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Dinamica cuantica a sistemelor opto-mecanice

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Sumar

- Laboratorul meu
- Punct cuantic in rezonator mechanic
- Punct cuantic in cavitate optica
- Multe puncte cuantice in rezonator mechanic

• Laboratorul de Fotonica Cuantica

Studiul teoretic:

- **Opto-mecanica cuantica**: sisteme de nano-rezonatoare mecanice care interactioneaza cu lumina
  (miscarea materiei la nivel cuantic, determinarea masei moleculelor, racire cuantica)

- **Sisteme de atomi artificiali** care interactioneaza la nivel cuantic cu fotonii (lumina) si fononii (sunet)
  (interfata cuantica intre electronica si tehnologii cuantice)

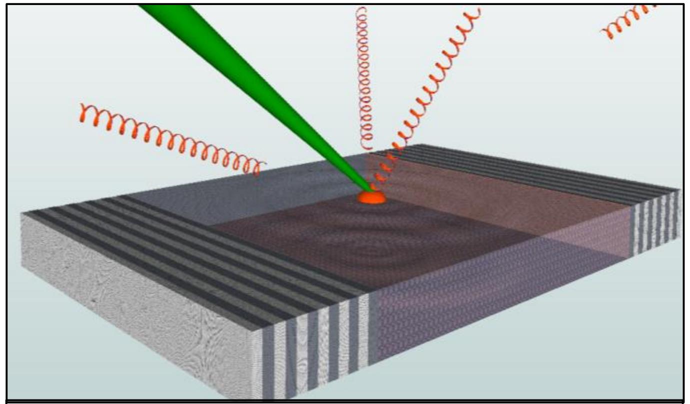
- **Disipare cuantica** (pierderea informatiei cuantice, calculatorul cuantic),
  corelatiile fotonilor si/sau fononilor in sisteme cuantice
  inserparabilitate cuantica (teleportarea semnalului, encriptarea cuantica a informatiei)

- **Cooperare** cu Institutul Max-Planck de fizica nucleara din Heidelberg (MPIK)

http://www.phys.asm.md/ro/divisions/lfc/publications

Punct cuantic
in rezonator mecanic

• Punct cuantic in rezonator mecanic



The model

Cu ce lucram:

- ✓ Un punct cuantic (PC) in rezonator mechanic
- ✓ Laser
- ✓ Temperatura (fononi termali)
- ✓ Intuneric (vacuum electromagnetic)

Ce se intampla

- ➢ ***Laser albastru defazat =>*** *Excitarea PC + crearea fononilor* *si* *Dezexcitarea PC + absorbirea fononilor*
- ➢ ***Laser rosu defazat =>*** *Dezexcitarea PC + absorbirea fononilor* *si* *Excitarea PC + crearea fononilor*
- ➢ ***Emisia spontana =>*** *doar dezexcitare*

Emisie spontana + **Laser albastru defazat** = **GENERARE** fononi

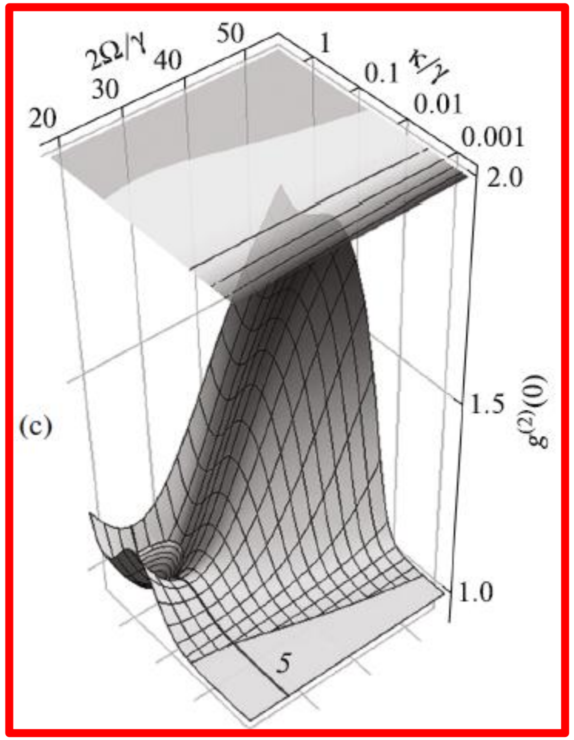
Emisie spontana + **Laser rosu defazat** = **RACIRE** cuantica

