

Concurrent light squeezing and spin squeezing in atom ensemble

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Abstract: Investigation on the analogies and distinctions between atoms and light is fundamental, with the study of wave-particle duality and the field of “atom optics” as prominent examples. Recent years, light squeezing and atomic spin squeezing, both seen as generation of correlated pair excitations, have attracted great interests due to applications in quantum information science and quantum metrology. So far, they have only been studied separately in experiments. Simultaneously squeezing them can provide new platforms to study the relationship between atoms and light, and can also offer new application opportunities. However, it is in general challenging to achieve concurrent squeezing of the two. Here, we report theoretical and experimental observations of concurrent spin squeezing and light squeezing in an atomic ensemble. By stroboscopic interactions, atoms and light act as quantum bus for each other, producing deterministic spin squeezed state and “comb-like” entangled light with squeezing.

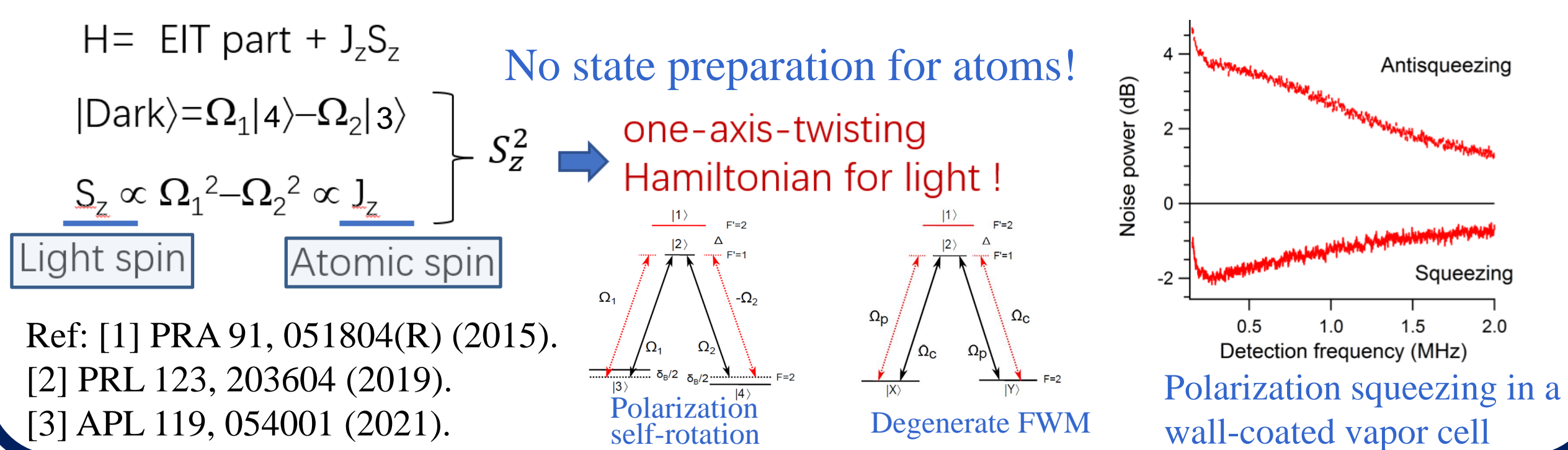
Basic model

Holstein-Primakoff approximation

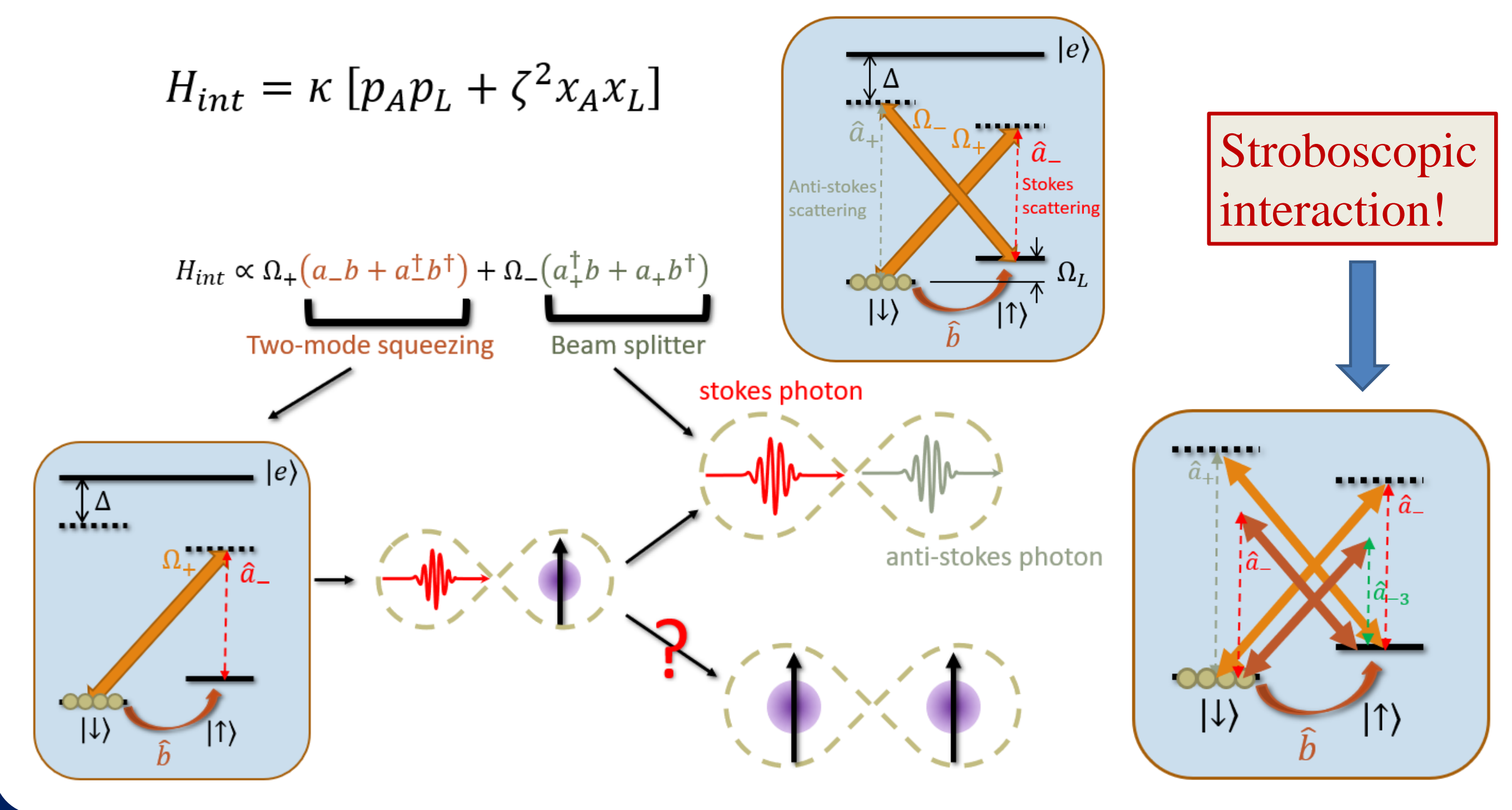
Spin $\hat{J}_x = J$, $\hat{J}_y = \hat{J}_z$, $\hat{J}_z = \Phi/2$

Light $\hat{x}_L = \frac{\hat{S}_x}{\sqrt{|S_x|}}$, $\hat{p}_L = \frac{\hat{S}_z}{\sqrt{|S_x|}}$

Squeezed light with atom ensemble (⁸⁷Rb)

