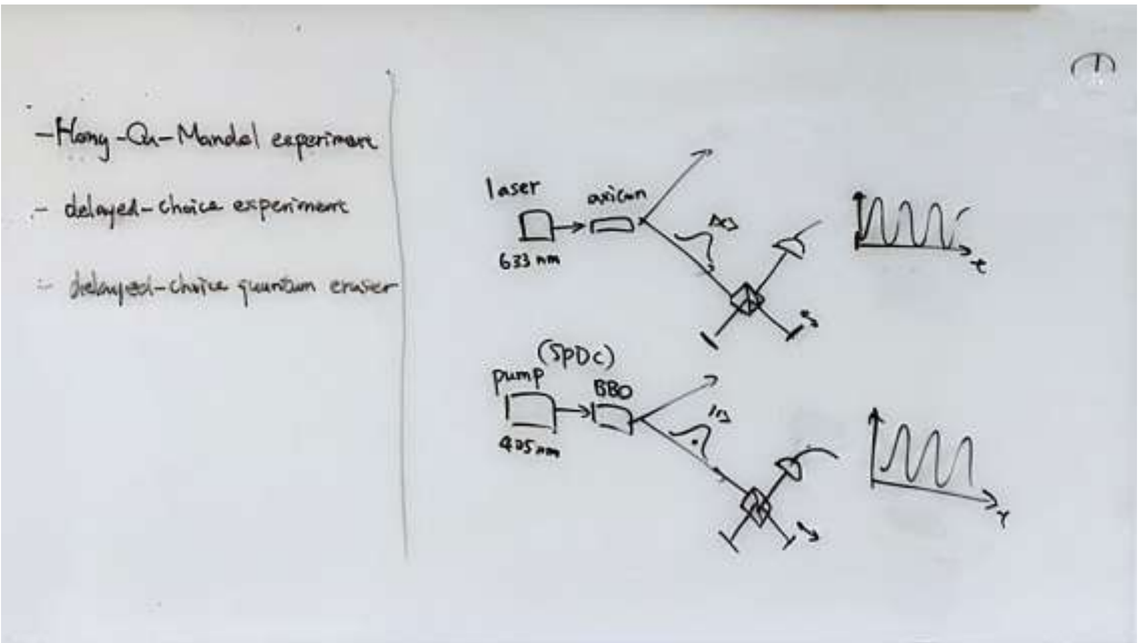
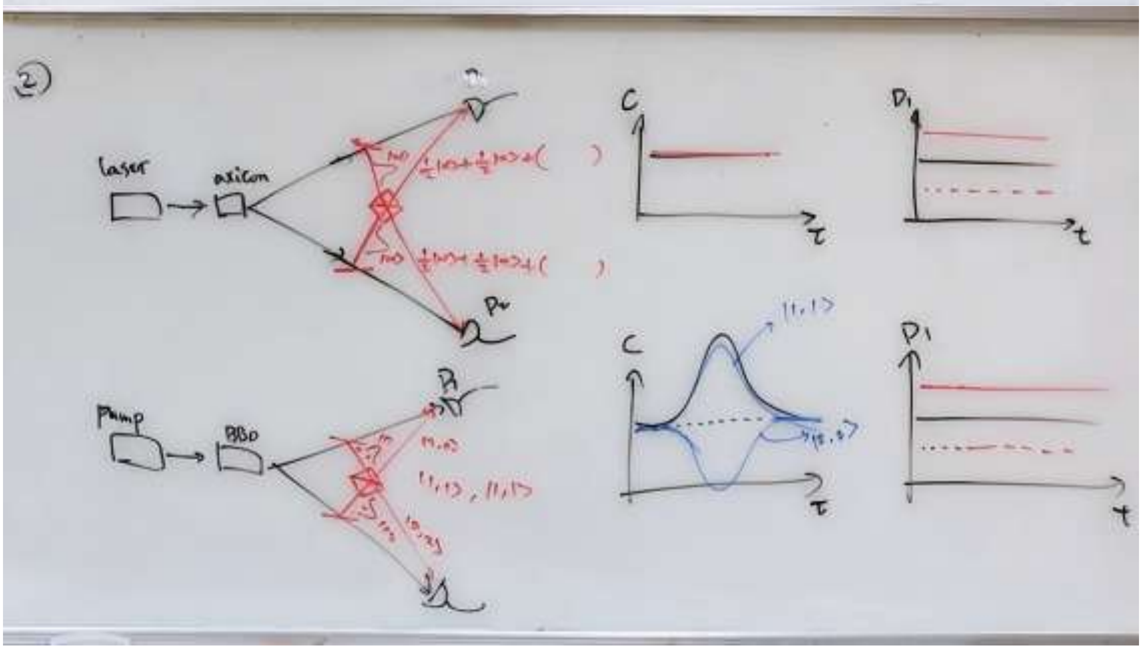