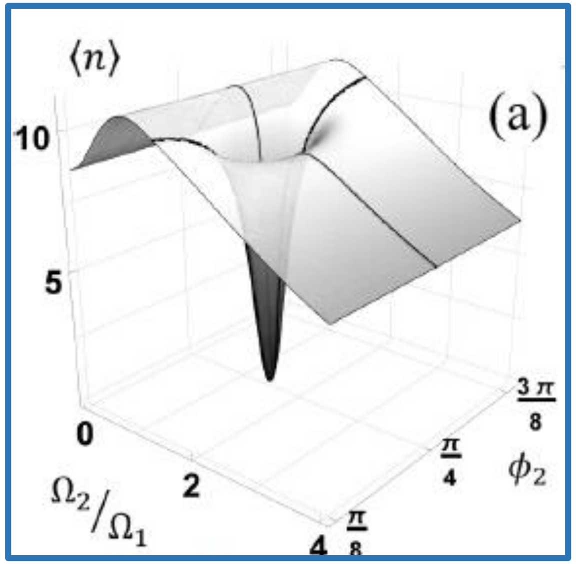
• Modelul Teoretic

$$H = \hbar\omega_{qd}S_z + \hbar\omega_{ph}b^\dagger b + \hbar\Omega\left(S^+e^{-i\omega_L t} + S^-e^{i\omega_L t}\right) + \hbar g S^+S^-\left(b^\dagger + b\right),$$

$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + \kappa\bar{n}\mathcal{L}\left(b^\dagger\right) + \kappa(1+\bar{n})\mathcal{L}\left(b^\dagger\right) + \gamma\mathcal{L}(S^-) + \gamma_c\mathcal{L}(S_z)$$

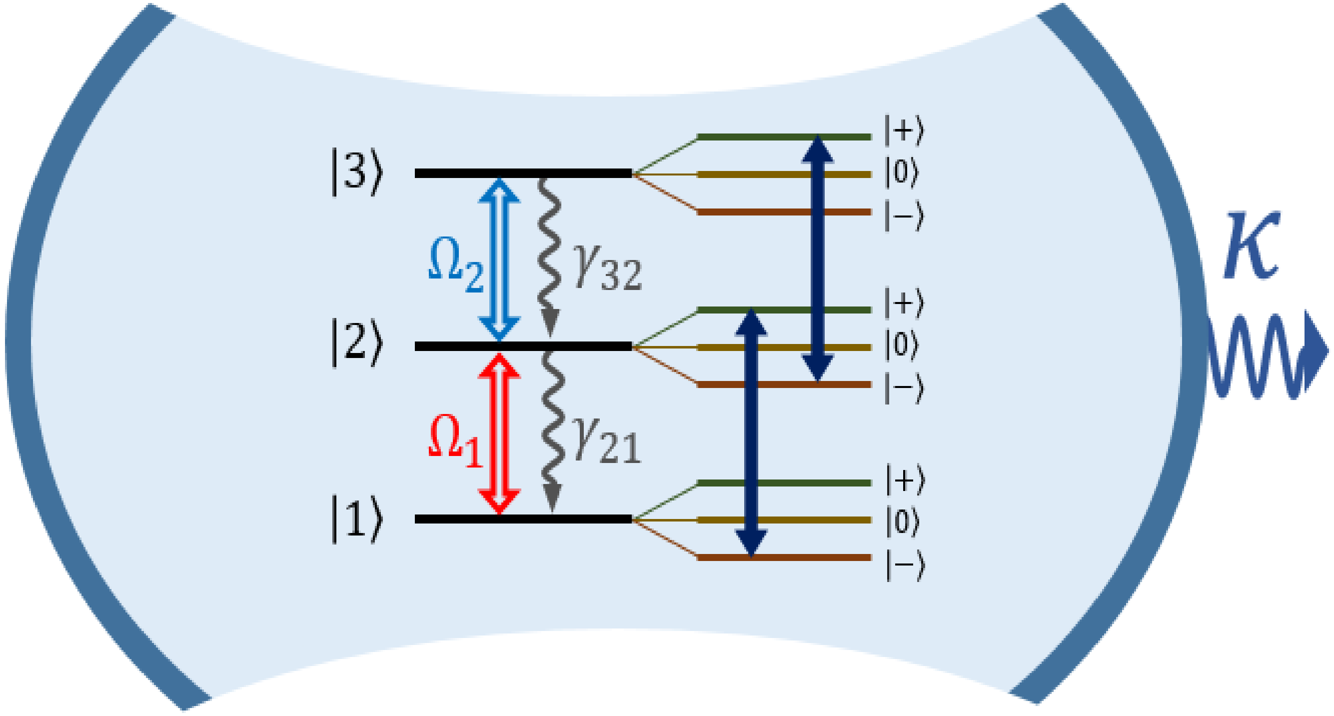
$$\begin{aligned}
\dot{P}_n^{(0)} &= -2|g|(P_n^{(4)} - P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(0)} - \kappa n P_n^{(0)},\\
\dot{P}_n^{(1)} &= -2|g|(P_n^{(4)} - P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(1)} - (\kappa n + \alpha/2)P_n^{(1)} + \gamma_2\cos^2\theta P_n^{(0)},\\
\dot{P}_n^{(2)} &= -2|g|(P_n^{(4)} + P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(2)} - (\kappa n + \beta/2)P_n^{(2)},\\
\dot{P}_n^{(3)} &= |g|n(P_{n-1}^{(1)} - P_n^{(1)} + P_{n-1}^{(2)} + P_n^{(2)})/2 - \kappa P_n^{(4)} + \kappa(n+1)P_{n+1}^{(3)}\\
&\quad - (\kappa(n-1/2) + \zeta)P_n^{(3)},\\
\dot{P}_n^{(4)} &= |g|(n+1)(P_{n+1}^{(2)} + P_n^{(2)} - P_{n+1}^{(1)} + P_n^{(1)})/2 + \kappa(n+1)P_{n+1}^{(4)}\\
&\quad - (\kappa(n+1/2) + \zeta)P_n^{(4)},
\end{aligned}$$





