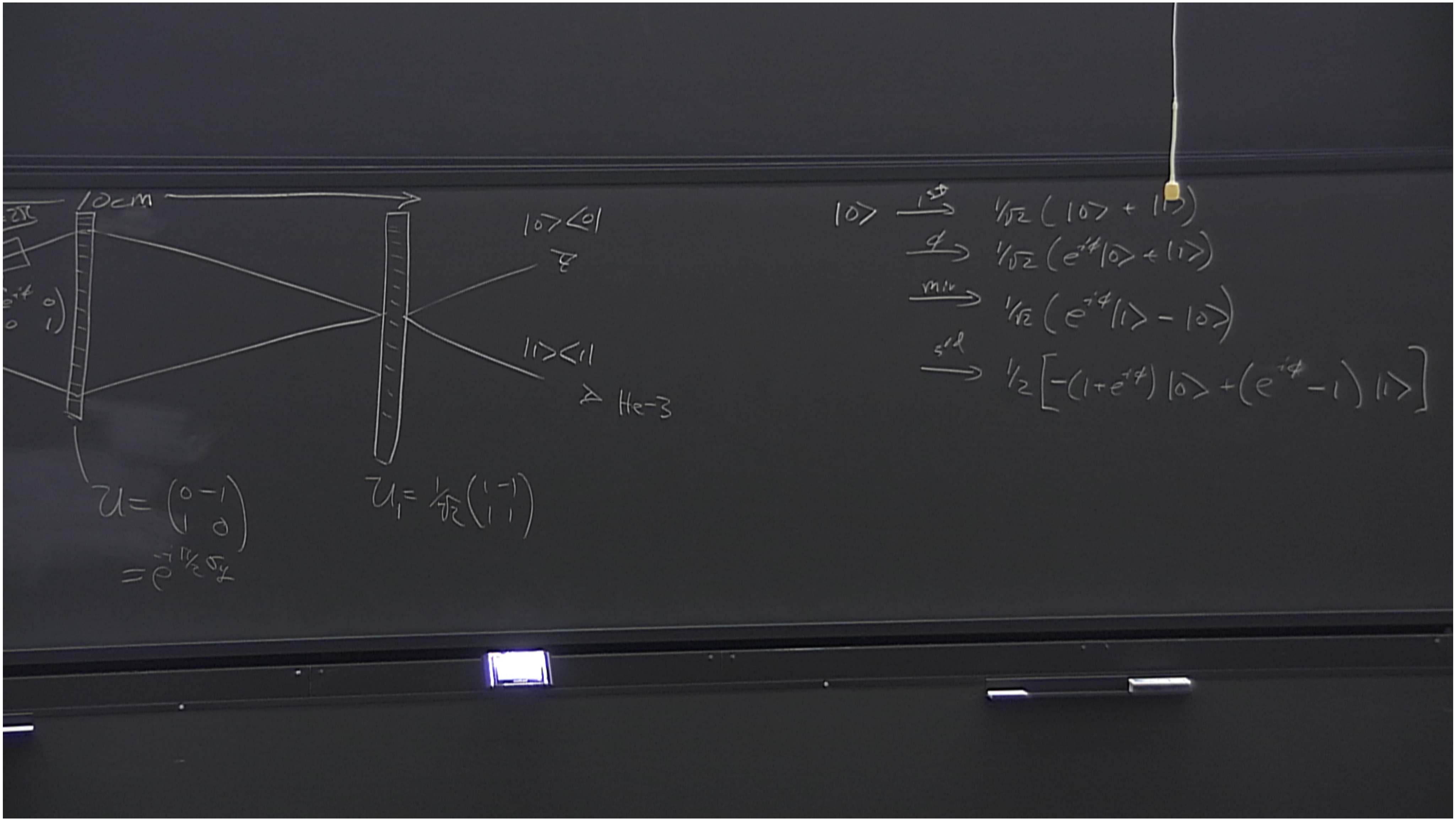
10cm
Bragg
|0>
|1>
|0>
v = 1.8 km/sec
He-3
$e^{-i\frac{\pi}{4}\sigma_y}$
$= U_1 = \frac{1}{\sqrt{2}}\begin{pmatrix}1 & -1\\1 & 1\end{pmatrix}$
$U = \begin{pmatrix}0 & -1\\1 & 0\end{pmatrix}$
$= e^{-i\frac{\pi}{2}\sigma_y}$
$U_1 = \frac{1}{\sqrt{2}}\begin{pmatrix}1 & -1\\1 & 1\end{pmatrix}$