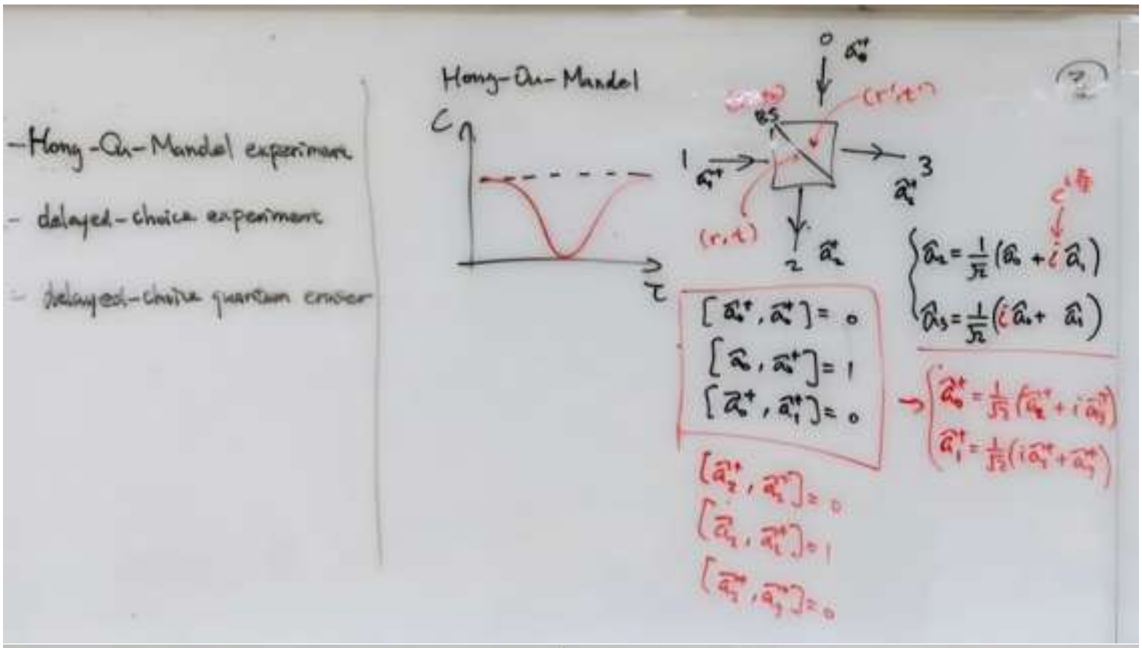
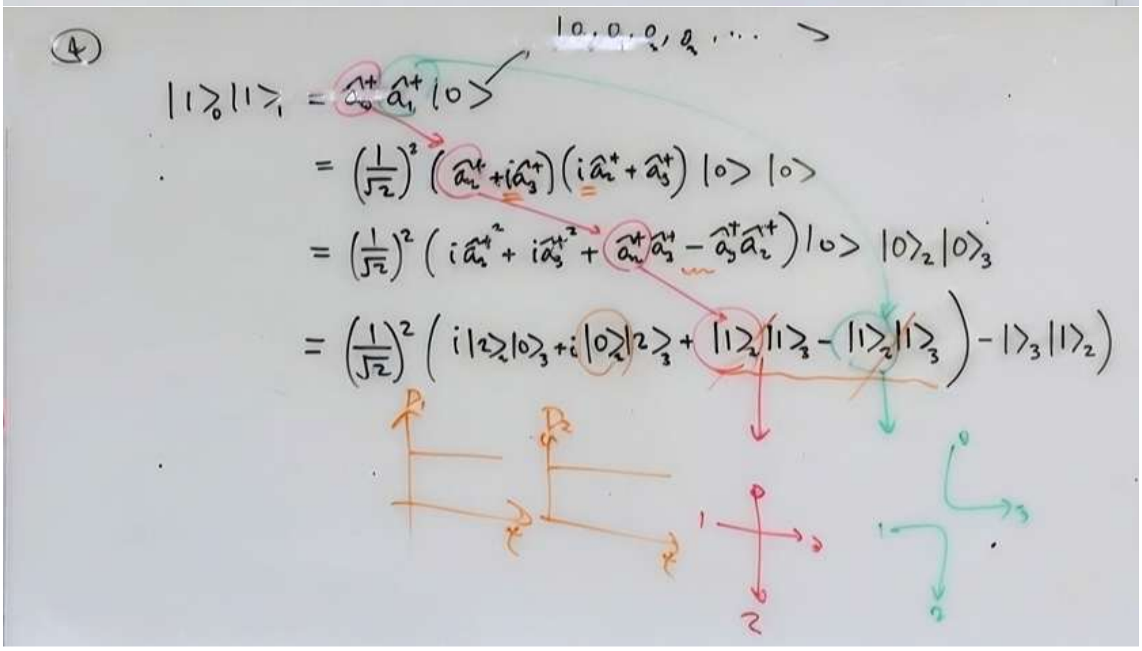
