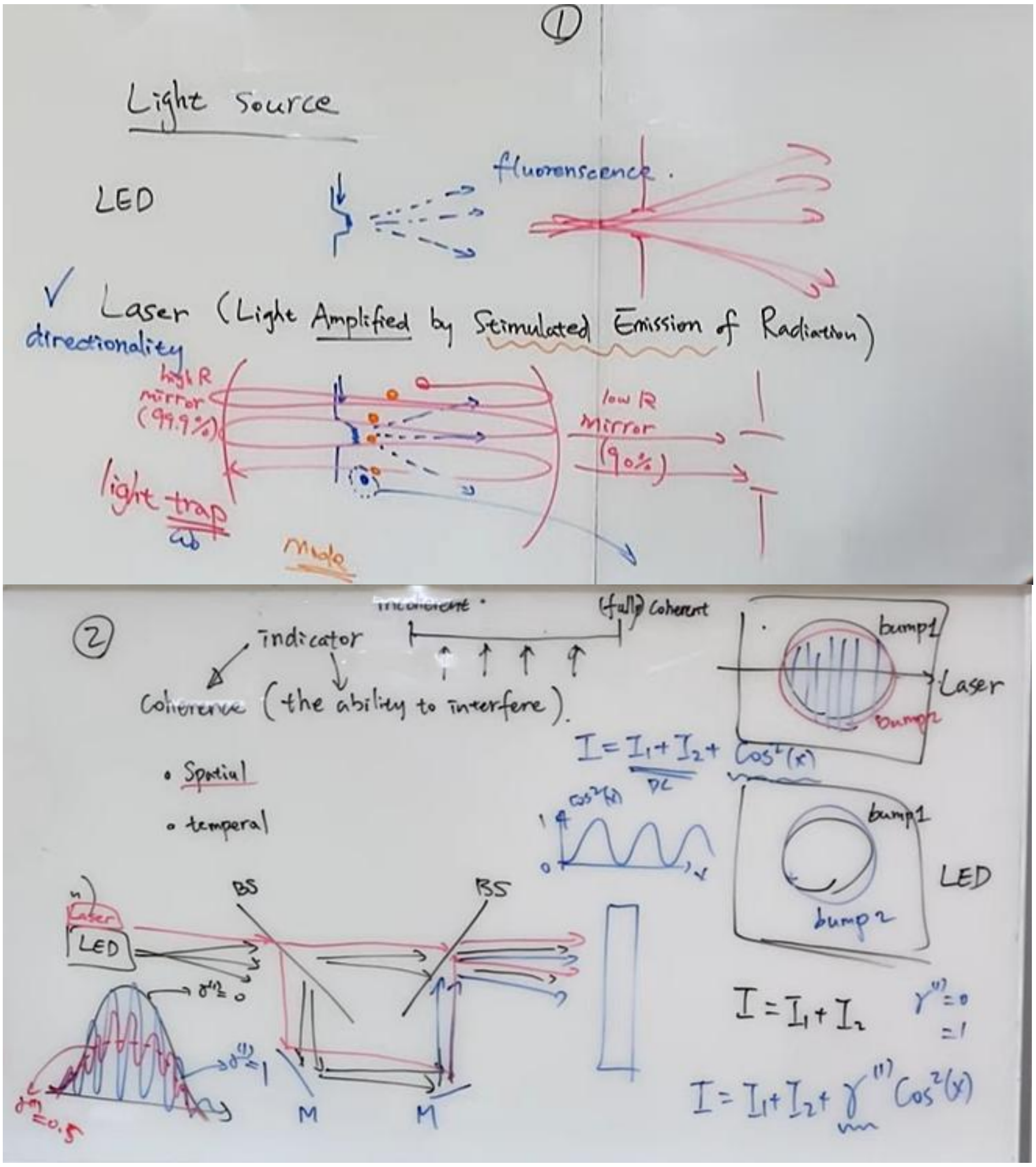
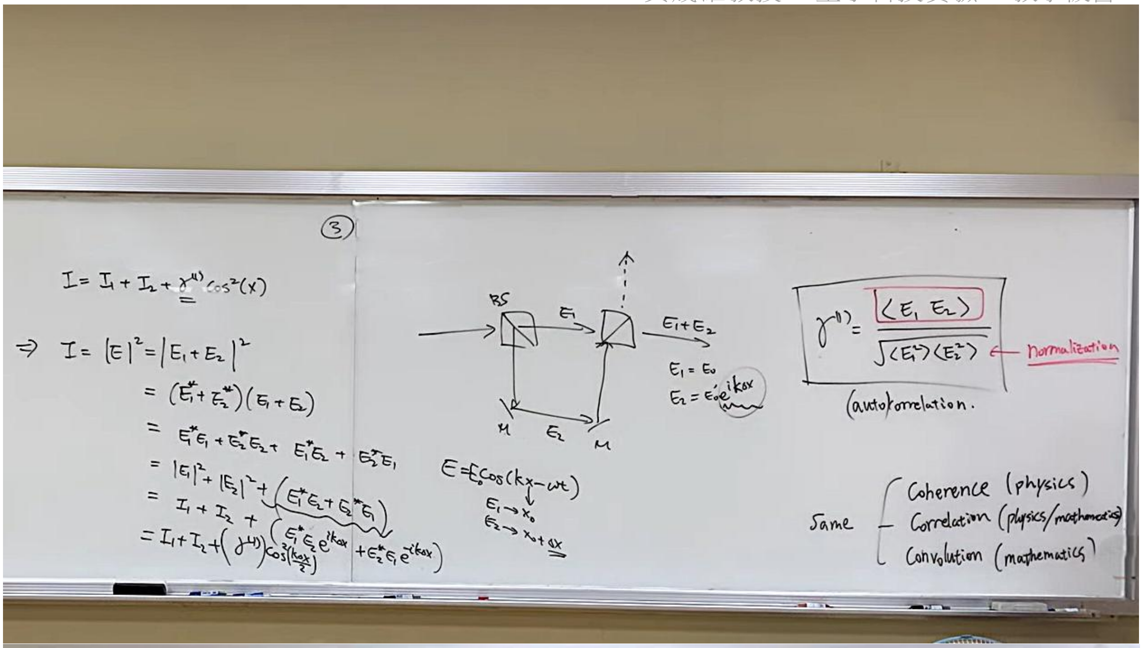
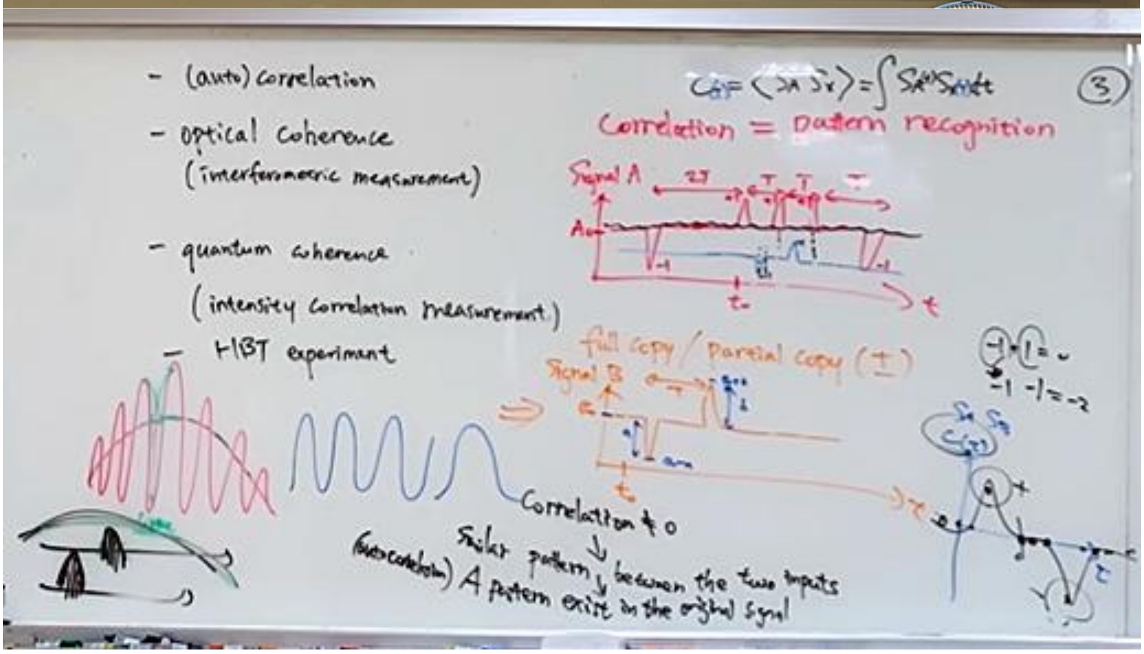
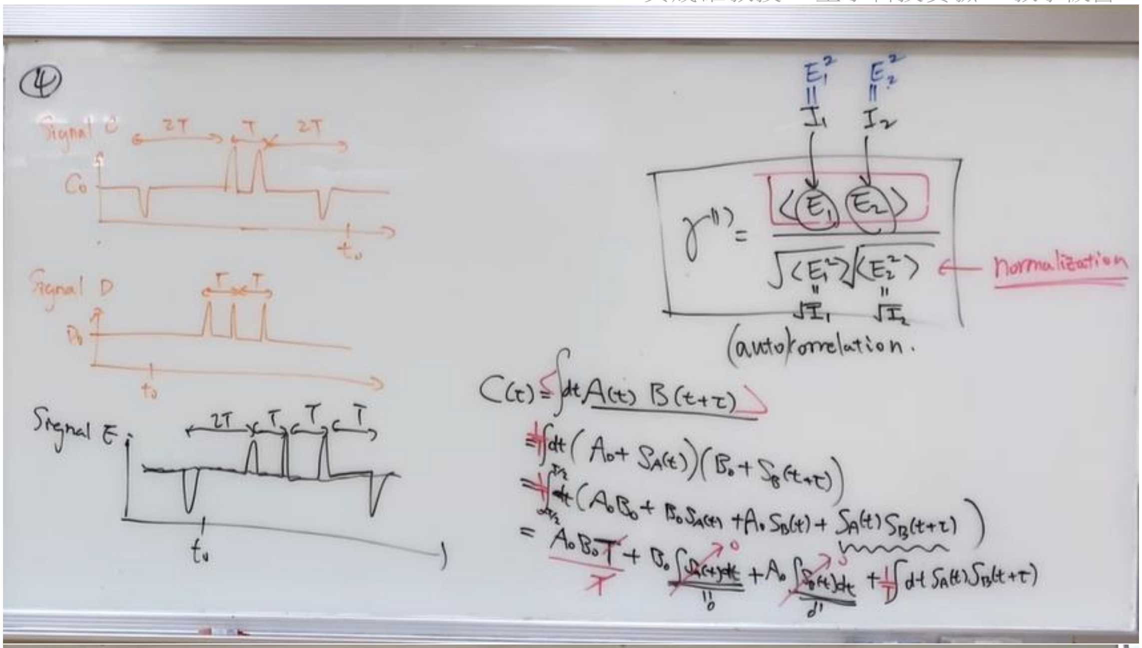
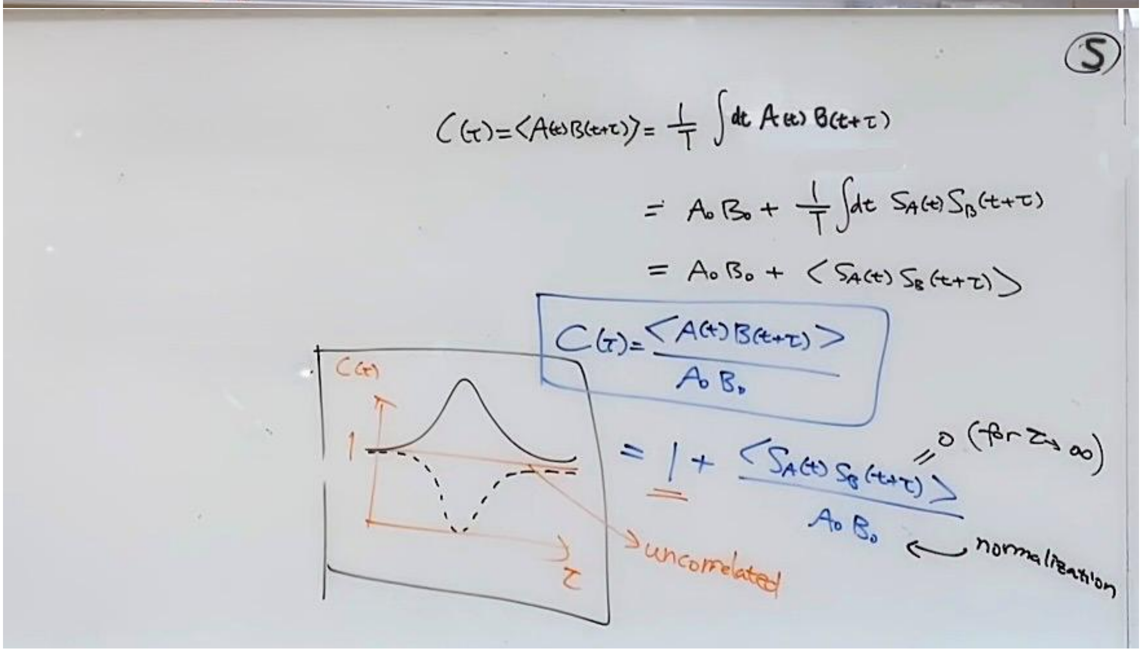
Lecture3 Correlation and optical coherence

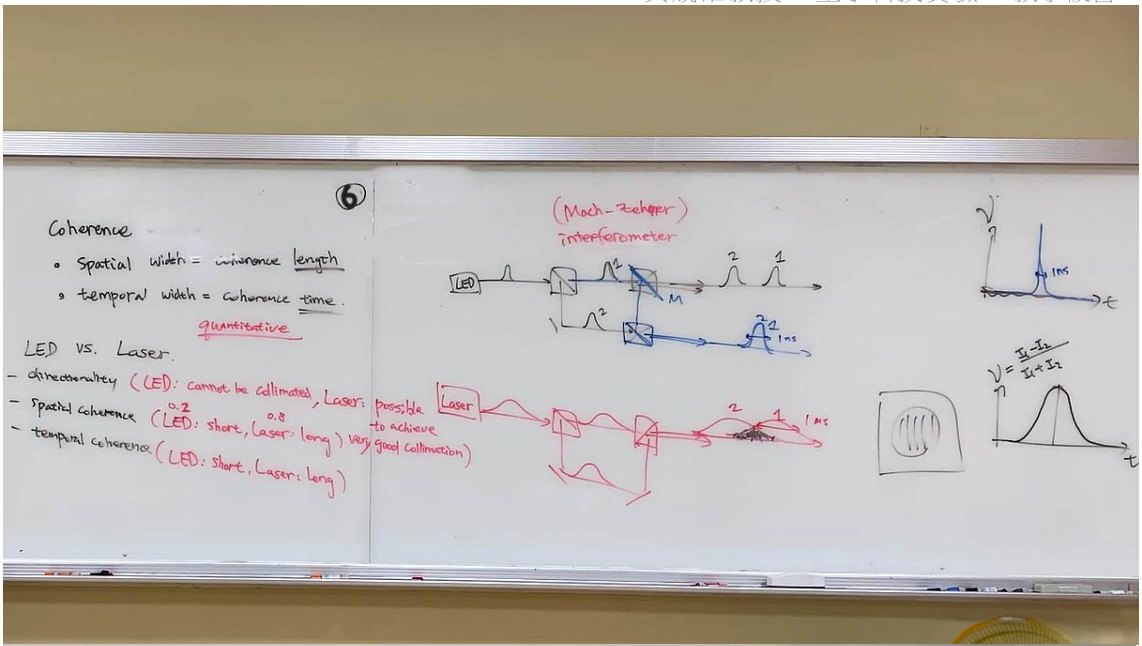


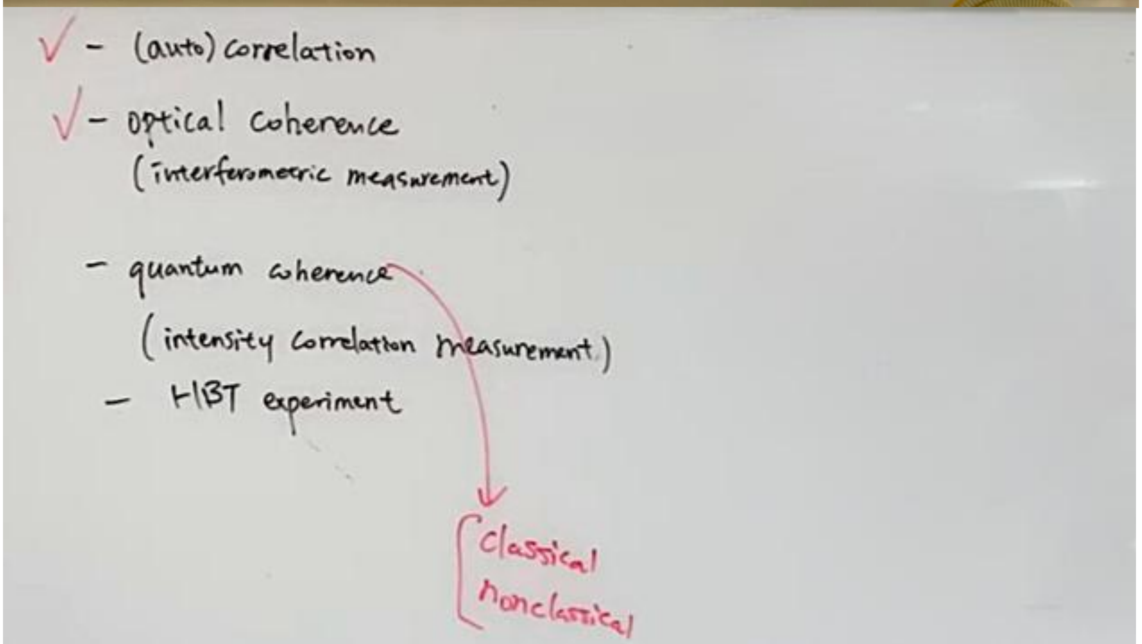

③
$I = I_1 + I_2 + \gamma^{(1)}\cos^2(x)$
$\Rightarrow I = |E|^2 = |E_1 + E_2|^2$
$= (E_1^* + E_2^*)(E_1 + E_2)$
$= E_1^*E_1 + E_2^*E_2 + E_1^*E_2 + E_2^*E_1$
$= |E_1|^2 + |E_2|^2 + (E_1^*E_2 + E_2^*E_1)$