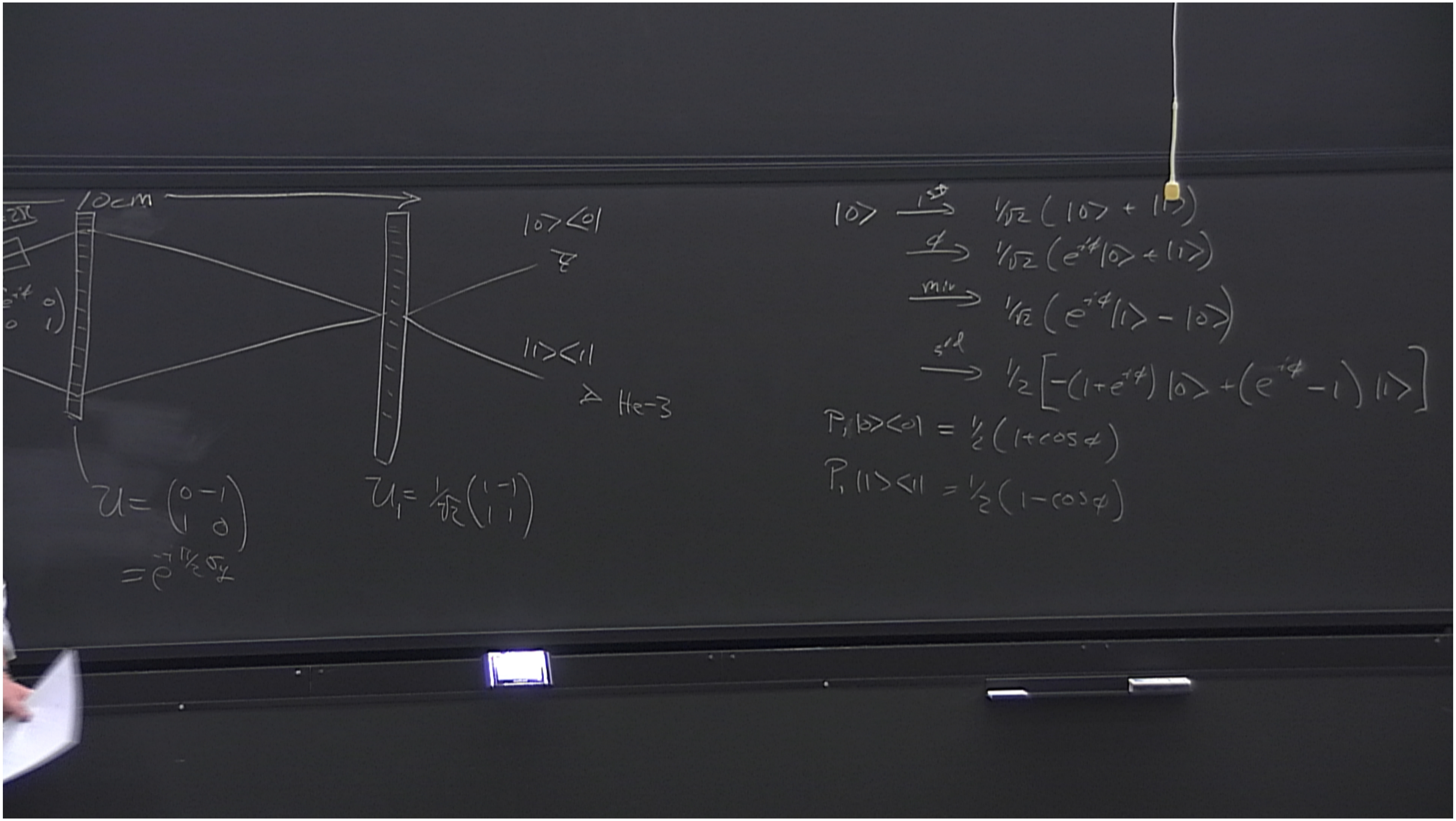


10cm
y
x
Bragg
|0⟩ ; k_y > 0
|1⟩ ; k_y < 0
v = 1.8 km/sec
|0⟩
|1⟩
→ He-3

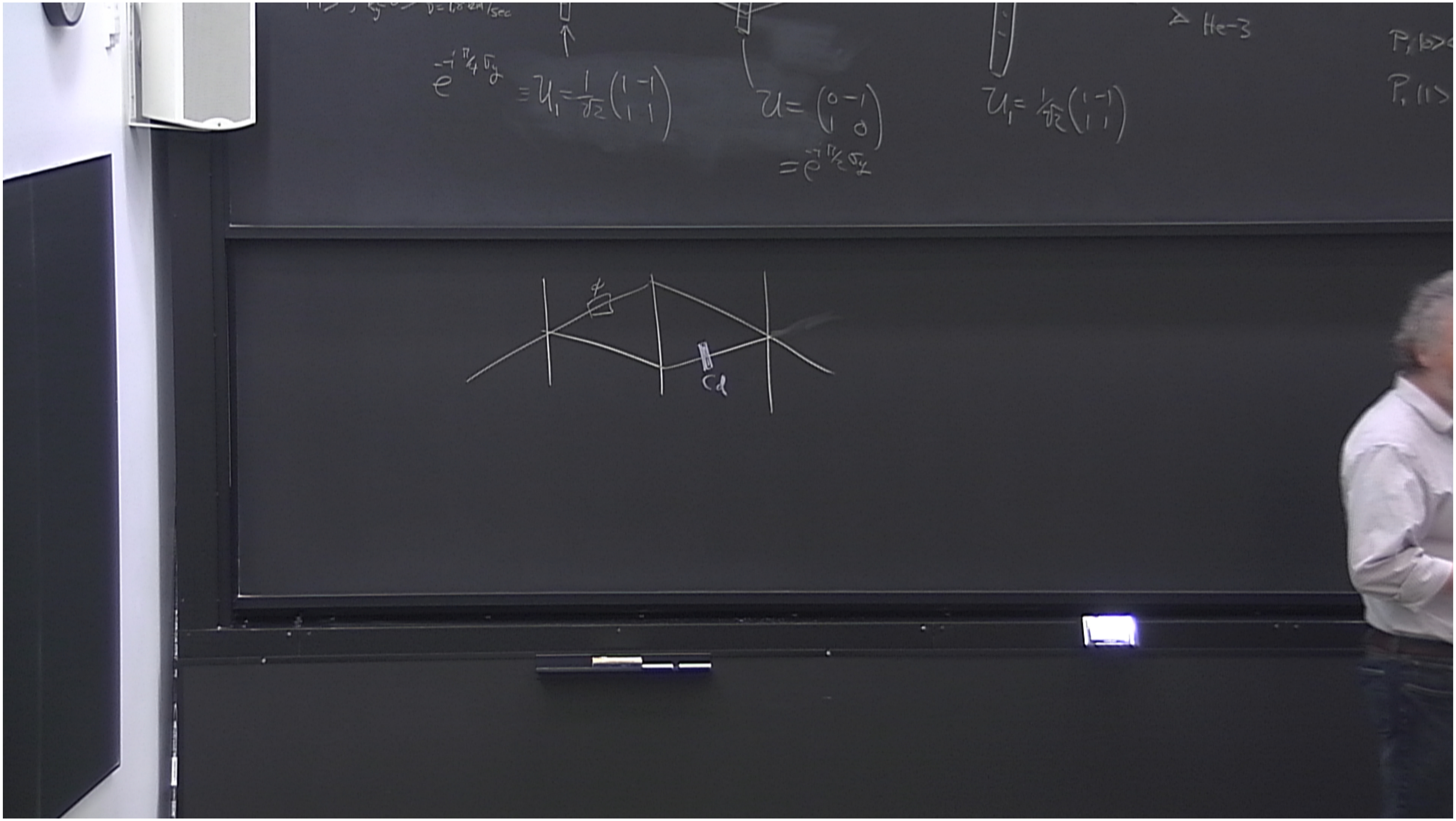

10cm
Bragg
|0> ; k_y > 0
|1> ; k_y < 0
v = 1.8 km/sec
|0>
|1>
He-3
U = (0 −1; 1 0) = e^{−i π/2 σ_y}
U_1 = 1/√2 (1 −1; 1 1)


