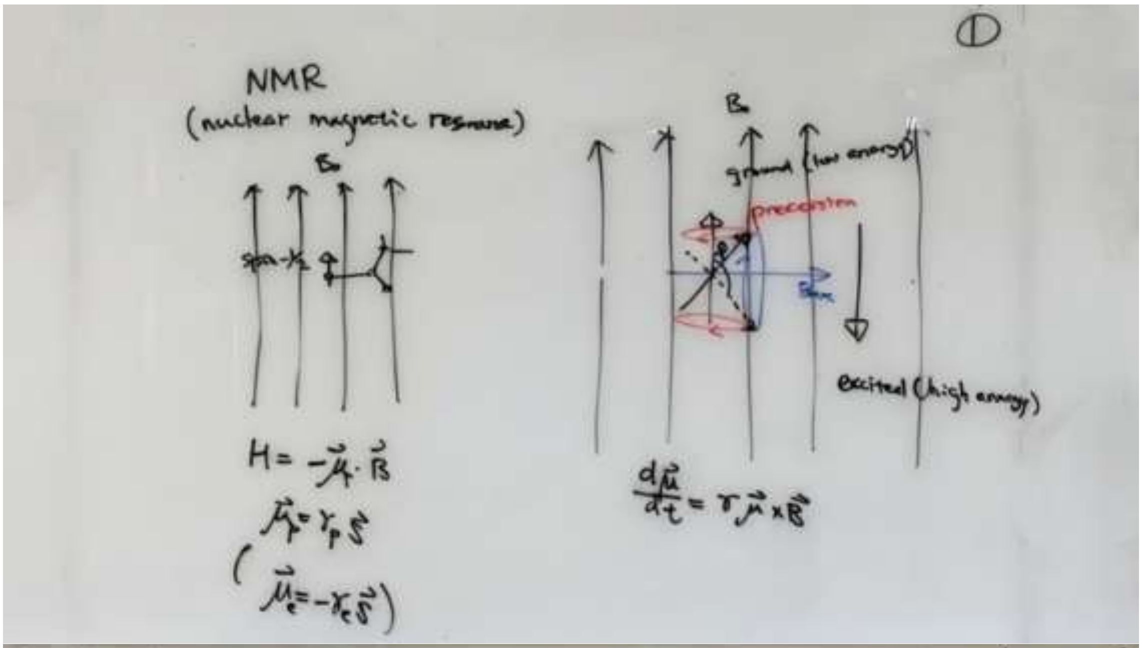
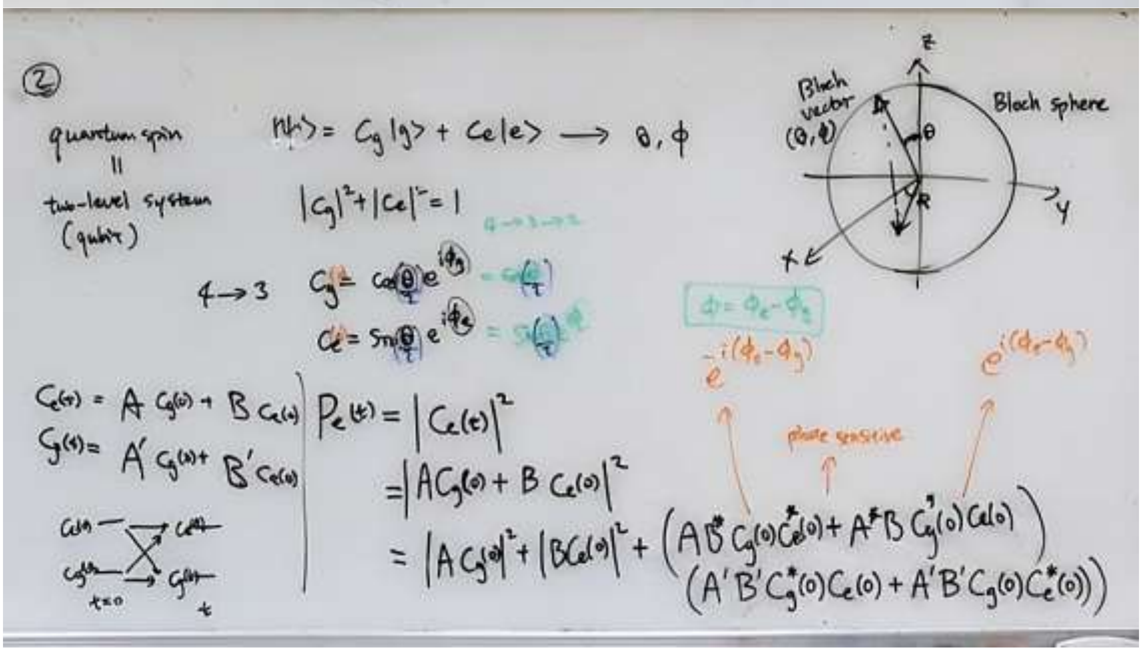
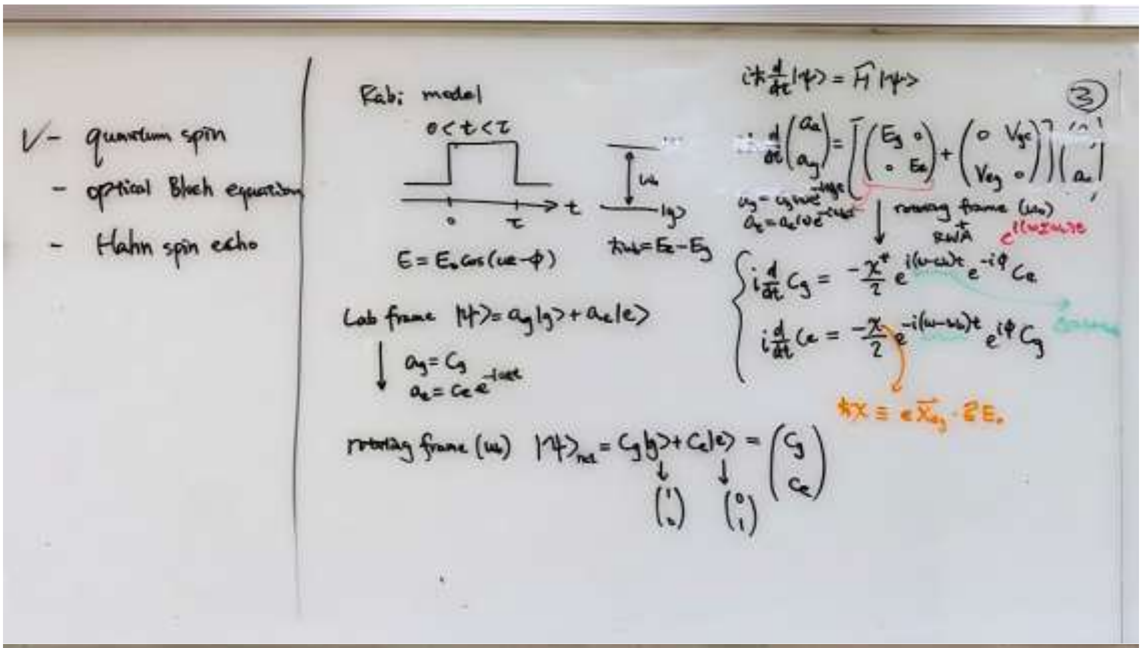
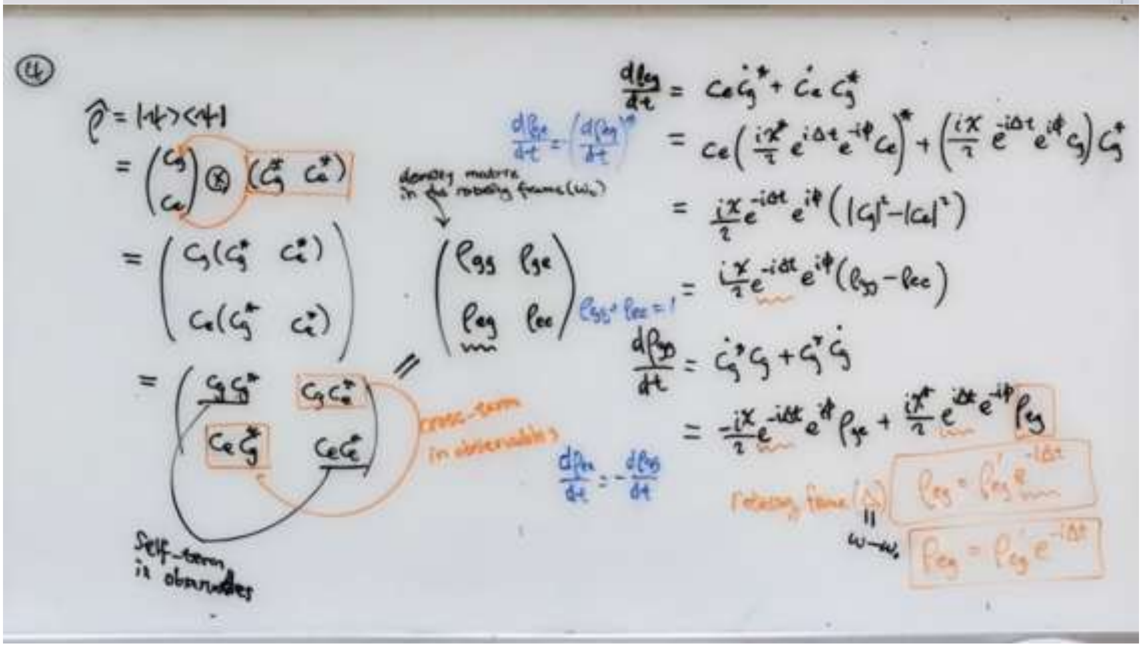
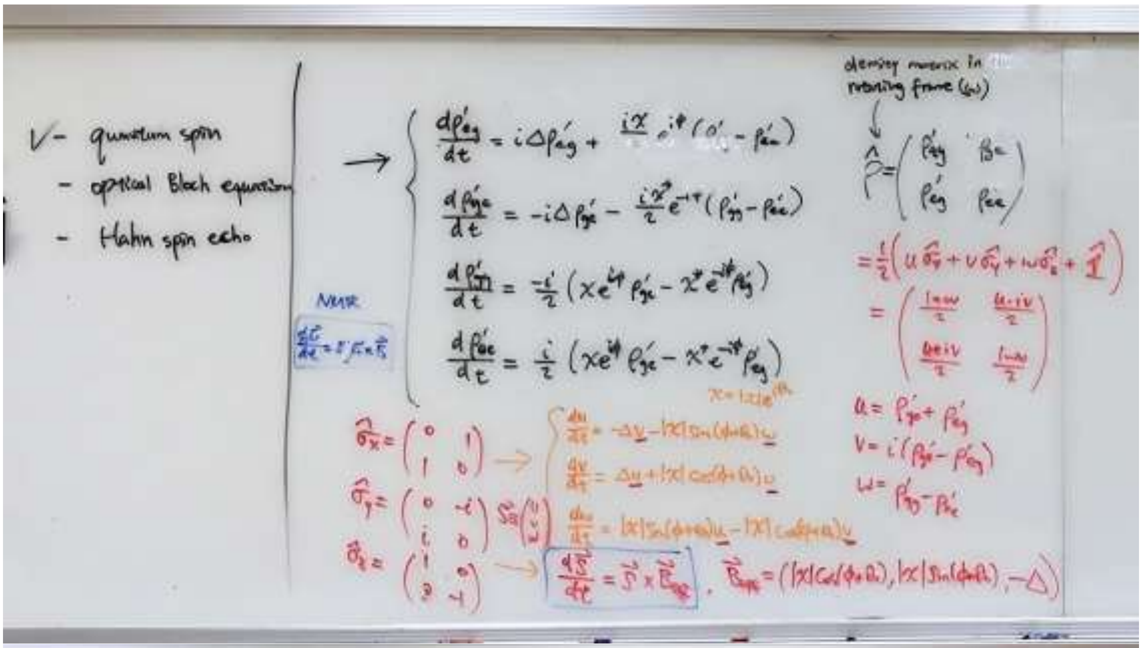
Lecture11 (spin) quantum spin and Hahn echo

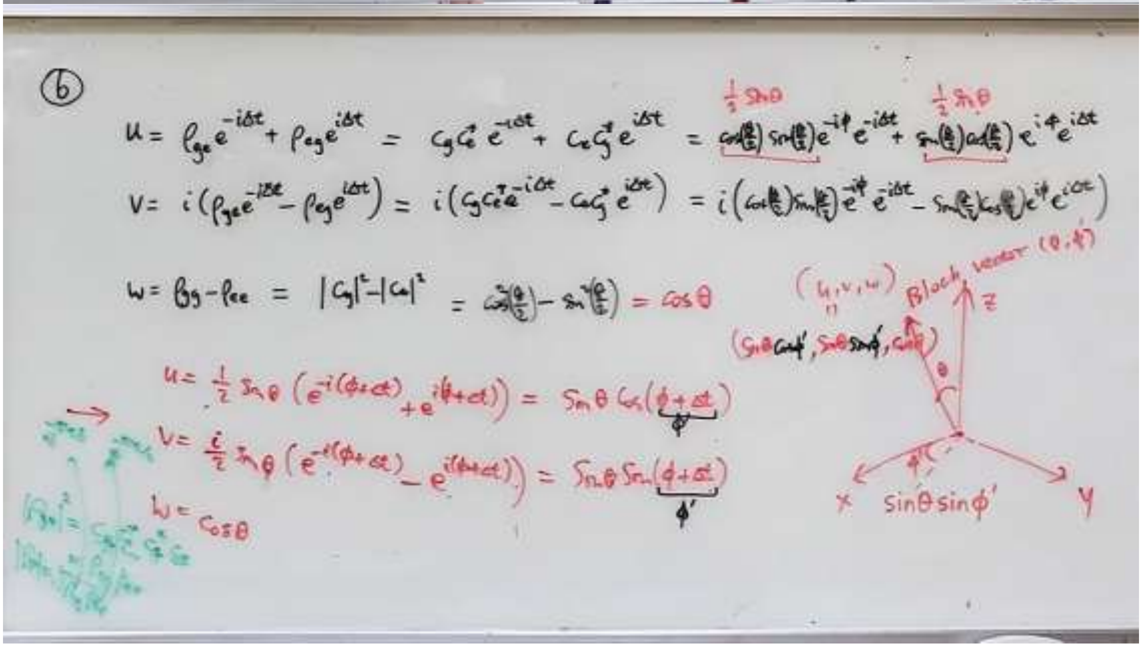


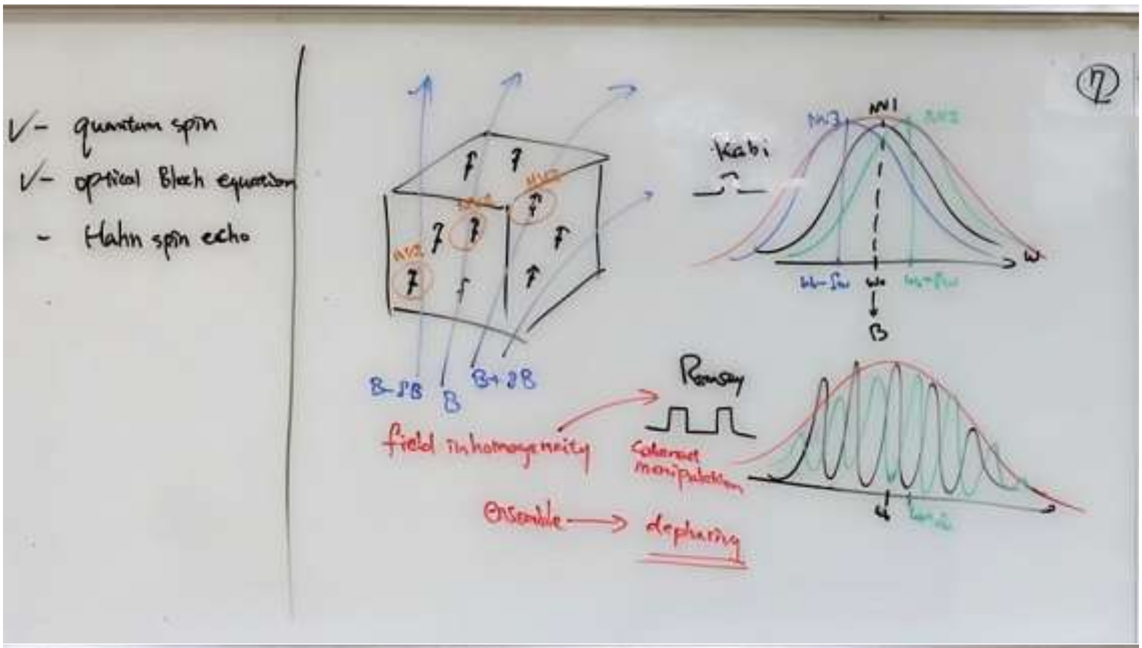



V - quantum spin
- optical Bloch equation
- Hahn spin echo
Rabi model
$0<t<\tau$
$E = E_0 \cos(\omega t - \phi)$
$\hbar\omega_0 = E_e - E_g$
$|g\rangle$
