Simultaneous Trapping of Two Optical Pulses in an Atomic Ensemble as Stationary Light Pulses

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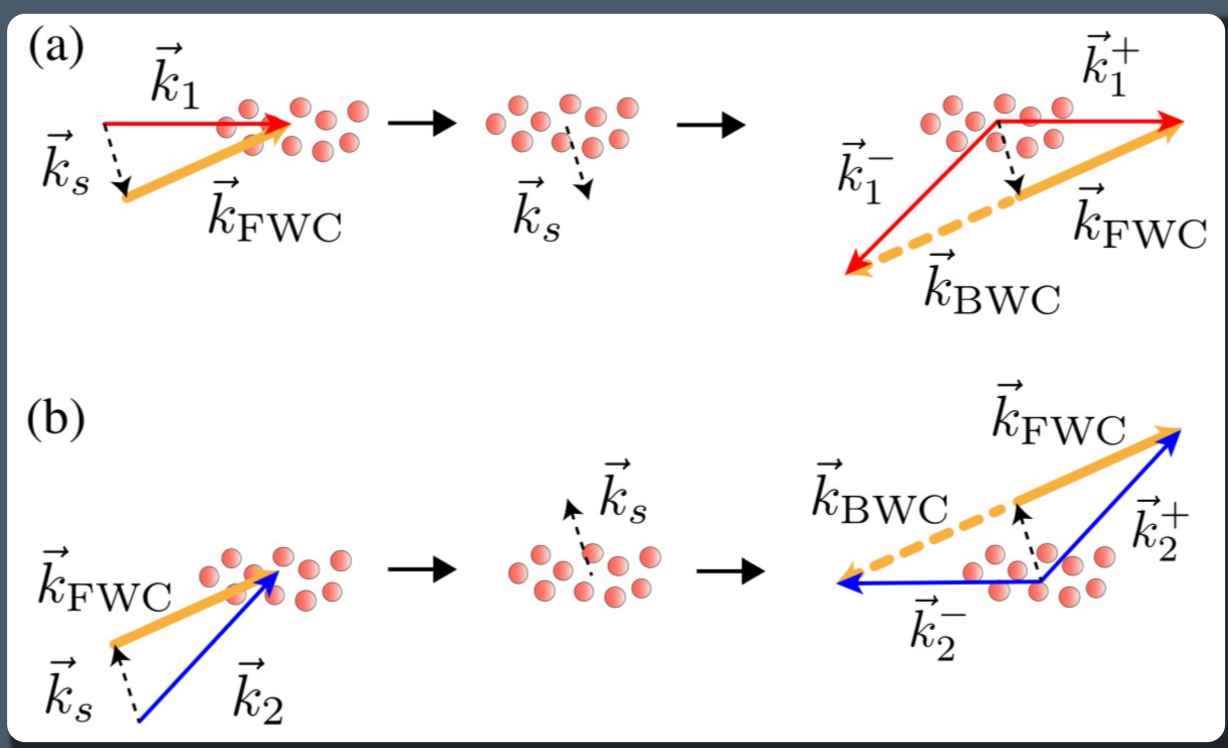
Introduction

Stationary light pulse (SLP) refers to a zero-group-velocity optical pulse in an atomic ensemble. Despite its unique properties, it has been limited to trapping a single optical pulse. Here, we first show theoretically that SLP trapping process in fact support multiple phase-matching conditions, and then demonstrate experimentally the simultaneous SLP trapping process from 0.8 to 2.0 μs. The characteristic dissipation time of released efficiency is obtained to be 1.22 μs, which corresponds to an effective Q-factor of 2.9×10^9.