He-3

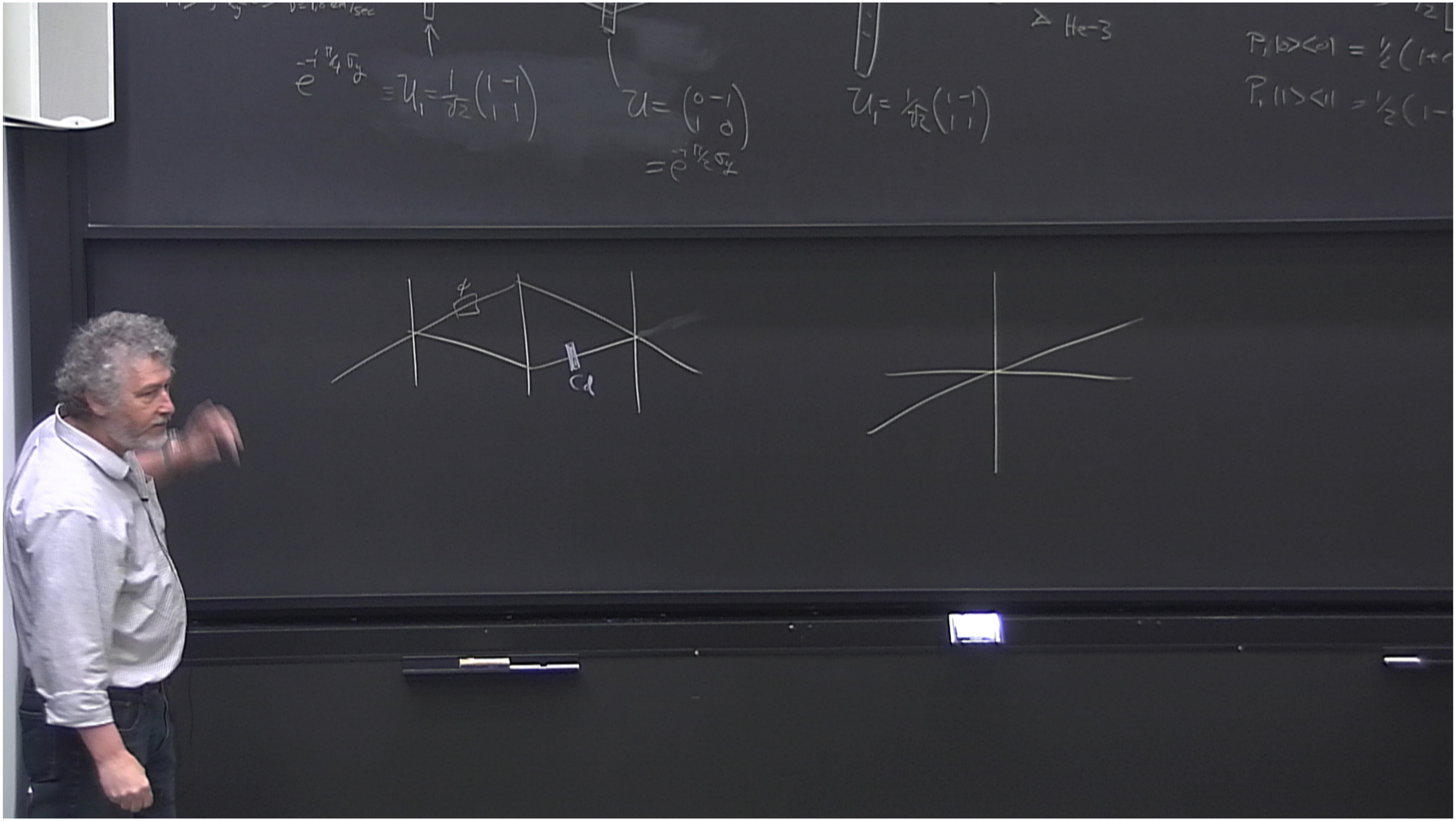

10cm
|0><0|
|1><1|
He-3
U = (0 -1; 1 0)
U₁ = 1/√2 (1 -1; 1 1)
|0> → 1/√2 (|0> + |1>)
→ 1/√2 (e^{-iφ}|0> + |1>)
mir → 1/√2 (e^{-iφ}|1> - |0>)
→ 1/2 [-(1+e^{-iφ}) |0> + (e^{-iφ} - 1) |1>]