$= I_1 + I_2 + (E_1^*E_1 e^{ik\Delta x} + E_2^*E_1 e^{-ik\Delta x})$
BS
M
M
E_1
E_2
$E_1 + E_2$
$E_1 = E_0$
$E_2 = E_0 e^{ik\Delta x}$
$E = E_0\cos(kx - \omega t)$
$E_1 \to x_0$
$E_2 \to x_0 + \Delta x$
$\gamma^{(1)} = \frac{\langle E_1 E_2 \rangle}{\sqrt{\langle E_1^2 \rangle \langle E_2^2 \rangle}}$
normalization
(auto)correlation.
Same
Coherence (physics)
Correlation (physics/mathematics)
Convolution (mathematics)


- (auto) correlation
- optical coherence
(interferometric measurement)
- quantum coherence
(intensity correlation measurement)
- HBT experiment
Correlation = pattern recognition
Signal A
Signal B
full copy / partial copy (±)
③
Correlation ≠ 0
Similar pattern between the two inputs
A pattern exist in the original signal


④
Signal C
2T
T
2T
C_0
t_0
Signal D
T
T
D_0
t_0
Signal E
2T
T
T
T
t_0
$E_1^2 = I_1$
$E_2^2 = I_2$
$\gamma^{(1)} = \frac{\langle E_1 E_2 \rangle}{\sqrt{\langle E_1^2 \rangle}\sqrt{\langle E_2^2 \rangle}}$
$\sqrt{I_1}$ $\sqrt{I_2}$
normalization
(auto)correlation.
$C(\tau) = \int dt\, A(t)\, B(t+\tau)$
$= \int dt\, (A_0 + S_A(t))(B_0 + S_B(t+\tau))$
