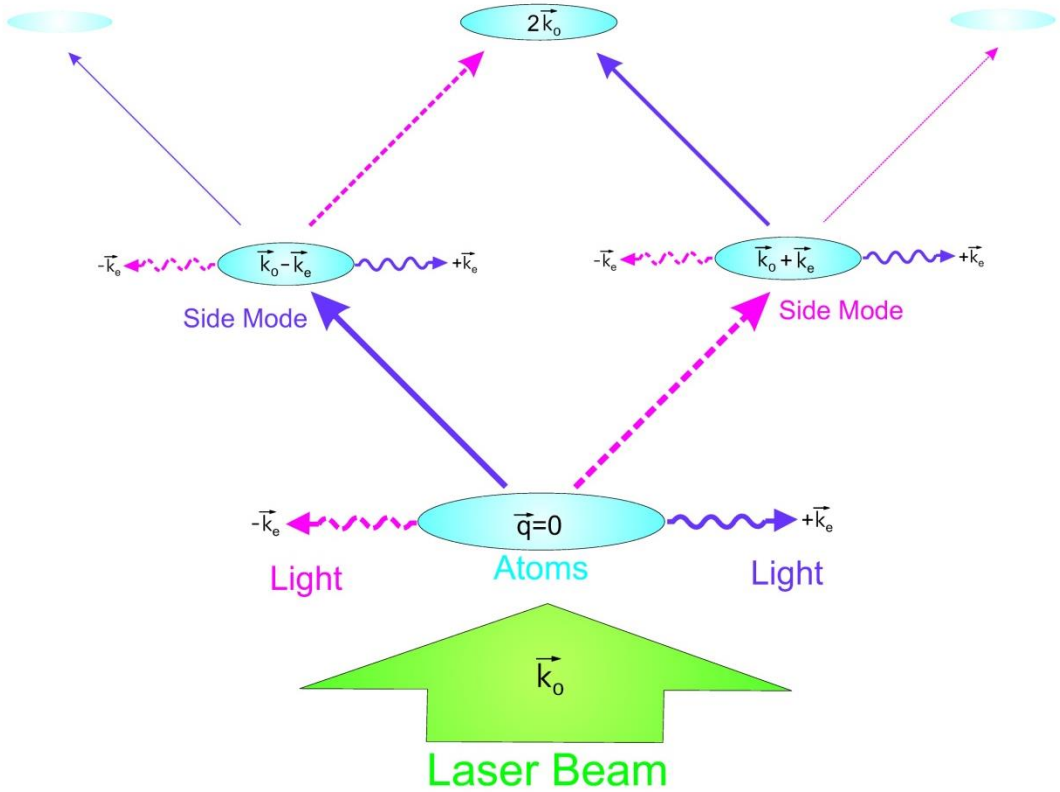
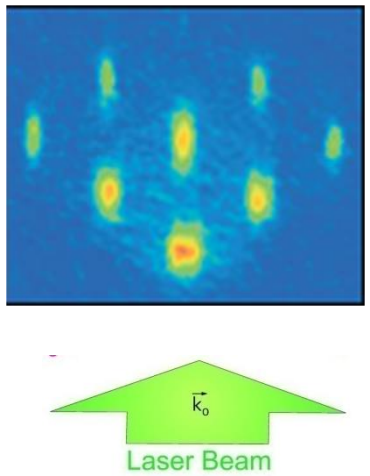