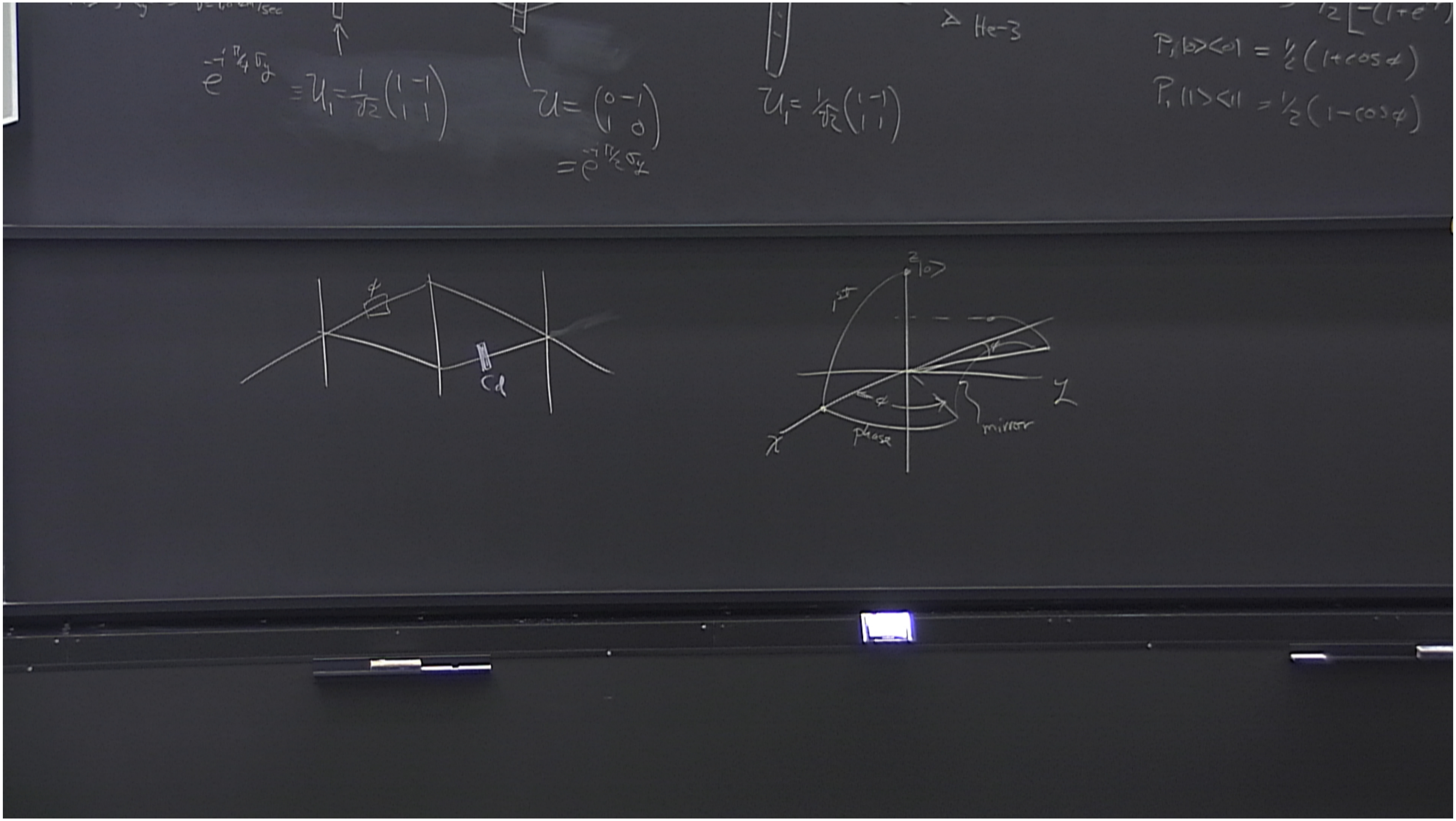


10cm
|0><0|
|1><1|
He-3
U = (0 −1; 1 0)
= e^{−i π/2 σ_y}
U_1 = 1/√2 (1 −1; 1 1)
|0> → 1st → 1/√2 (|0> + |1>)
φ → 1/√2 (e^{−iφ}|0> + |1>)
mir → 1/√2 (e^{−iφ}|1> − |0>)
2nd → 1/2 [−(1+e^{−iφ}) |0> + (e^{−iφ} − 1) |1>]
P, |0><0| = 1/2 (1+cos φ)
P, |1><1| = 1/2 (1−cos φ)