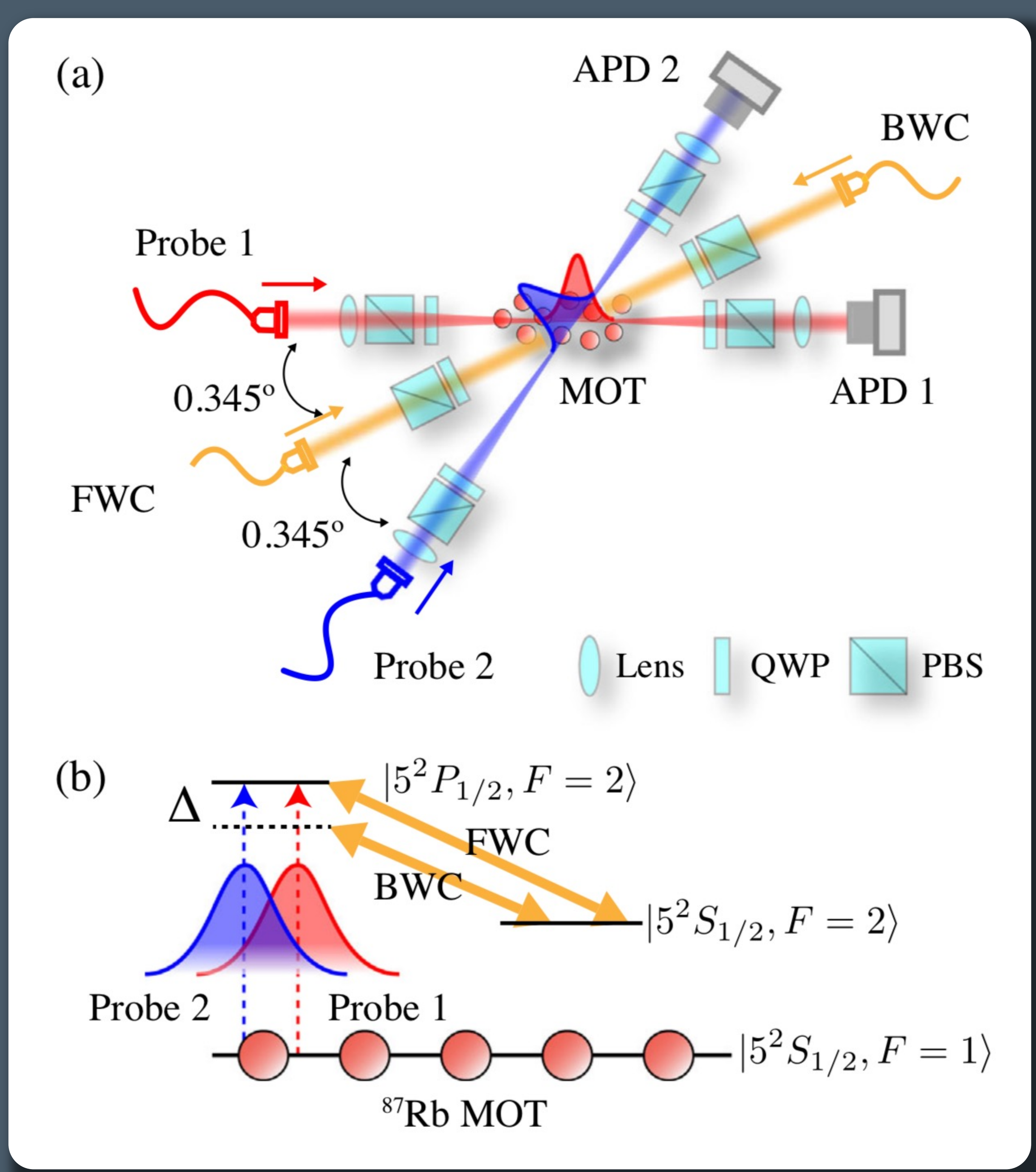
Phase-matching condition of SLP



Optical pulse → atomic coherence → SLPs

Formation of multimode SLPs for more than two optical pulses
→ Any k vectors on *the cone containing k_1 and k_2* can be simultaneously trapped as SLPs