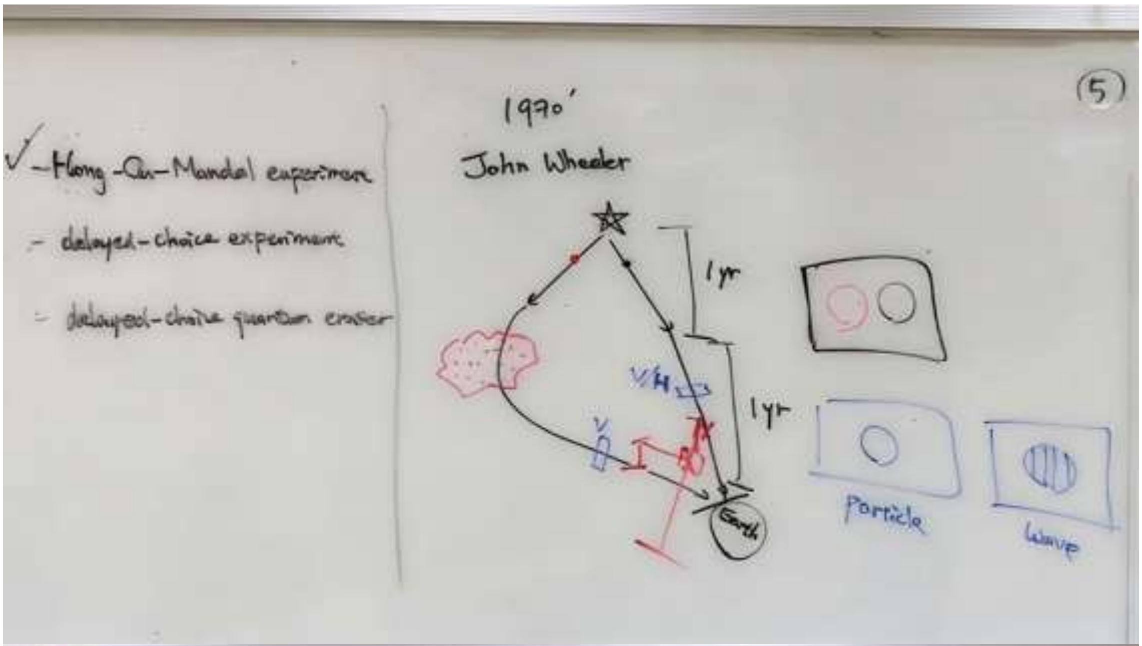
Lecture12 (optics) delayed-choice quantum eraser