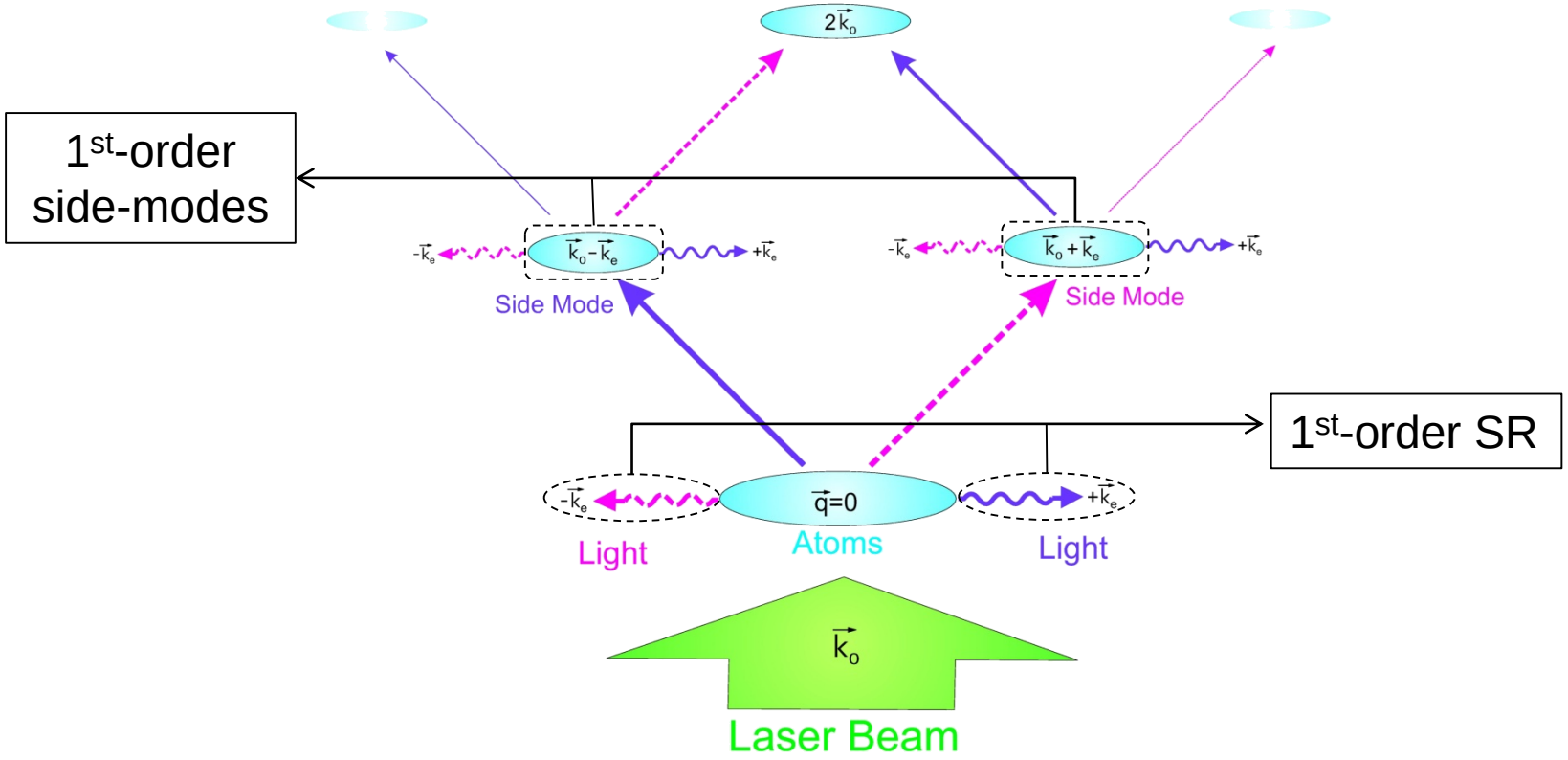
BEC Superradiance (sequential SR)