Punct cuantic
in rezonator optic

• Punct cuantic in rezonator optic



Cu ce lucram:

- Atom cu 3 nivele
- 2 lasere
- Intuneric (vacuum electromagnetic)
- Cavitate buna
- Dipoli de tranzitie perpendiculari

Ce se intampla:

- Laserele pregatesc atomul intr-o superpozitie de stari
- Cavitatea optica interactioneaza cu toate tranzitiile
- Interferente cuantice se produc deoarece se interactioneaza cu mai multe tranzitii

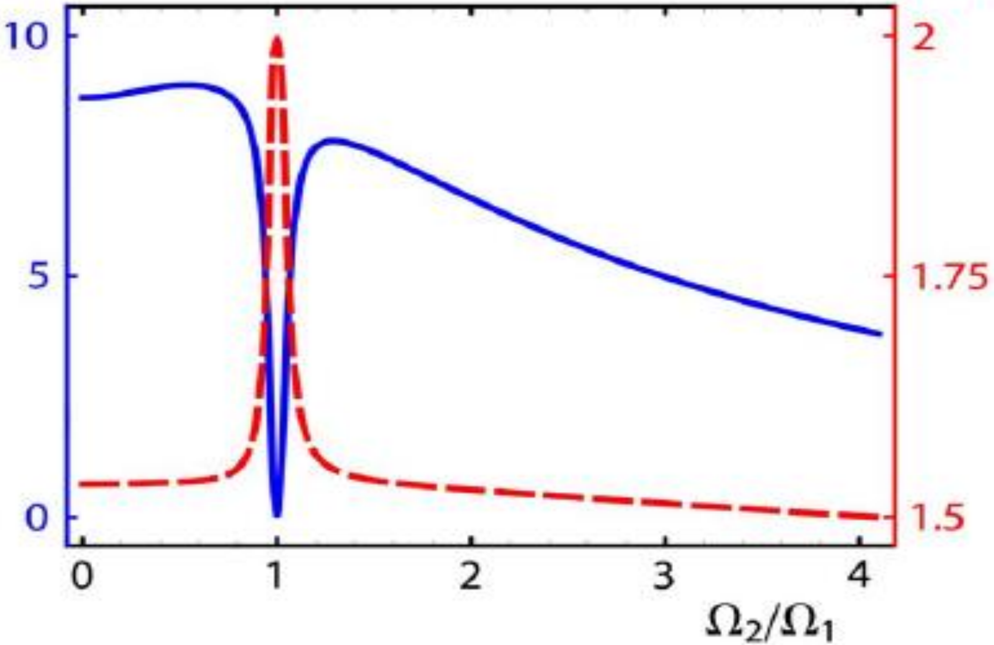
→ Campul electromagnetic din cavitate **DISPARE**