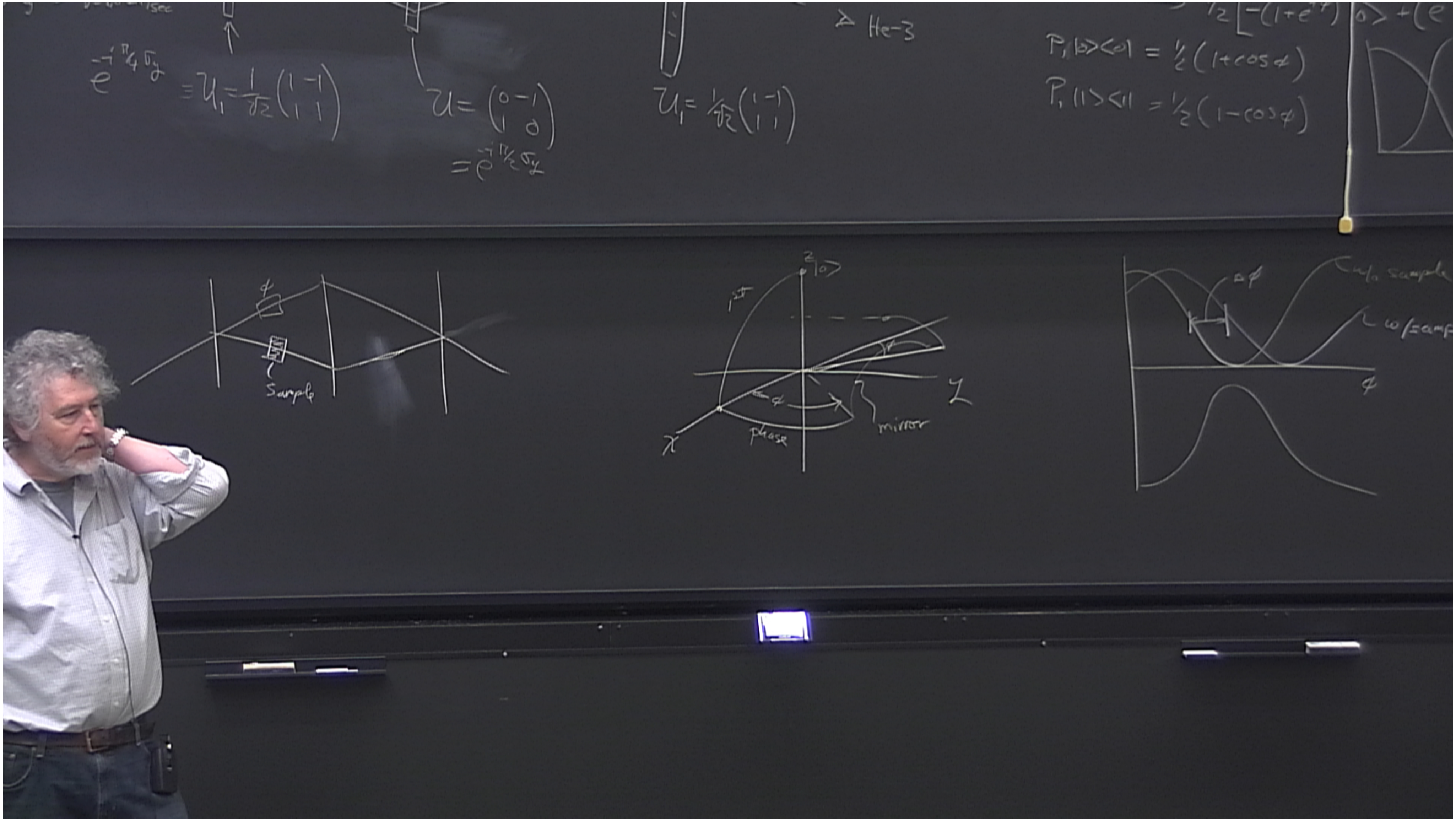


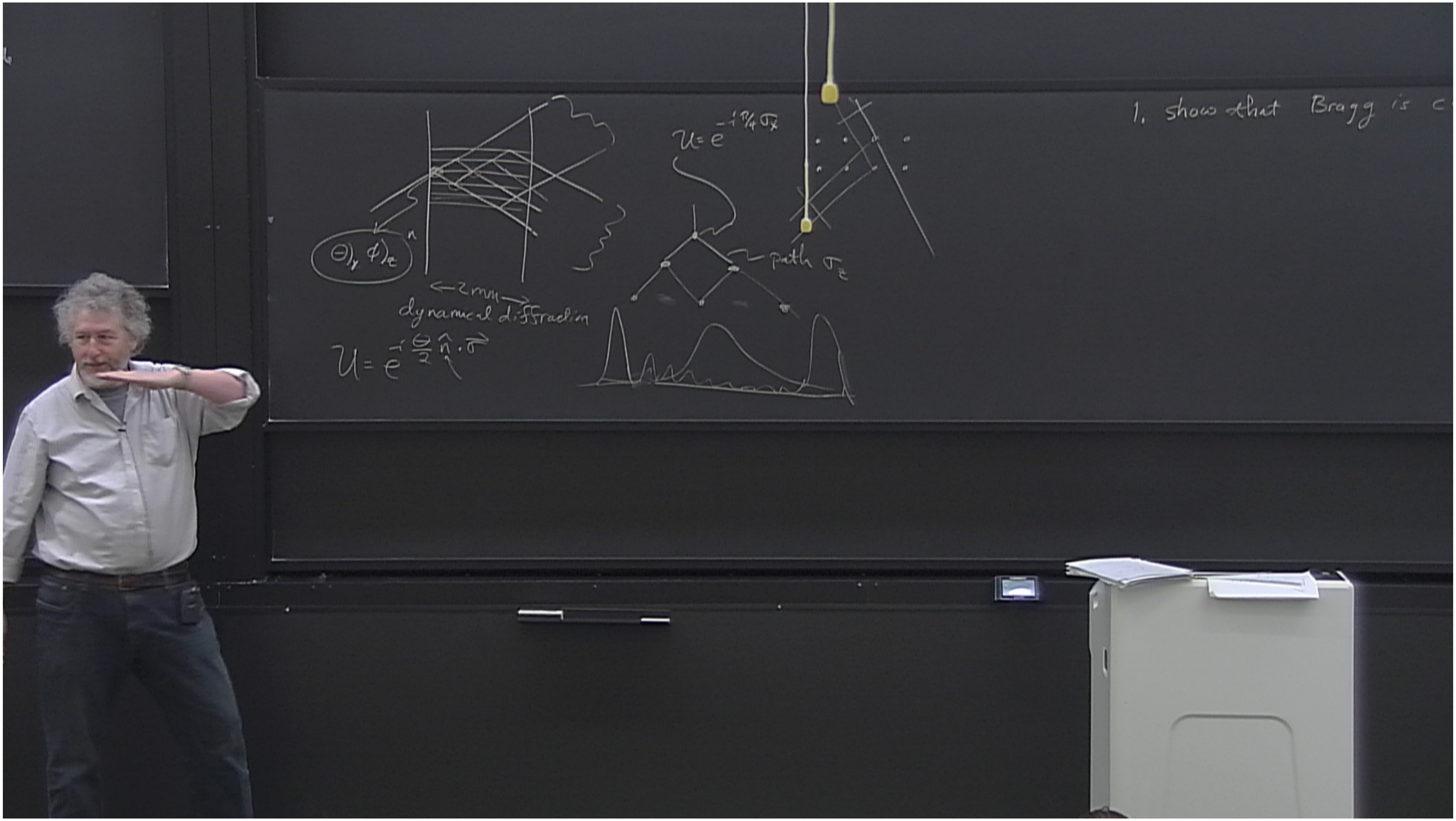
He-3



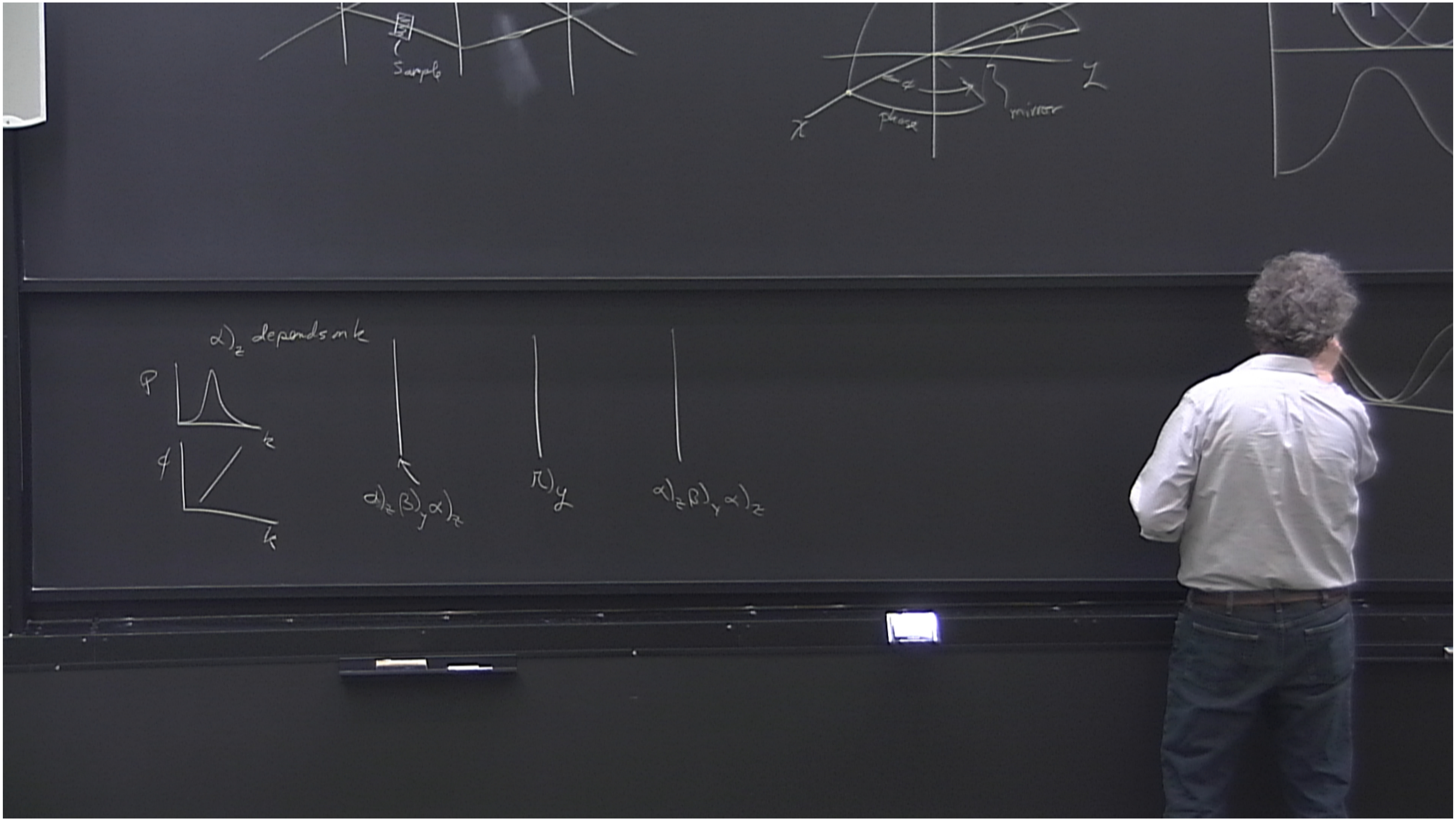