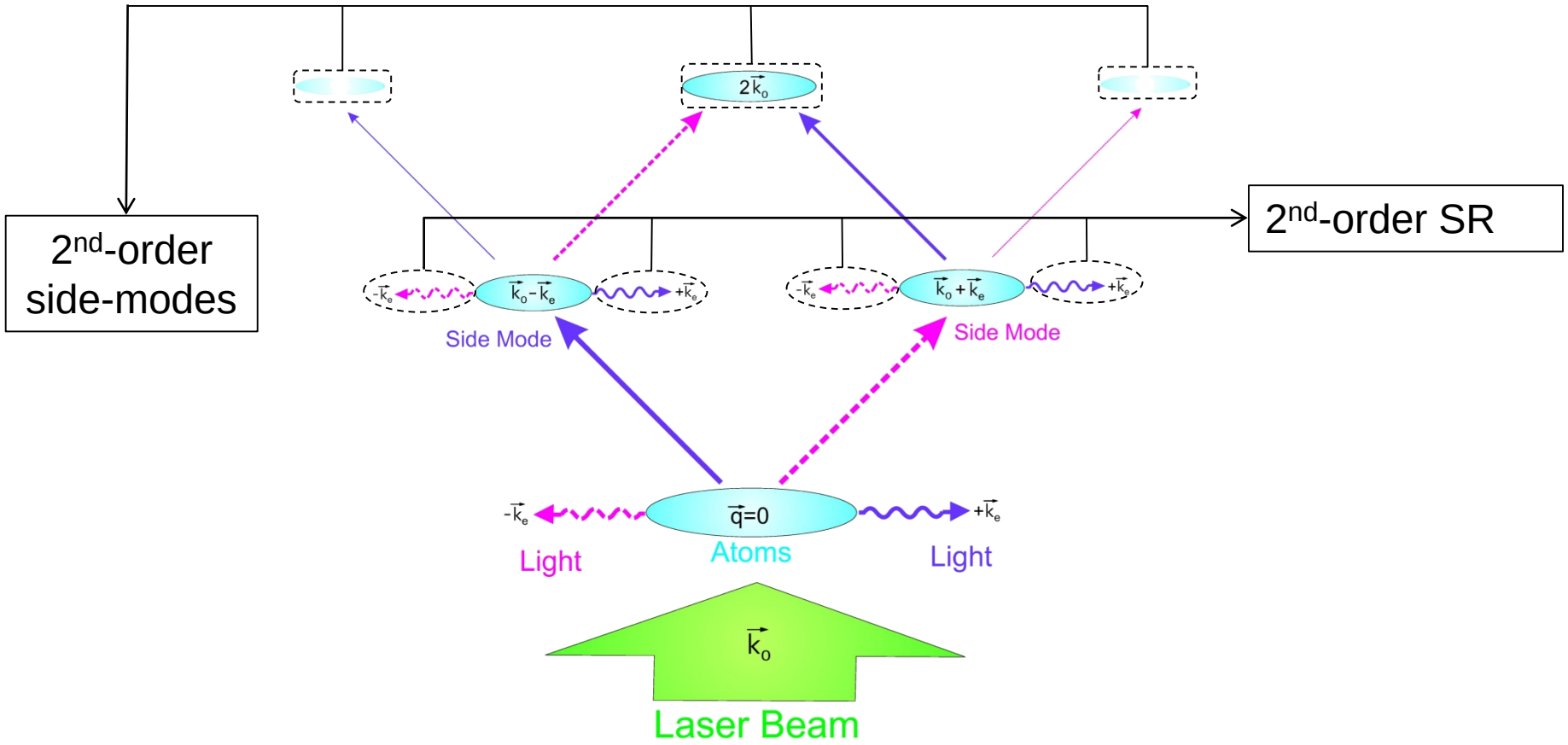
- End-fire mode ($+\vec{k}_e$) ⟺ Atomic side-mode ($\vec{k}_0-\vec{k}_e$)
- End-fire mode ($-\vec{k}_e$) ⟺ Atomic side-mode ($\vec{k}_0+\vec{k}_e$)