• Modelul Teoretic

$$H = \hbar\omega_c a^\dagger a + \hbar\sum_{i=1}^{3}\omega_i S_{ii} + i\hbar g_1(a^\dagger S_{12} - S_{21}a) + i\hbar g_2(a^\dagger S_{23} - S_{32}a)$$
$$+\hbar\Omega_1(S_{21}e^{-i(\omega_{L1}t+\phi_1)} + S_{12}e^{i(\omega_{L1}t+\phi_1)})$$
$$+\hbar\Omega_2(S_{32}e^{-i(\omega_{L2}t+\phi_2)} + S_{23}e^{i(\omega_{L2}t+\phi_2)}).$$

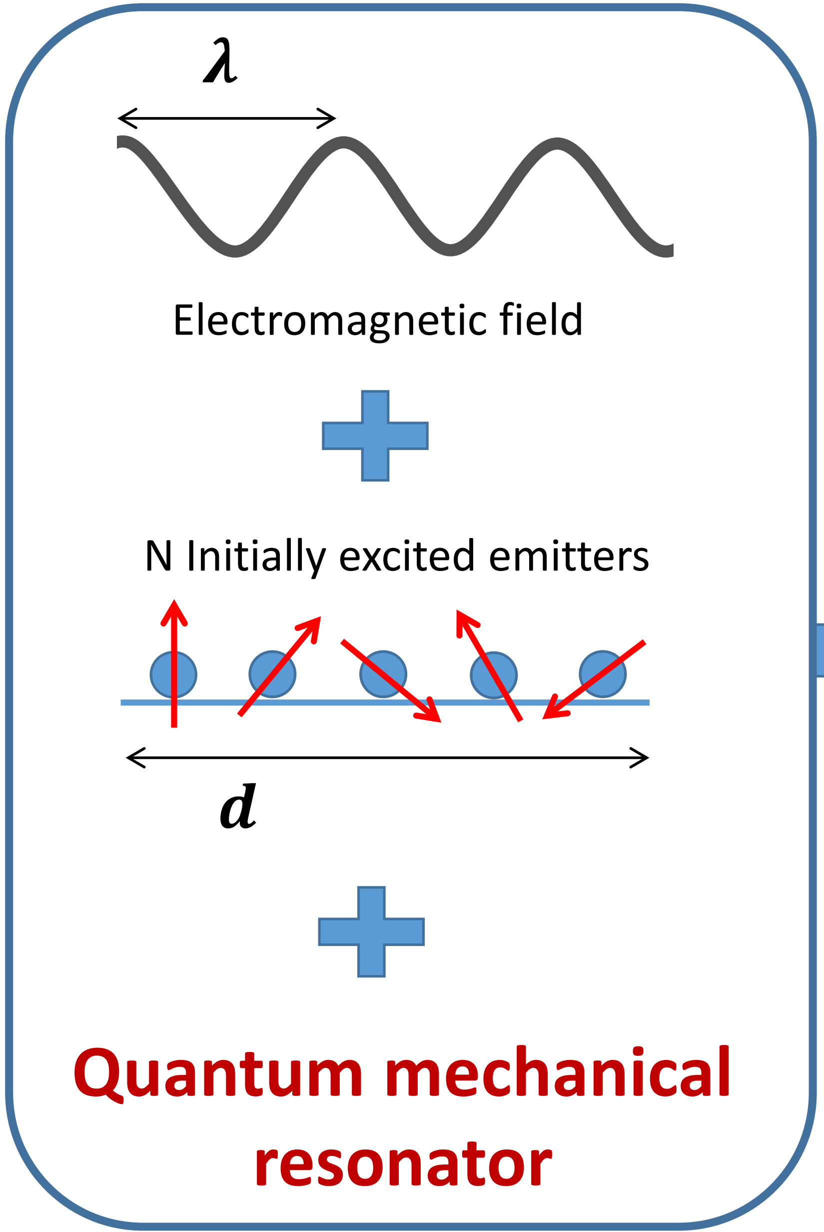
$$\frac{\partial\rho}{\partial t} = -\frac{i}{\hbar}[H,\rho] + \frac{\kappa}{2}\mathcal{L}(a) + \frac{\gamma_{32}}{2}\mathcal{L}(S_{23}) + \frac{\gamma_{21}}{2}\mathcal{L}(S_{12}).$$