Lab frame $|\psi\rangle = a_g|g\rangle + a_e|e\rangle$
$a_g = C_g$
$a_e = C_e e^{-i\omega t}$
rotating frame (ω) $|\psi\rangle_{rot} = C_g|g\rangle + C_e|e\rangle = \begin{pmatrix} C_g \\ C_e \end{pmatrix}$
$\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$
$i\hbar\frac{d}{dt}|\psi\rangle = \hat{H}|\psi\rangle$
③
$\begin{pmatrix} E_g & 0 \\ 0 & E_e \end{pmatrix} + \begin{pmatrix} 0 & V_{ge} \\ V_{eg} & 0 \end{pmatrix}$
rotating frame (ω_0)
RWA
$i\frac{d}{dt}C_g = -\frac{\chi^*}{2} e^{i(\omega-\omega_0)t} e^{-i\phi} C_e$
$i\frac{d}{dt}C_e = -\frac{\chi}{2} e^{-i(\omega-\omega_0)t} e^{i\phi} C_g$
$\hbar\chi \equiv e\vec{X}_{eg}\cdot\hat{\varepsilon}E_0$


④
$\hat{\rho} = |\psi\rangle\langle\psi|$
$= \begin{pmatrix} C_g \\ C_e \end{pmatrix} \otimes (C_g^* \; C_e^*)$
$= \begin{pmatrix} C_g(C_g^* & C_e^*) \\ C_e(C_g^* & C_e^*) \end{pmatrix}$
$= \begin{pmatrix} C_gC_g^* & C_gC_e^* \\ C_eC_g^* & C_eC_e^* \end{pmatrix}$
cross-term in observables
Self-term in observables