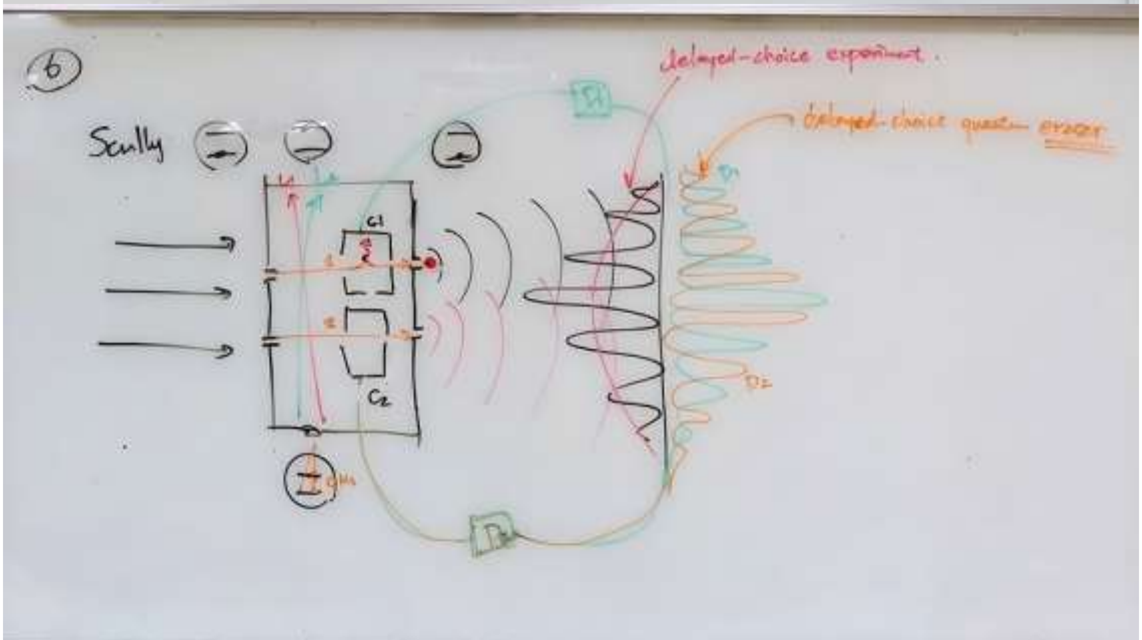


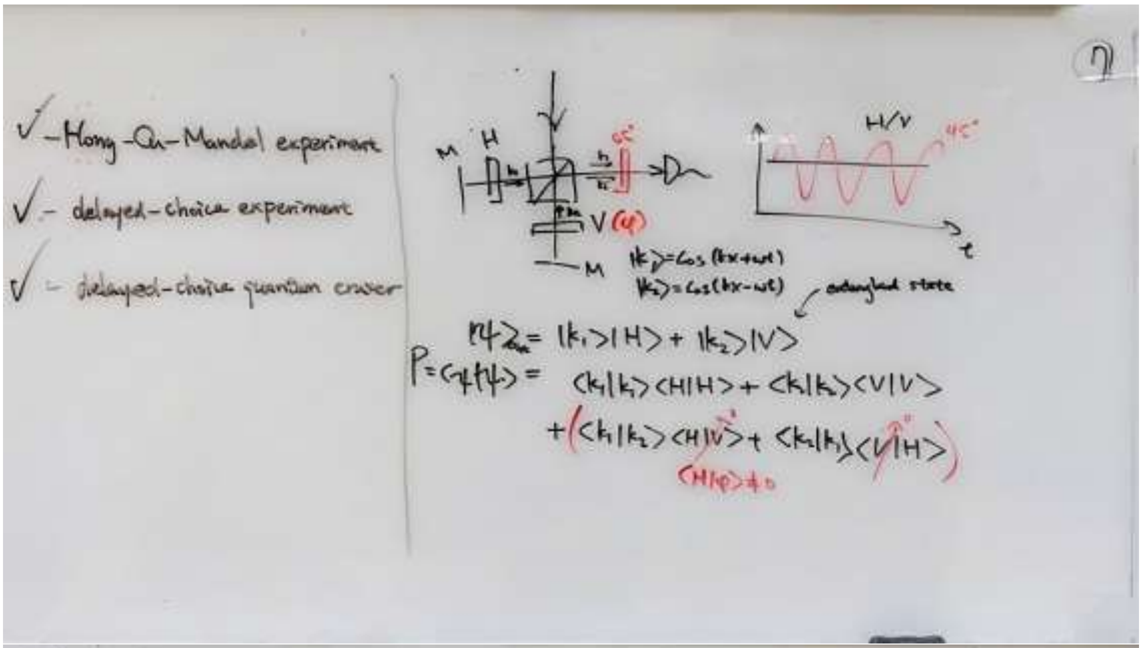


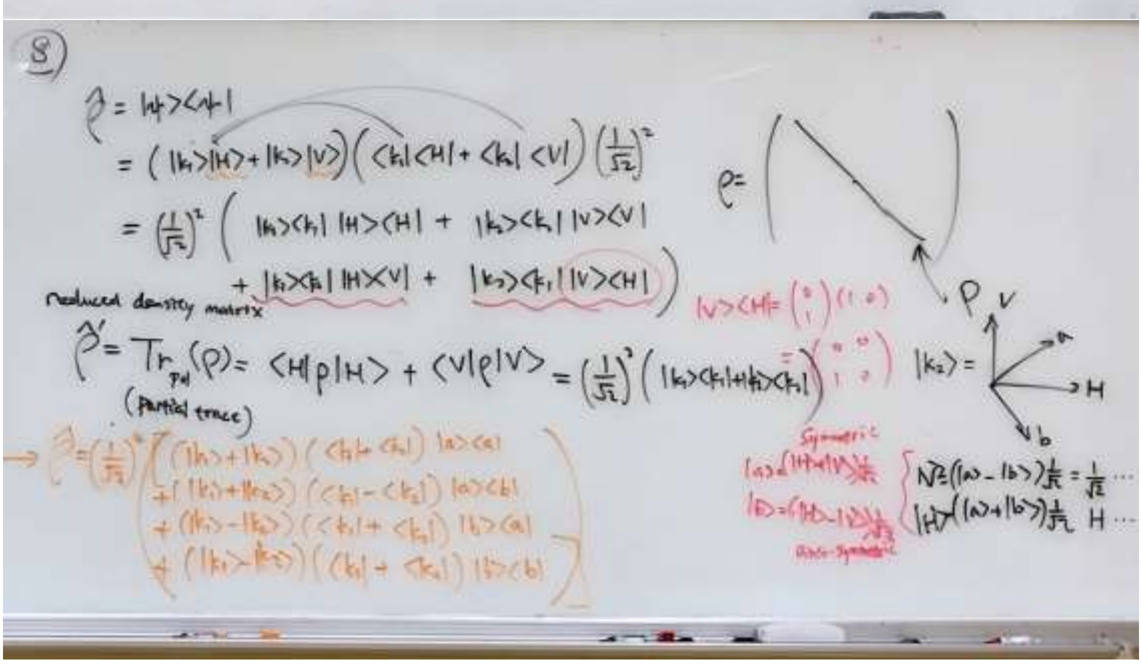

- Hong-Ou-Mandel experiment
- delayed-choice experiment
- delayed-choice quantum eraser
Hong-Ou-Mandel
C
τ
BS
(r', t')
(r, t)
$[\hat{a}_0^+, \hat{a}_1^+] = 0$
$[\hat{a}_0, \hat{a}_0^+] = 1$
$[\hat{a}_0^+, \hat{a}_1^+] = 0$
$[\hat{a}_2^+, \hat{a}_3^+] = 0$
$[\hat{a}_2, \hat{a}_2^+] = 1$
$[\hat{a}_2^+, \hat{a}_3^+] = 0$
$\hat{a}_2 = \frac{1}{\sqrt{2}}(\hat{a}_0 + i\hat{a}_1)$
$\hat{a}_3 = \frac{1}{\sqrt{2}}(i\hat{a}_0 + \hat{a}_1)$
$\hat{a}_0^+ = \frac{1}{\sqrt{2}}(\hat{a}_2^+ + i\hat{a}_3^+)$
$\hat{a}_1^+ = \frac{1}{\sqrt{2}}(i\hat{a}_2^+ + \hat{a}_3^+)$