$$\dot{P}_n^{(0)} = -2g(P_n^{(4)} - P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(0)} - \kappa n P_n^{(0)},$$
$$\dot{P}_n^{(1)} = -2g(P_n^{(4)} - P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(1)}$$
$$- (\kappa n + \alpha/2)P_n^{(1)} + \gamma_{32}\cos^2\theta P_n^{(0)},$$
$$\dot{P}_n^{(2)} = -2g(P_n^{(4)} + P_n^{(3)}) + \kappa(n+1)P_{n+1}^{(2)} - (\kappa n + \beta/2)P_n^{(2)}$$
$$\dot{P}_n^{(3)} = gn(P_{n-1}^{(1)} - P_n^{(1)} + P_{n-1}^{(2)} + P_n^{(2)})/2 - \kappa P_n^{(4)}$$
$$+ \kappa(n+1)P_{n+1}^{(3)} - (\kappa(n-1/2) + \zeta)P_n^{(3)},$$
$$\dot{P}_n^{(4)} = g(n+1)(P_{n+1}^{(2)} + P_n^{(2)} - P_{n+1}^{(1)} + P_n^{(1)})/2$$
$$+ \kappa(n+1)P_{n+1}^{(4)} - (\kappa(n+1/2) + \zeta)P_n^{(4)}, \quad ($$



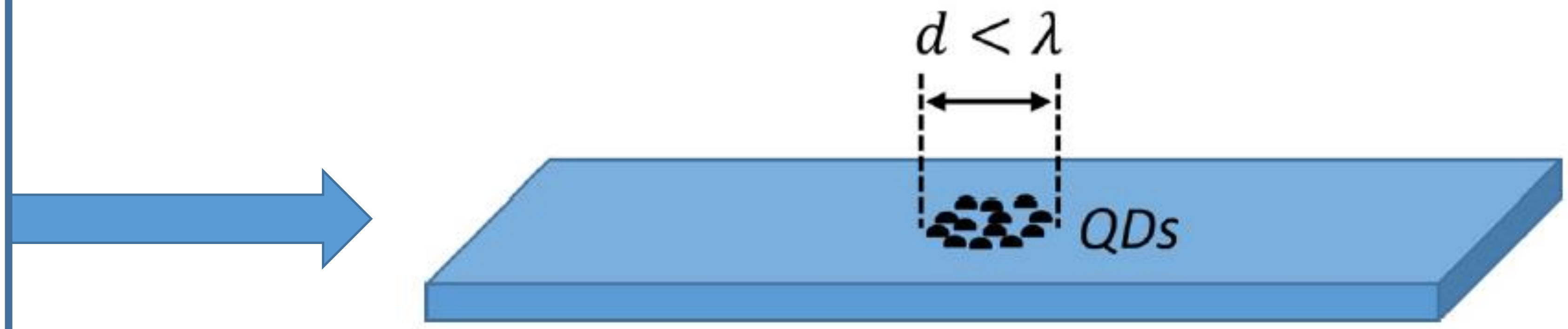
Multe puncte cuantice in rezonator mecanic

• Multe puncte cuantice in un rezonator mecanic



Cu ce lucram:

- Multe puncta cuantice aprope unul de altul
- Plasate pe un rezonator mecanic
- Excitam initial cu laser de scurta durata



Ce se intampla:

- ❑ Deoarece sunt aproape, PC se dezexcit mai rapid si mai intens
- ❑ Interactioneaza mai rapid si mai intens cu rezonatorul mechanic
- ❑ Se produce un impuls sonor (de fononi) puternic de scurta durata