BEC Superradiance (sequential SR)



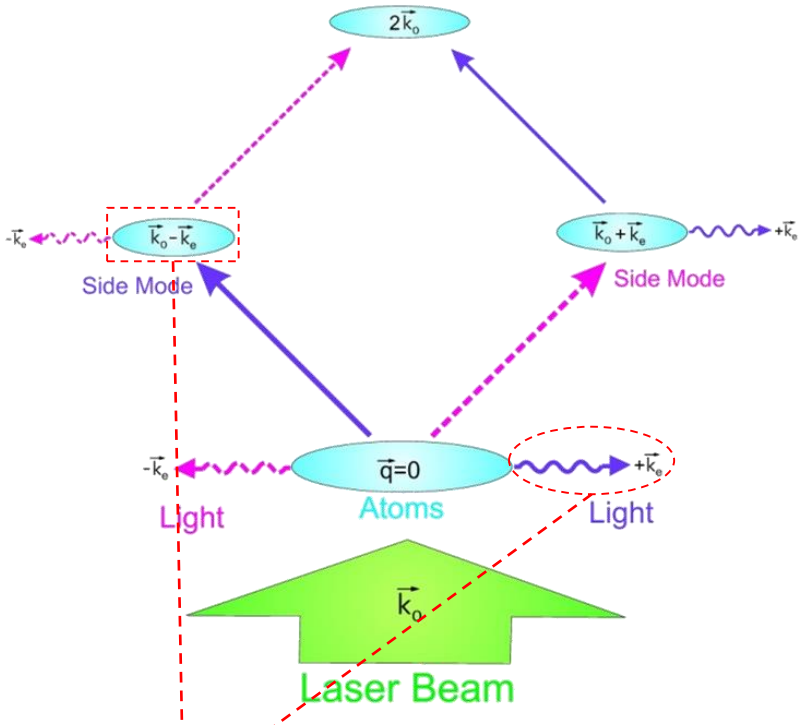
- End-fire mode ($\rightsquigarrow +\vec{k}_e$) $\Leftrightarrow$ Atomic side-mode ($\vec{k}_0 - \vec{k}_e$)
- End-fire mode ($-\vec{k}_e \rightsquigarrow$) $\Leftrightarrow$ Atomic side-mode ($\vec{k}_0 + \vec{k}_e$)

BEC Superradiance (sequential SR)

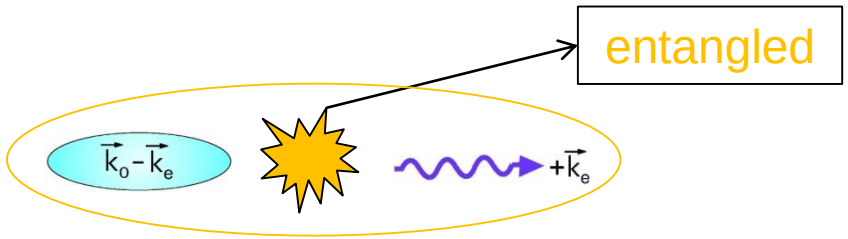


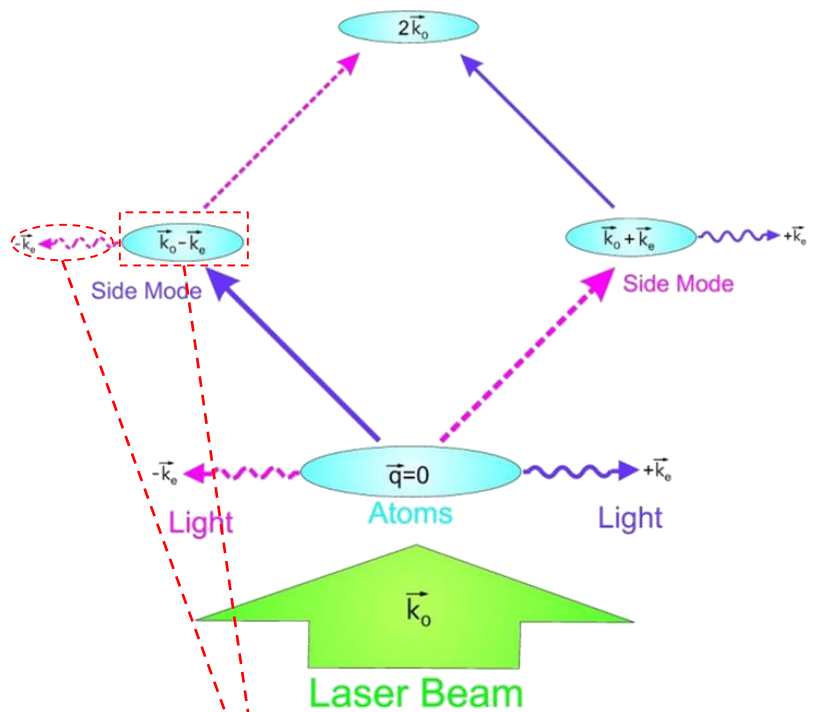
1st-order side-modes highly occupied → 1st-order side-modes superradiates → forms 2nd-order side-modes