density matrix in the rotating frame (ω_0)
$\begin{pmatrix} \rho_{gg} & \rho_{ge} \\ \rho_{eg} & \rho_{ee} \end{pmatrix}$
$\rho_{gg} + \rho_{ee} = 1$
$\frac{d\rho_{ge}}{dt} = \left(\frac{d\rho_{eg}}{dt}\right)^*$
$\frac{d\rho_{ee}}{dt} = -\frac{d\rho_{gg}}{dt}$
$\frac{d\rho_{eg}}{dt} = C_e\dot{C}_g^* + \dot{C}_e C_g^*$
$= C_e\left(\frac{i\chi^*}{2} e^{i\Delta t} e^{-i\phi} C_e\right)^* + \left(\frac{i\chi}{2} e^{-i\Delta t} e^{i\phi} C_g\right) C_g^*$
$= \frac{i\chi}{2} e^{-i\Delta t} e^{i\phi} (|C_g|^2 - |C_e|^2)$
$= \frac{i\chi}{2} e^{-i\Delta t} e^{i\phi} (\rho_{gg} - \rho_{ee})$
$\frac{d\rho_{gg}}{dt} = \dot{C}_g^* C_g + C_g^* \dot{C}_g$
$= \frac{-i\chi}{2} e^{-i\Delta t} e^{i\phi} \rho_{ge} + \frac{i\chi^*}{2} e^{i\Delta t} e^{-i\phi} \rho_{eg}$
rotating frame (Δ)
$\omega - \omega_0$
$\rho_{eg} = \rho_{eg}' e^{-i\Delta t}$


V - quantum spin
- optical Bloch equation
- Hahn spin echo
density matrix in rotating frame (ω)
NMR
Bloch vector


⑥
w = cos θ