• Modelul Teoretic

$$H = \hbar\omega b^\dagger b + \hbar\omega_{\rm qd} S_z + \hbar\eta S_{22}(b + b^\dagger).$$

$$\frac{\partial\rho}{\partial t} = -\frac{i}{\hbar}[H,\rho] + \kappa\bar{n}\mathcal{L}(b^\dagger) + \kappa(1+\bar{n})\mathcal{L}(b) + \gamma\mathcal{L}(S^-).$$

$$\frac{\partial\langle b^\dagger b\rangle}{\partial t} = i\eta\{\langle S_z b\rangle - \langle S_z b^\dagger\rangle + j\langle b\rangle - j\langle b^\dagger\rangle\} - 2\kappa\langle b^\dagger b\rangle + 2\kappa\bar{n},$$

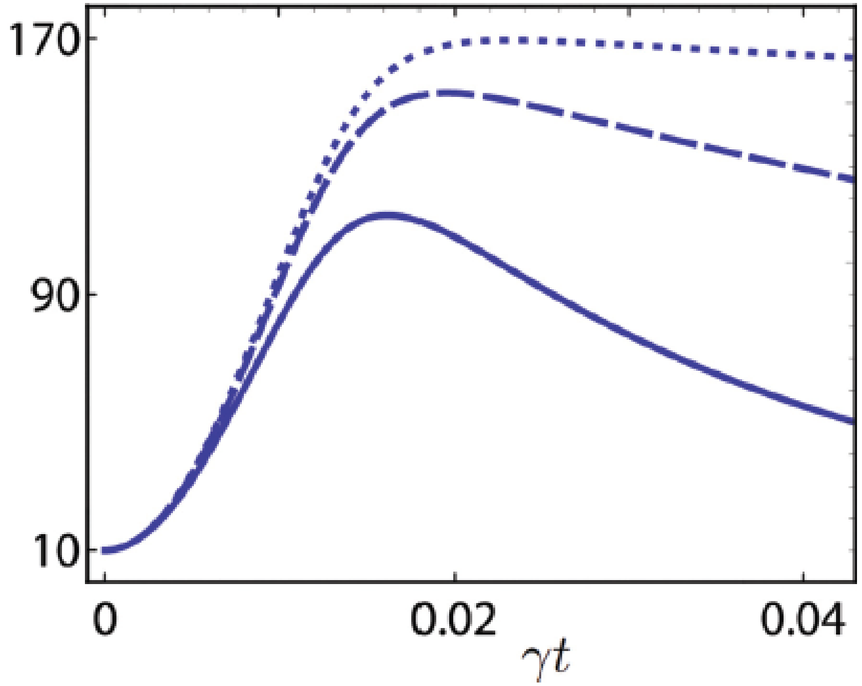
$$\frac{\partial\langle S_z b\rangle}{\partial t} = -(\kappa + 2\gamma + i\omega)\langle S_z b\rangle + 2\gamma\langle S_z^2 b\rangle - i\eta\{\langle S_z^2\rangle + j\langle S_z\rangle\} - 2\gamma j(j+1)\langle b\rangle,$$

$$\frac{\partial\langle S_z b^\dagger\rangle}{\partial t} = -(\kappa + 2\gamma - i\omega)\langle S_z b^\dagger\rangle + 2\gamma\langle S_z^2 b^\dagger\rangle + i\eta\{\langle S_z^2\rangle + j\langle S_z\rangle\} - 2\gamma j(j+1)\langle b^\dagger\rangle,$$

$$\frac{\partial\langle b\rangle}{\partial t} = -(\kappa + i\omega)\langle b\rangle - i\eta\{\langle S_z\rangle + j\},$$

$$\frac{\partial\langle b^\dagger\rangle}{\partial t} = -(\kappa - i\omega)\langle b^\dagger\rangle + i\eta\{\langle S_z\rangle + j\},$$

$$\frac{\partial\langle S_z\rangle}{\partial t} = -2\gamma\{\langle S_z\rangle - \langle S_z^2\rangle + j(j+1)\}.$$



• Concluzii

- Studii de relevanta mondiala => diploma recunoscuta international
- Studiu teoretic nu necesita utilaj costisitor => pe larg accesibil
- Cea mai grea teorie a opticii => putin accesibila experimentatorilor

Multumesc!