Entanglement of pulses (via entanglement-swap)

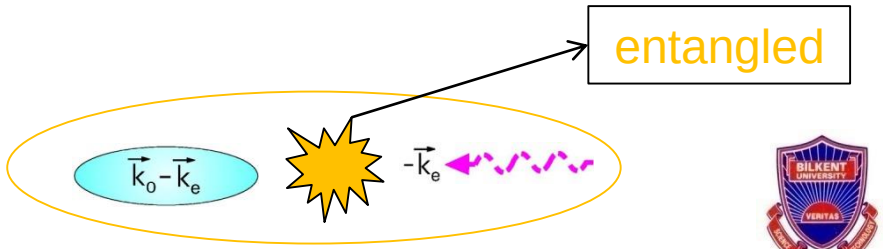


Interacts in the 1st SR sequence

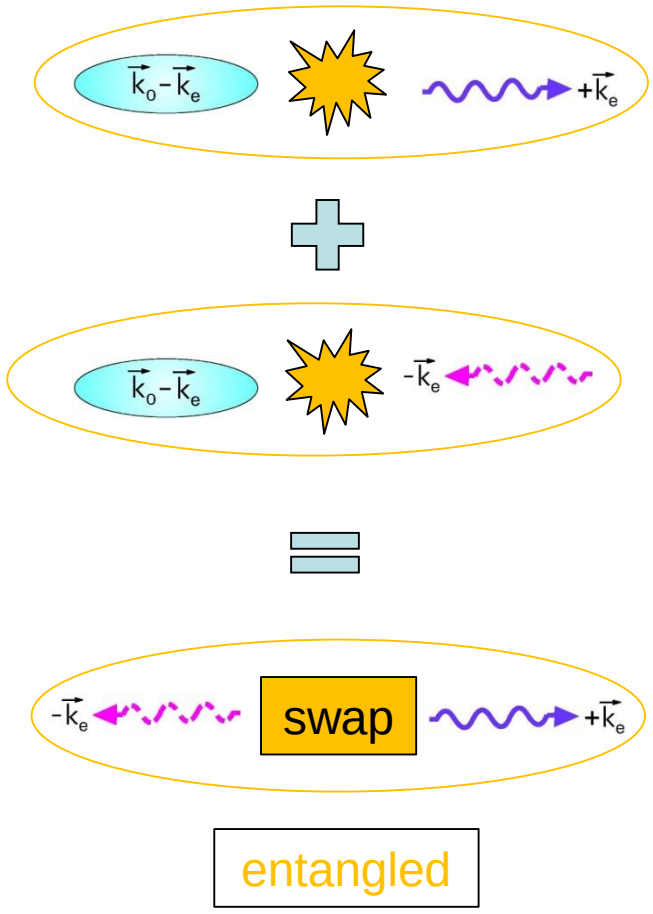


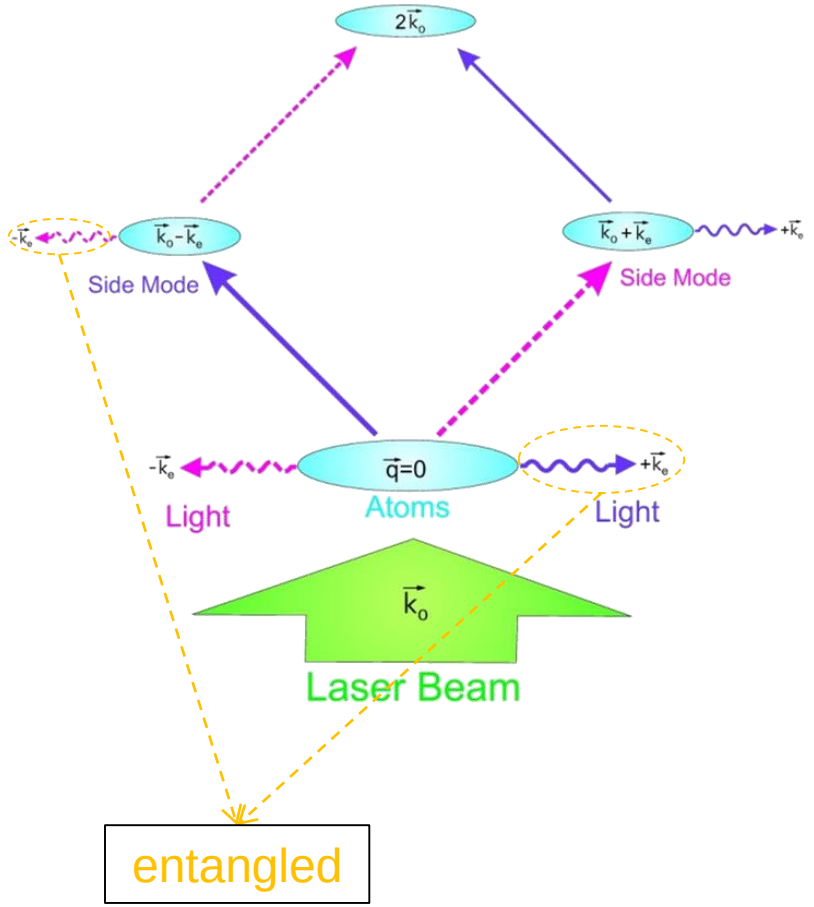


Interacts in the 2nd SR sequence



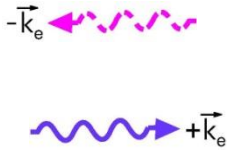
Entanglement of pulses (via entanglement-swap)

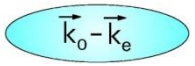