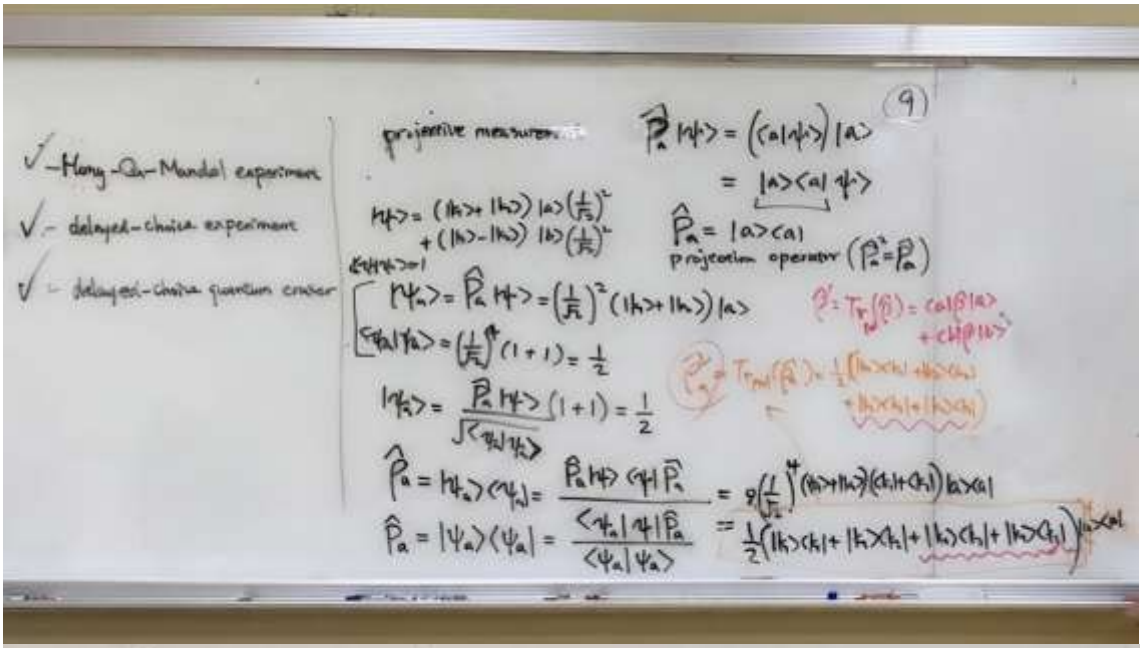

④
$|0, 0, 0, 0, \cdots\rangle$
$|1\rangle_0|1\rangle_1 = \hat{a}_0^+\hat{a}_1^+|0\rangle$
$= \left(\frac{1}{\sqrt{2}}\right)^2(\hat{a}_2^+ + i\hat{a}_3^+)(i\hat{a}_2^+ + \hat{a}_3^+)|0\rangle|0\rangle$
$= \left(\frac{1}{\sqrt{2}}\right)^2(i\hat{a}_2^{+2} + i\hat{a}_3^{+2} + \hat{a}_2^+\hat{a}_3^+ - \hat{a}_3^+\hat{a}_2^+)|0\rangle|0\rangle_2|0\rangle_3$
$= \left(\frac{1}{\sqrt{2}}\right)^2(i|2\rangle_2|0\rangle_3 + i|0\rangle_2|2\rangle_3 + |1\rangle_2|1\rangle_3 - |1\rangle_2|1\rangle_3) - |1\rangle_3|1\rangle_2)$
D_1
D_2