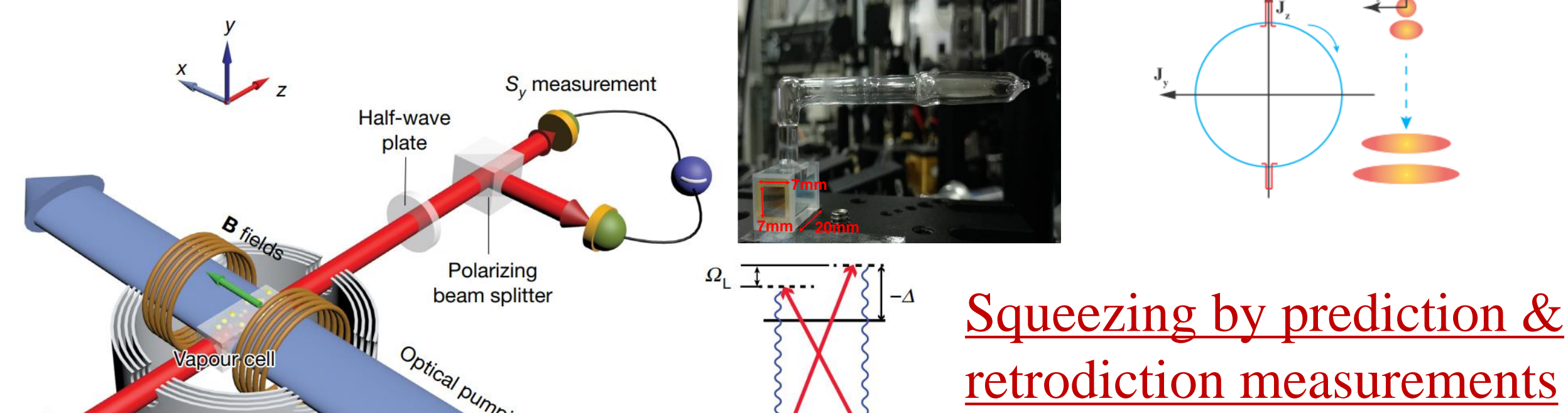


Concurrent squeezing: principle

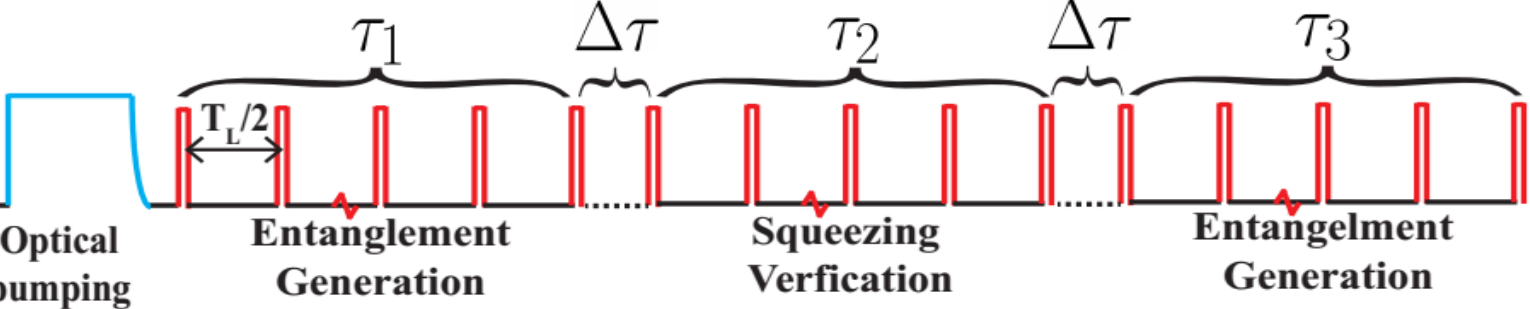


Spin squeezing in large atom ensemble

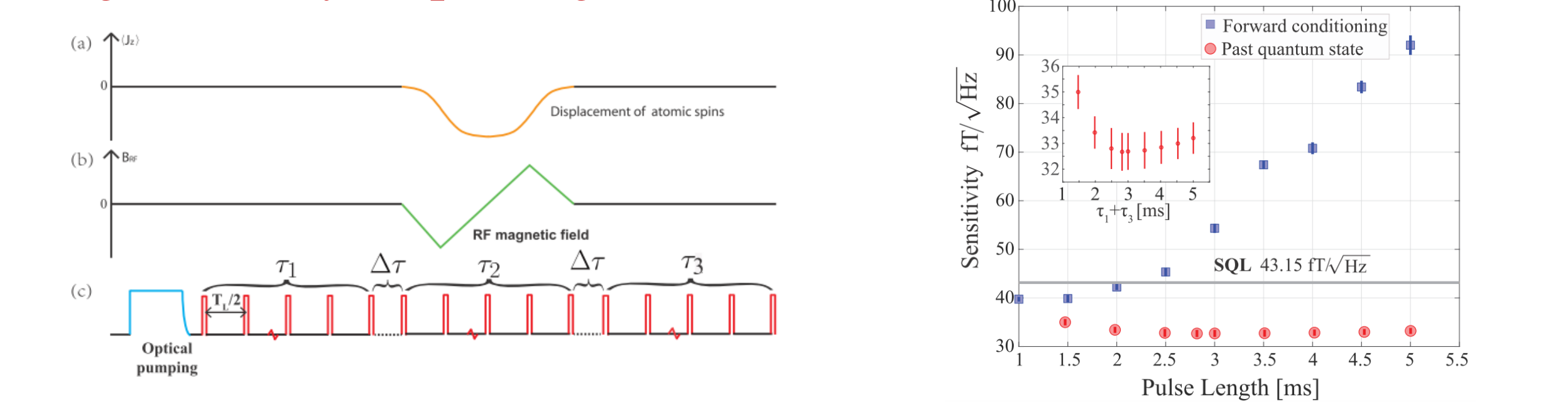