Entanglement-Swap

Entanglement swap: Entangle systems that never before interacted.

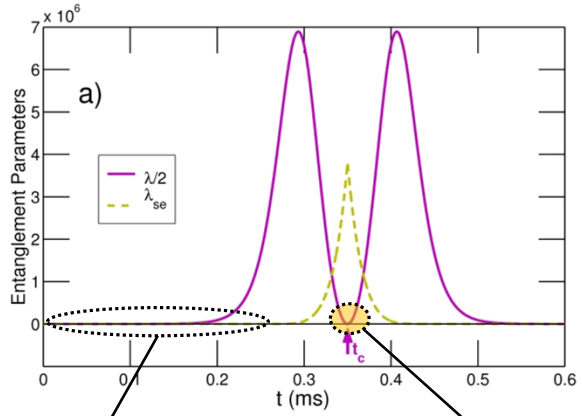
Both 

interact with 

at different times.

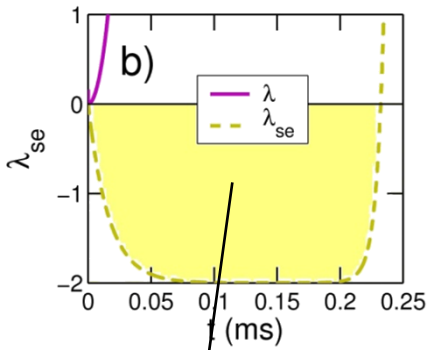
Entanglement of pulses (via entanglement-swap)

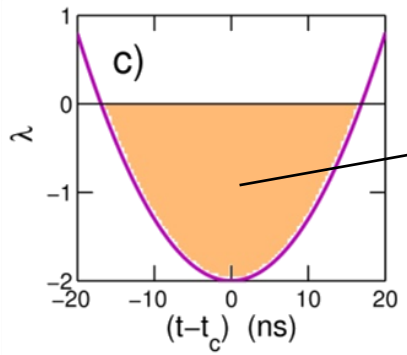
Evolution of Quantum Correlation



λ_{se} (side-mode)-(end-fire) entang.