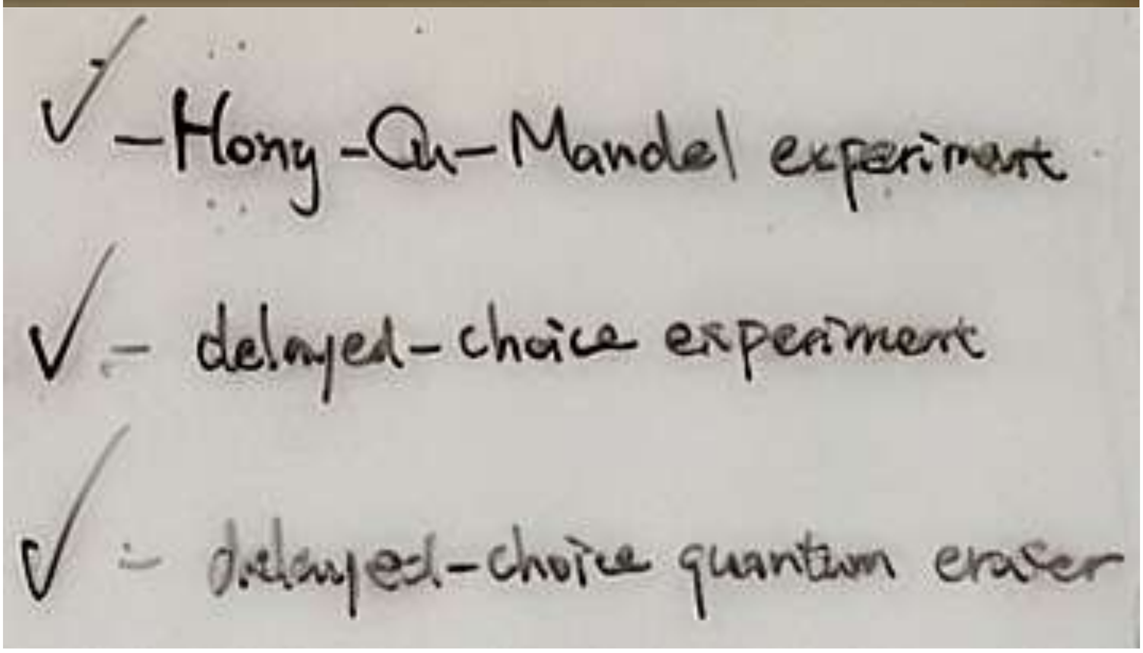

5
1970'
John Wheeler
Hong-Ou-Mandel experiment
- delayed-choice experiment
- delayed-choice quantum eraser
1yr
1yr
V/H
V
Earth
Particle
Wave


6
Scully
delayed-choice experiment.
delayed-choice quantum eraser
C1
C2
D1
D2


7
✓ – Hong-Ou-Mandel experiment
✓ – delayed-choice experiment
✓ – delayed-choice quantum eraser
M
H
V
M
H/V
45°
t
|k₁⟩ = cos(kx+ωt)
|k₂⟩ = cos(kx−ωt)
entangled state
|ψ⟩ = |k₁⟩|H⟩ + |k₂⟩|V⟩
ρ = ⟨ψ|ψ⟩ = ⟨k₁|k₁⟩⟨H|H⟩ + ⟨k₂|k₂⟩⟨V|V⟩
+ (⟨k₁|k₂⟩⟨H|V⟩ + ⟨k₂|k₁⟩⟨V|H⟩)
⟨H|φ⟩ ≠ 0


8
ρ = |ψ⟩⟨ψ|
= (|k₁⟩|H⟩ + |k₂⟩|V⟩)(⟨k₁|⟨H| + ⟨k₂|⟨V|)(1/√2)²
= (1/√2)² (|k₁⟩⟨k₁| |H⟩⟨H| + |k₂⟩⟨k₂| |V⟩⟨V|
+ |k₁⟩⟨k₂| |H⟩⟨V| + |k₂⟩⟨k₁| |V⟩⟨H|)
ρ =
reduced density matrix
ρ' = Tr_pol(ρ) = ⟨H|ρ|H⟩ + ⟨V|ρ|V⟩ = (1/√2)² (|k₁⟩⟨k₁| + |k₂⟩⟨k₂|)
(partial trace)
|V⟩⟨H| = (0 1)(1 0)
V
a
H
b
Symmetric
Anti-symmetric
H


Hong-Ou-Mandel experiment
delayed-choice experiment
delayed-choice quantum eraser
projective measurement
projection operator


Hong-Ou-Mandel experiment
delayed-choice experiment
delayed-choice quantum eraser