Stochastic Dynamics of a Feshbach-coupled Atomic- Molecular Bose-Einstein Condensate

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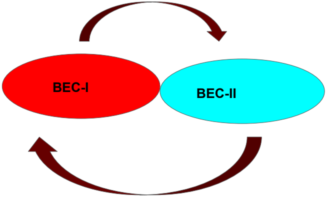
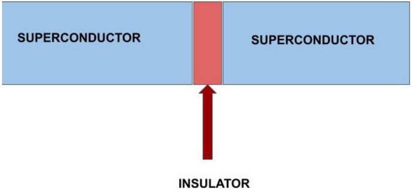
Bosonic Josephson Junctions:



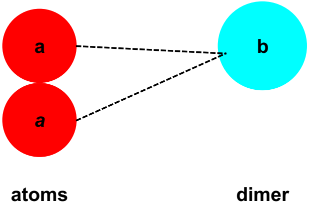


Two weakly coupled macroscopic quantum states show a mechanism similar to superconducting Josephson Junctions. The potential barrier between the states play the role of the insulating layer.

Interaction in Bose Condensate → Nonlinear → can lead to particle localization.

Atomic BEC to Molecular BEC : Hamiltonian

$$H = U_a \hat{a}^\dagger \hat{a}^\dagger \hat{a}\hat{a} + U_b \hat{b}^\dagger \hat{b}^\dagger \hat{b}\hat{b} + U_{ab} \hat{a}^\dagger \hat{b}^\dagger \hat{b}\hat{b} + g(\hat{a}^\dagger \hat{a}^\dagger \hat{b} + \hat{b}^\dagger \hat{a}\hat{a}) + \delta_1 \hat{b}^\dagger \hat{b}$$



- g : Feshbach coupling
- δ_1 : Feshbach detuning (the threshold energy for the formation of molecules)

δ_1 is adjustable !

In Presence of Noise:

$$H = U_a \hat{a}^\dagger \hat{a}^\dagger \hat{a}\hat{a} + U_b \hat{b}^\dagger \hat{b}^\dagger \hat{b}\hat{b} + U_{ab} \hat{a}^\dagger \hat{b}^\dagger \hat{b}\hat{b}$$
$$+(g + \xi_a(t))(\hat{a}^\dagger \hat{a}^\dagger \hat{b} + \hat{b}^\dagger \hat{a}\hat{a}) + \big(\delta_1 + \xi_b(t)\big)\hat{b}^\dagger \hat{b}$$

$\xi_a(t)$ and $\xi_b(t)$: White Gaussian noise

noise	corrupts	form	corresponding Wiener process
ξ_a	Feshbach coupling	$\frac{dw_a(t)}{dt}$	$w_a(t)$: strength γ_a
ξ_b	Feshbach detuning	$\frac{dw_b(t)}{dt}$	$w_b(t)$: strength γ_b

Relaxation of Bloch Vectors

Define:

$$L_x = \sqrt{2}(a^\dagger a^\dagger b + b^\dagger aa)$$

$$L_y = \sqrt{2}i(a^\dagger a^\dagger b - b^\dagger aa)$$

$$L_z = (2b^\dagger b - a^\dagger a)$$

($L_z = z$: imbalance in particle number between atomic and molecular states)

What if the system relaxes back to its fixed points (equilibrium configuration)?

Time-dependent Relaxation:

$$T_x = \frac{1}{\gamma_b}$$

$$T_y = \frac{1}{2\gamma_a(1 - 3L_z) + \frac{\gamma_b}{2}}$$

$$T_z = \frac{1}{4\gamma_a}$$

Particle Localization Crossover

In absence of noise

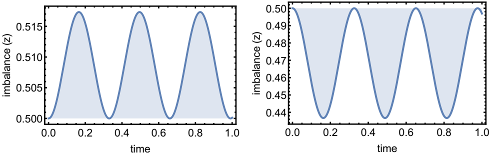


Figure: $\delta_1 = 11$ and $\delta_1 = 12$: from more-atoms to more-molecules state

In presence of noise

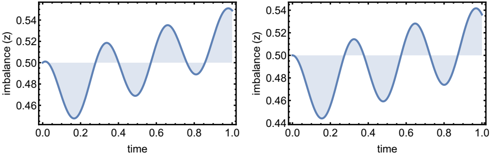


Figure: In presence of coupling noise and detuning noise respectively : a molecule-heavy state goes to an atom-heavy state in a later time

References :

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2. E. M. Graefe, M. Graney, A. Rush, Semiclassical quantization for a bosonic atom-molecule conversion system, Physical Review A, **92**(1), 012121. (2015)
3. Avinaba Mukherjee and Raka Dasgupta, Stochastic Josephson Oscillation Dynamics of a Feshbach-Coupled Atomic-Molecular Bose-Einstein Condensate, manuscript under preparation.

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THANK
YOU!