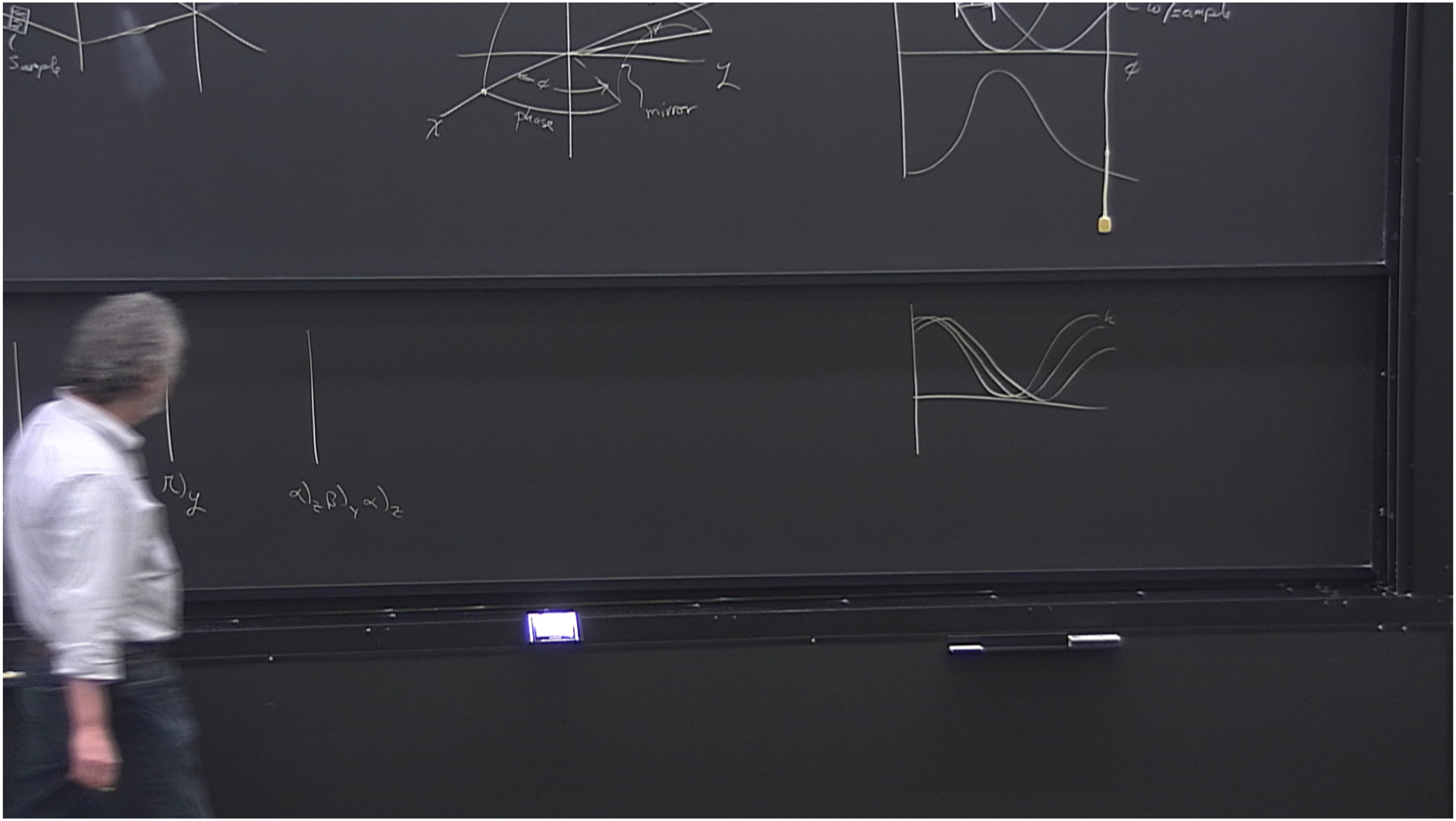
He-3
P₁|0⟩⟨0| = ½(1+cos φ)
P₁|1⟩⟨1| = ½(1−cos φ)
mirror
phase