QND: $H_{int} = \kappa p_A p_L$



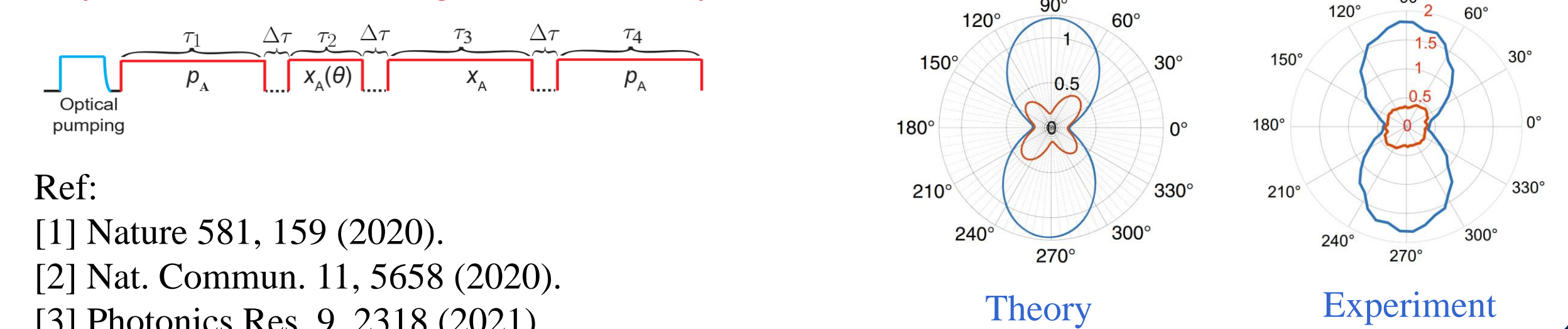
Stroboscopic probing & adiabatic pulses



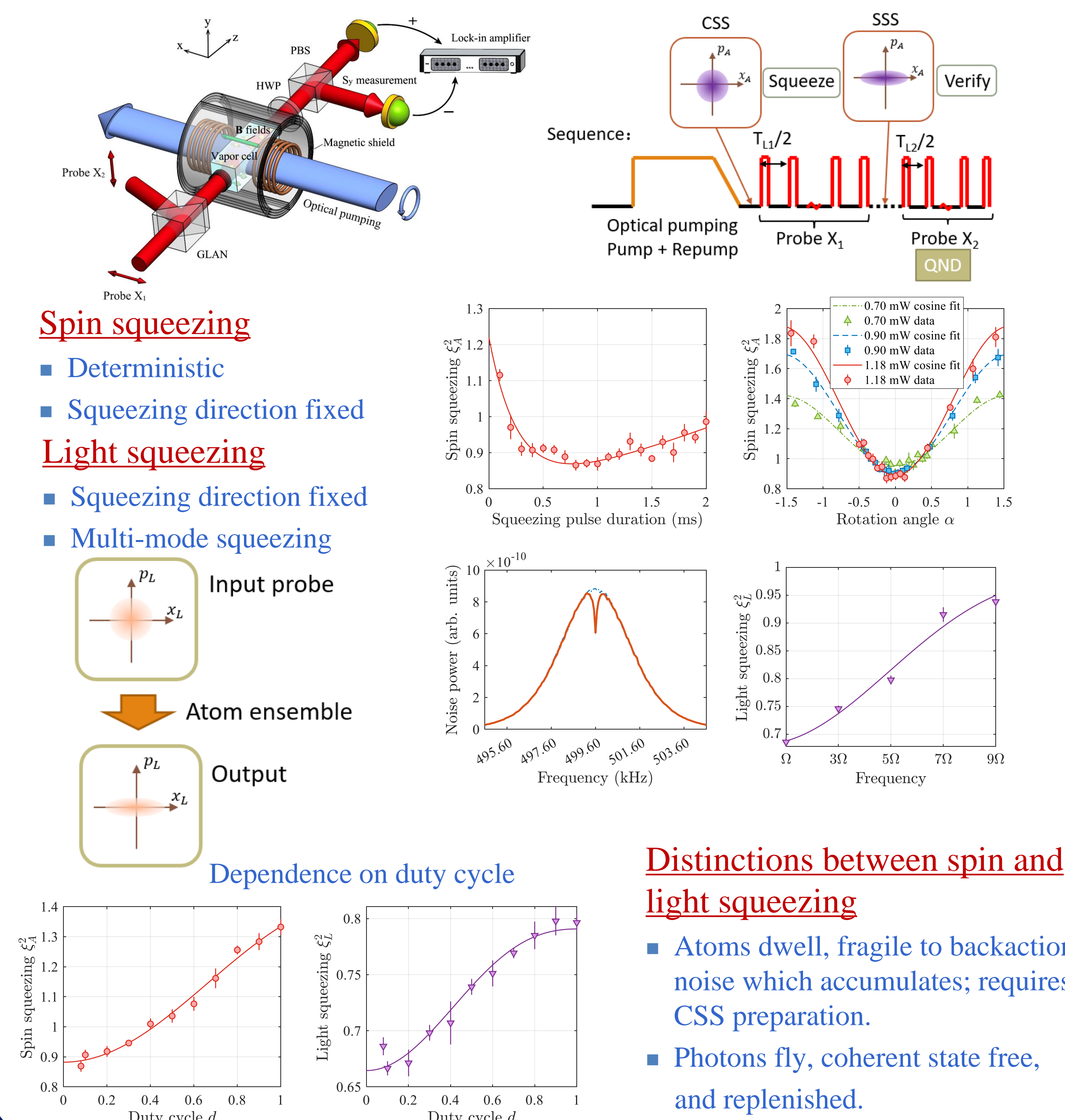
Magnetometry surpassing SQL