λ (end-fire)-(end-fire) entang.





Later on

$\lambda(t) < 0$ for $\Delta t = 30\text{ns}$

$-\vec{k}_e$ $+\vec{k}_e$ (entangled)

Initially

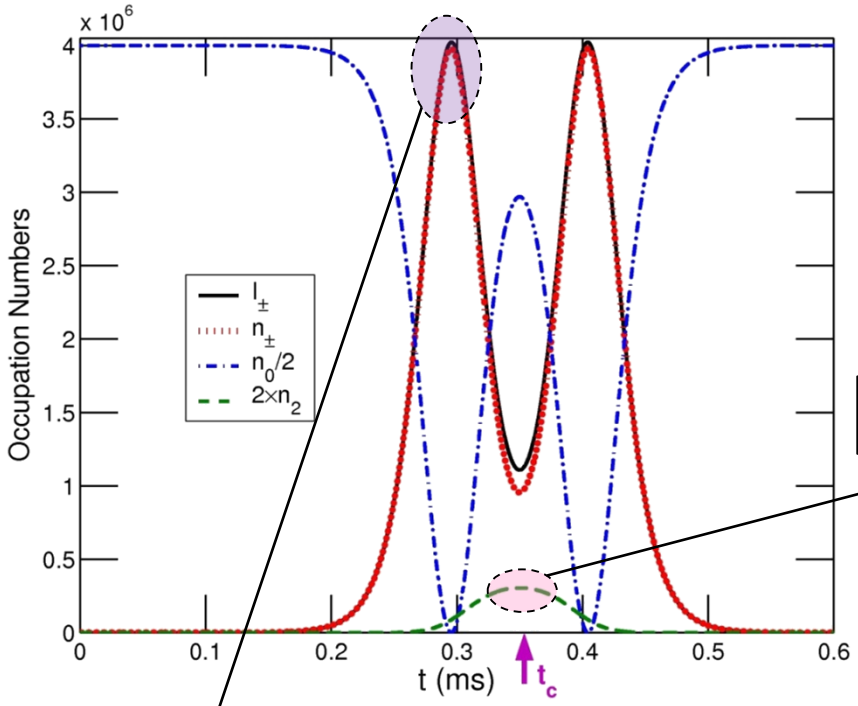
$\lambda_{se}(t) < 0$ for $\Delta t = 23\text{ms}$

$+\vec{k}_e$ $\vec{k}_0 - \vec{k}_e$ (entangled)

Simulations (intensity-occupations)

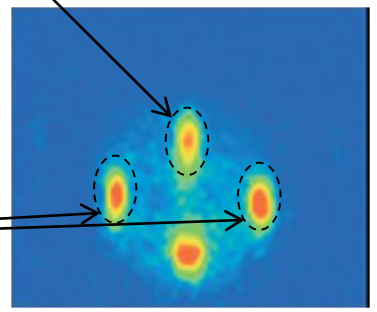
$I_{\pm}$: Intensity of end-fire modes

$n_0, n_{\pm}, n_2$: Occupation of side-modes



2nd-order SR → 2nd-order side-modes occupied

1st-order SR → 1st-order side-modes occupied



$\tau_p = 75\mu s$

- Similar behavior when decoherence introduced.

[1] M.E. Taşgın, M.Ö. Oktel, L. You, and Ö.E. Müstecaplıoğlu, Physical Review A, **79**, 053603 (2009).