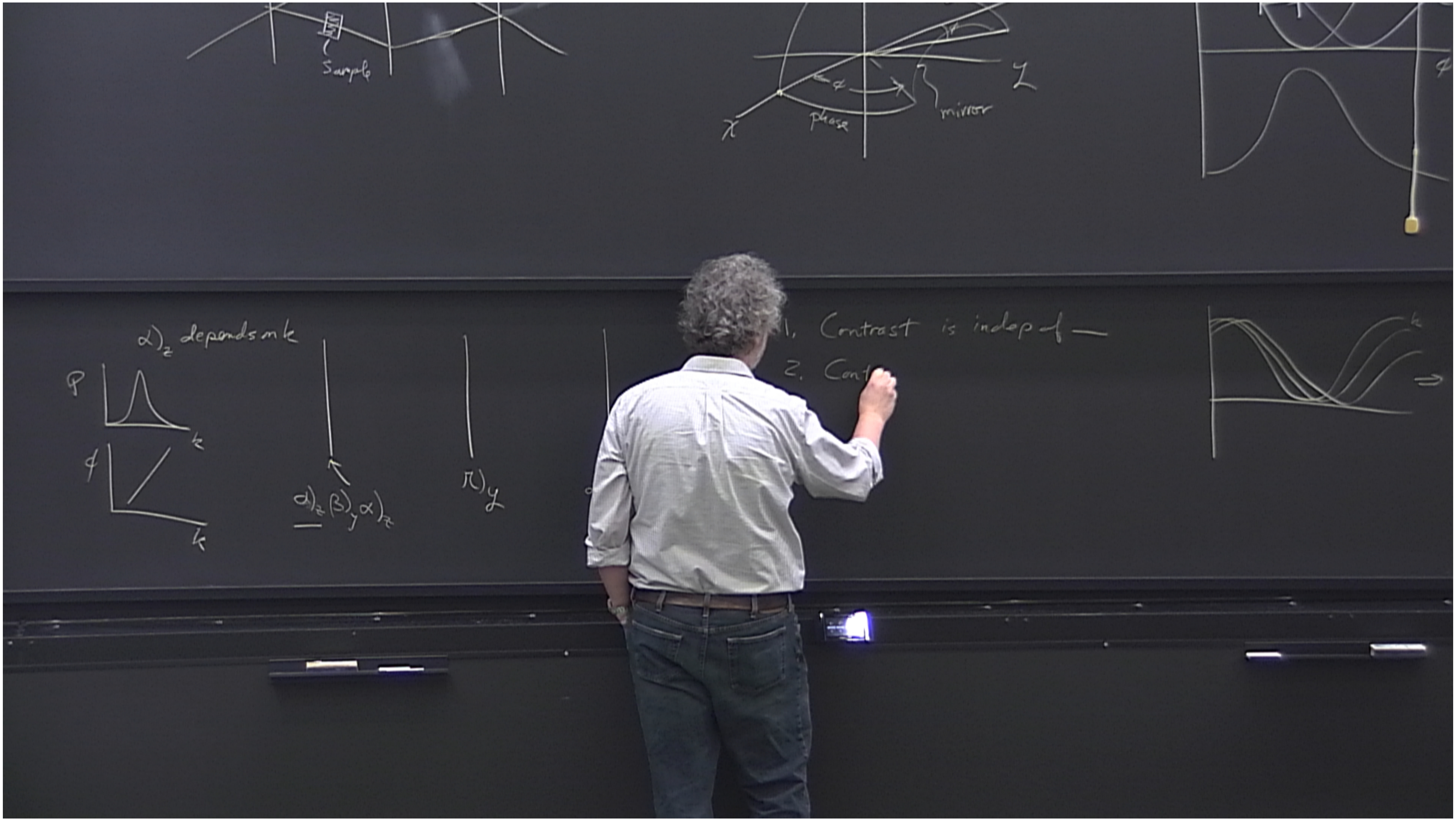

He-3
$U_1 = \frac{1}{\sqrt{2}}\begin{pmatrix}1 & -1\\ 1 & 1\end{pmatrix}$
$U = \begin{pmatrix}0 & -1\\ 1 & 0\end{pmatrix}$
$P_1 |0\rangle\langle 0| = \frac{1}{2}(1+\cos\phi)$
$P_1 |1\rangle\langle 1| = \frac{1}{2}(1-\cos\phi)$
Sample
phase
mirror
w/o sample
w/ samp
$\Delta\phi$