$= \int dt\, (A_0 B_0 + B_0 S_A(t) + A_0 S_B(t) + S_A(t) S_B(t+\tau))$
$= A_0 B_0 T + B_0 \int S_A(t)\, dt + A_0 \int S_B(t)\, dt + \int dt\, S_A(t) S_B(t+\tau)$


⑤
$C(\tau) = \langle A(t) B(t+\tau) \rangle = \frac{1}{T} \int dt\, A(t) B(t+\tau)$
$= A_0 B_0 + \frac{1}{T} \int dt\, S_A(t) S_B(t+\tau)$
$= A_0 B_0 + \langle S_A(t) S_B(t+\tau) \rangle$
$C(\tau) = \frac{\langle A(t) B(t+\tau) \rangle}{A_0 B_0}$
$= 1 + \frac{\langle S_A(t) S_B(t+\tau) \rangle}{A_0 B_0}$
$= 0$ (for $\tau \to \infty$)
normalization
$C(\tau)$
1
τ
uncorrelated


⑥
Coherence
• Spatial width = coherence length
• temporal width = coherence time
quantitative
LED vs. Laser
- directionality (LED: cannot be collimated, Laser: possible to achieve very good collimation)
- spatial coherence (LED: short, Laser: long)
- temporal coherence (LED: short, Laser: long)
(Mach-Zehnder)
interferometer
LED
M
1 ns
Laser
1 ns


- (auto) correlation
- optical coherence
(interferometric measurement)
- quantum coherence
(intensity correlation measurement)
- HBT experiment
classical
nonclassical