Bloch vector (θ, φ')
z
x
y
sinθ sinφ'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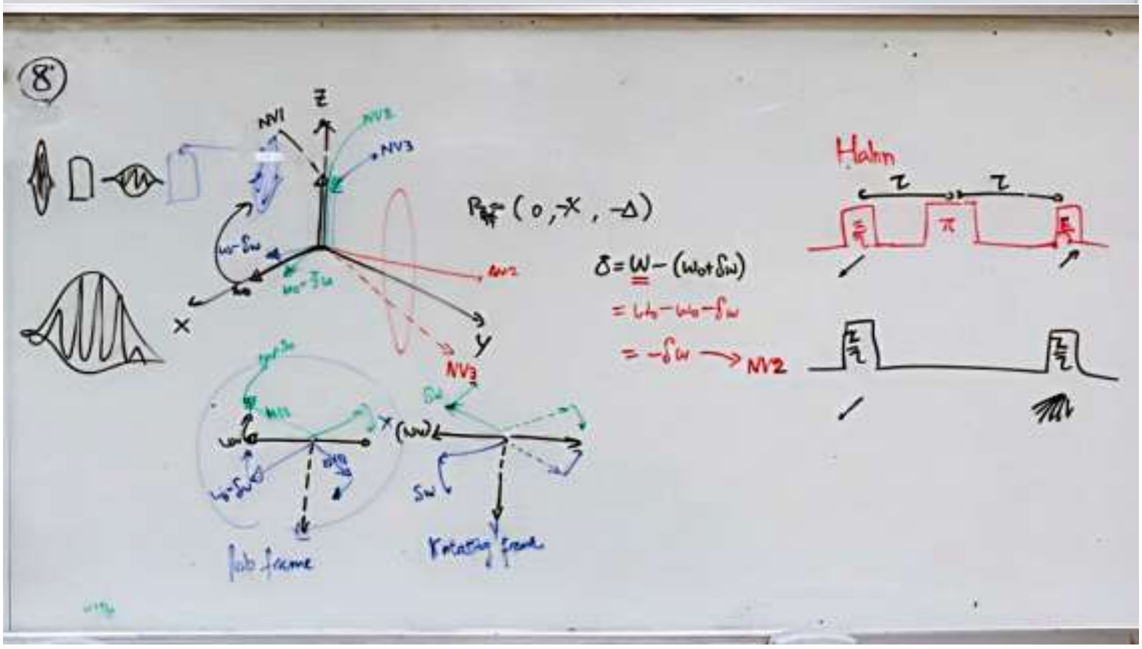
quantum spin
optical Bloch equation
Hahn spin echo
Rabi
NV1
NV3
NV2
ω
B
B-δB
B
B+δB
Ramsey
field inhomogeneity
coherent manipulation
Ensemble → dephasing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Z
NV1
NV2
NV3
X
Y
δ = W − (ω0+δω)
= ω0 − ω0 − δω
= −δω → NV2
Hahn
τ
π
lab frame
rotating frame

✓ - quantum spin

✓ - optical Bloch equation

✓ - Hahn spin echo