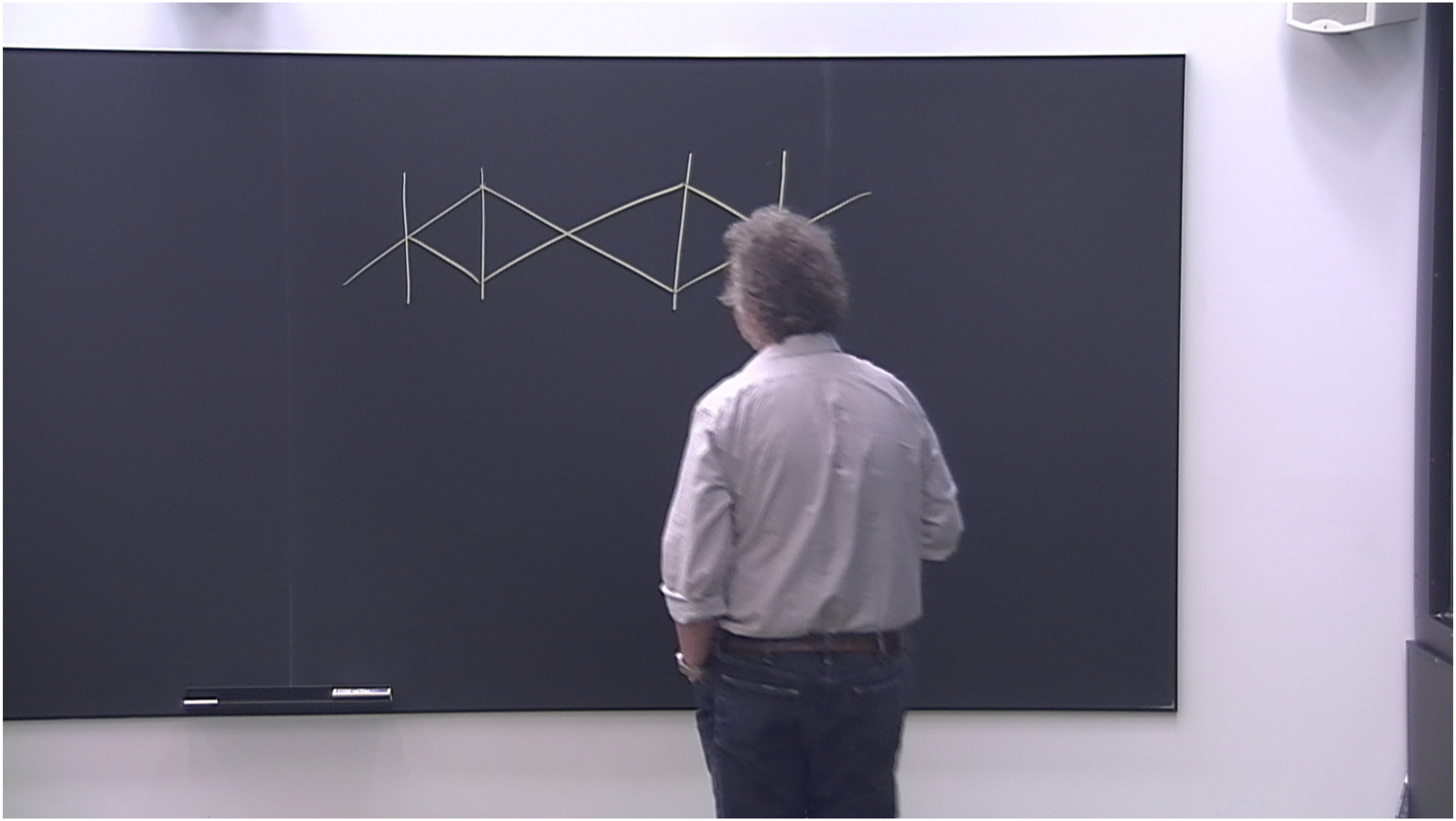


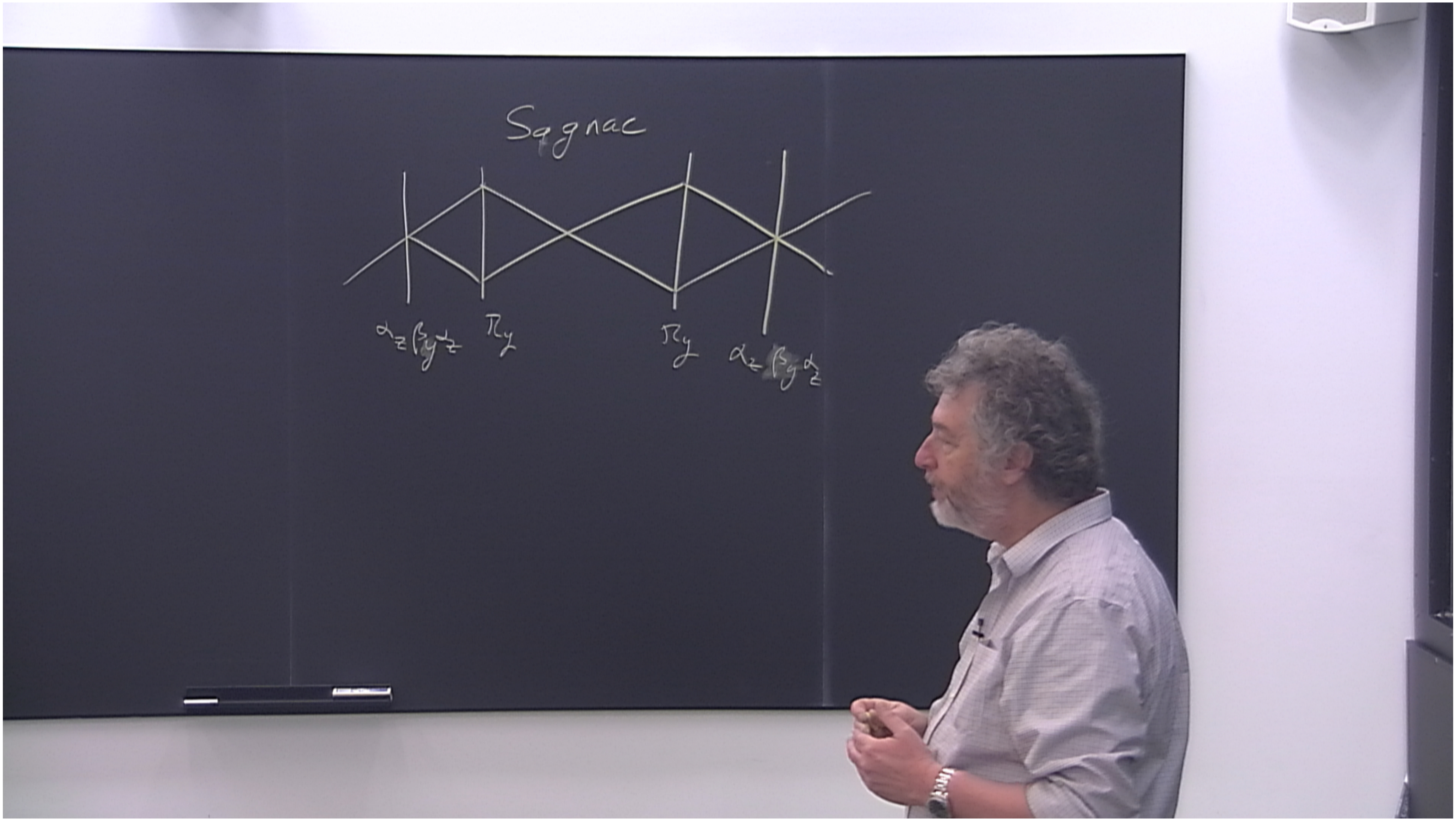
1. show that Bragg is c
dynamical diffraction
← 2mm →
path σ_z
$U = e^{-i\pi/4\,\sigma_x}$
$U = e^{-i\frac{\theta}{2}\hat{n}\cdot\vec{\sigma}}$

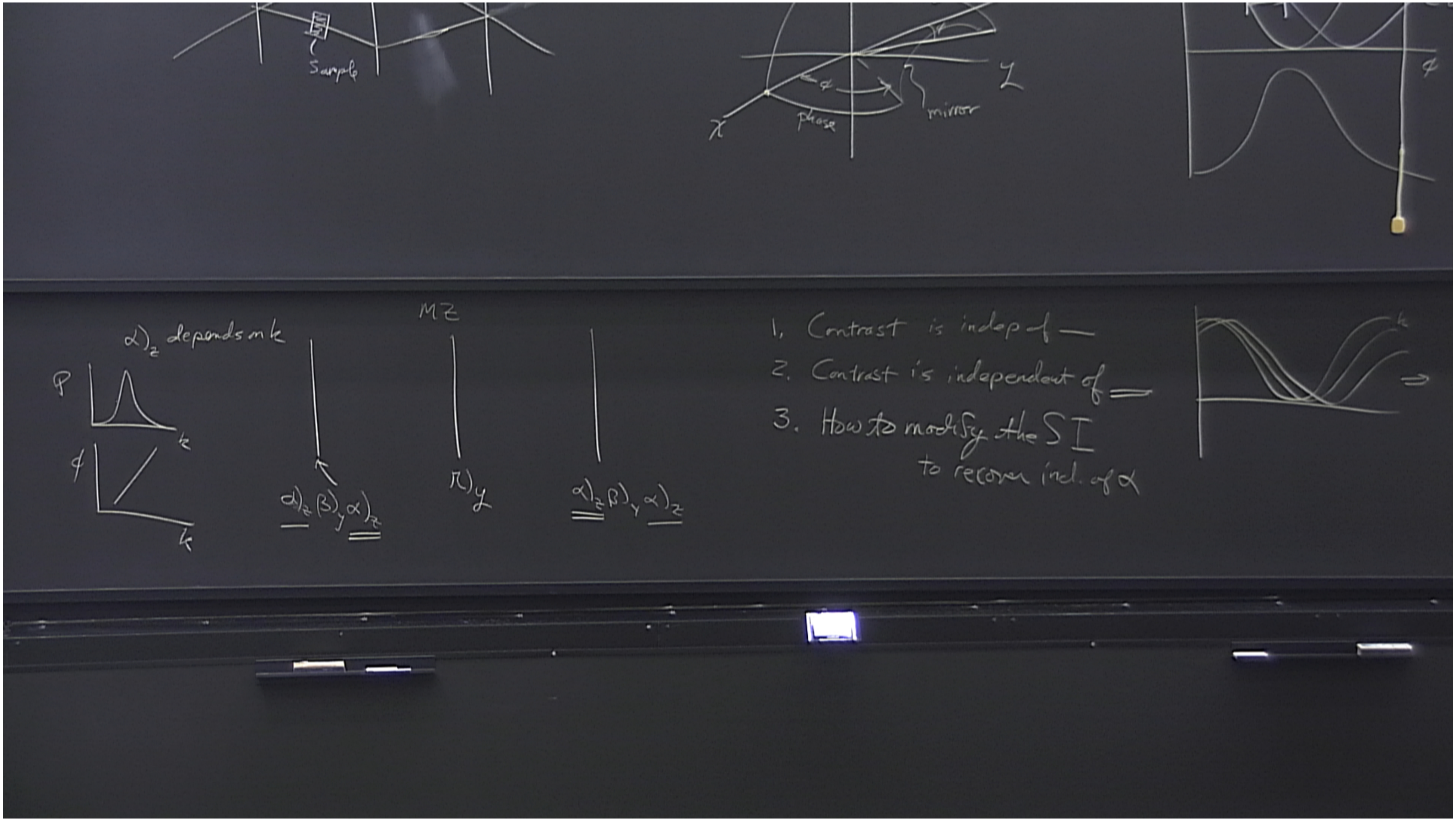

Sample
phase
mirror
$\alpha)_z$ depends on k
$\alpha)_z \beta)_y \alpha)_z$
$\pi)_y$
$\alpha)_z \beta)_y \alpha)_z$


Sample
phase
mirror
w/sample


Sample
phase
mirror
1. Contrast is indep of
2. Cont




Sagnac


Sample
phase
mirror
α)z depends on k
MZ
1. Contrast is indep of —
2. Contrast is independent of =
3. How to modify the SI
to recover ind. of α