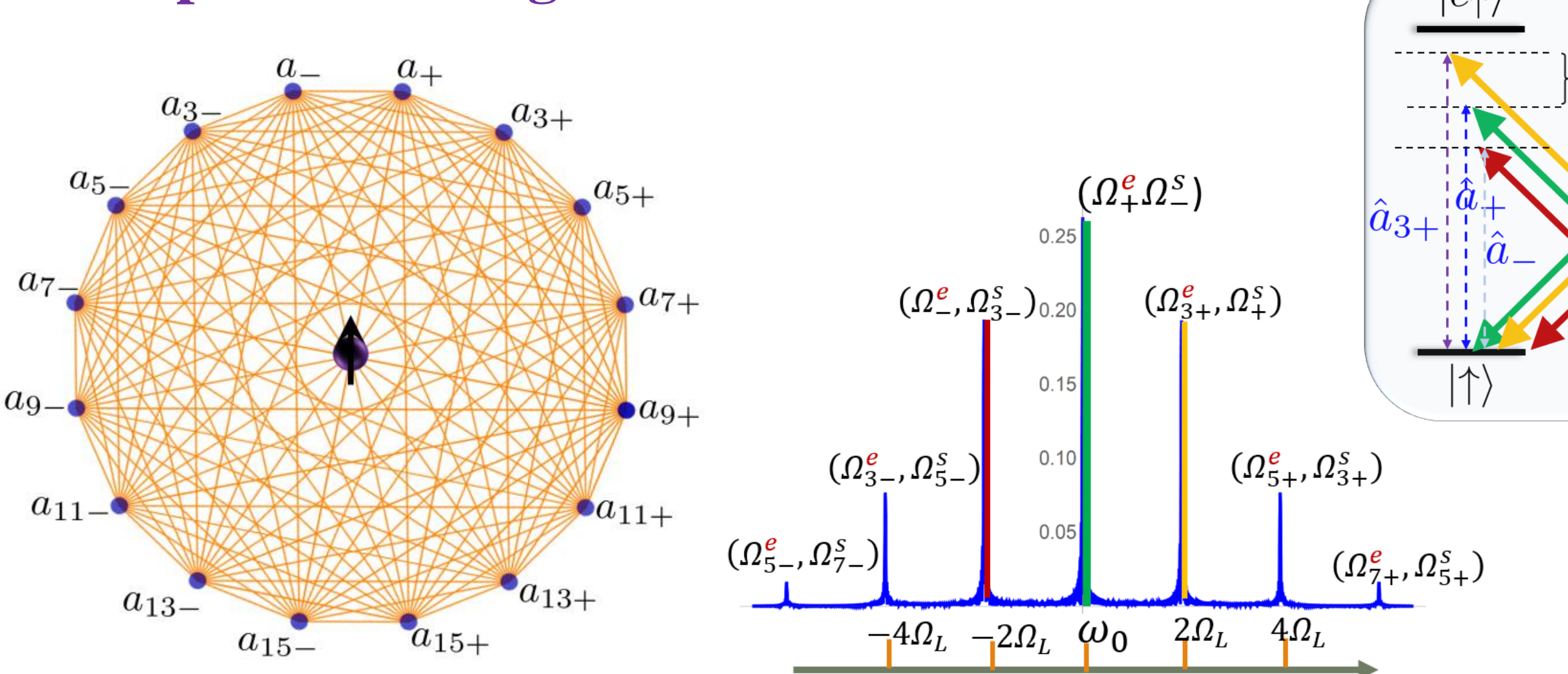
Beyond Heisenberg uncertainty relation



Concurrent squeezing: experiment results



Multipartite entangled state



Potential application in quantum metrology