Experimental Setup



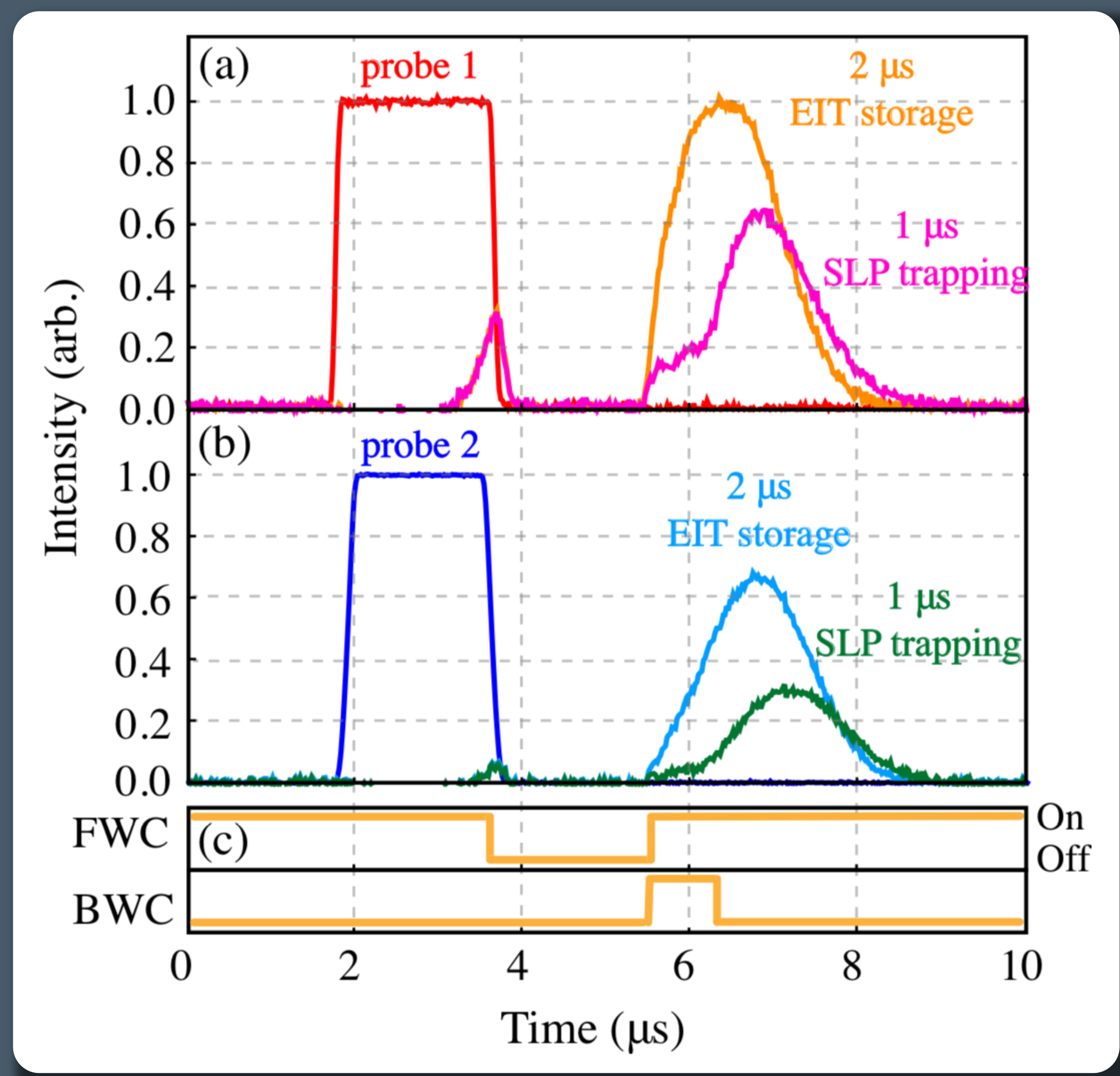
Cold ^{87}Rb ensemble trapped in a MOT

Optical depth = 60

$\gamma_{21} = 2\pi\times60\ kHz$

$\Delta = 2\pi\times4\ MHz$ (*prevents higher order Raman coherence*)

Simultaneous EIT and SLP process



Quantum state of SLP polariton

$$|\psi\rangle = \left(\hat{E}^+\cos\phi + \hat{E}^-\sin\phi\right)\cos\theta - \hat{S}\sin\theta$$
$$v_g = c_0\cos^2\theta\cos2\phi$$

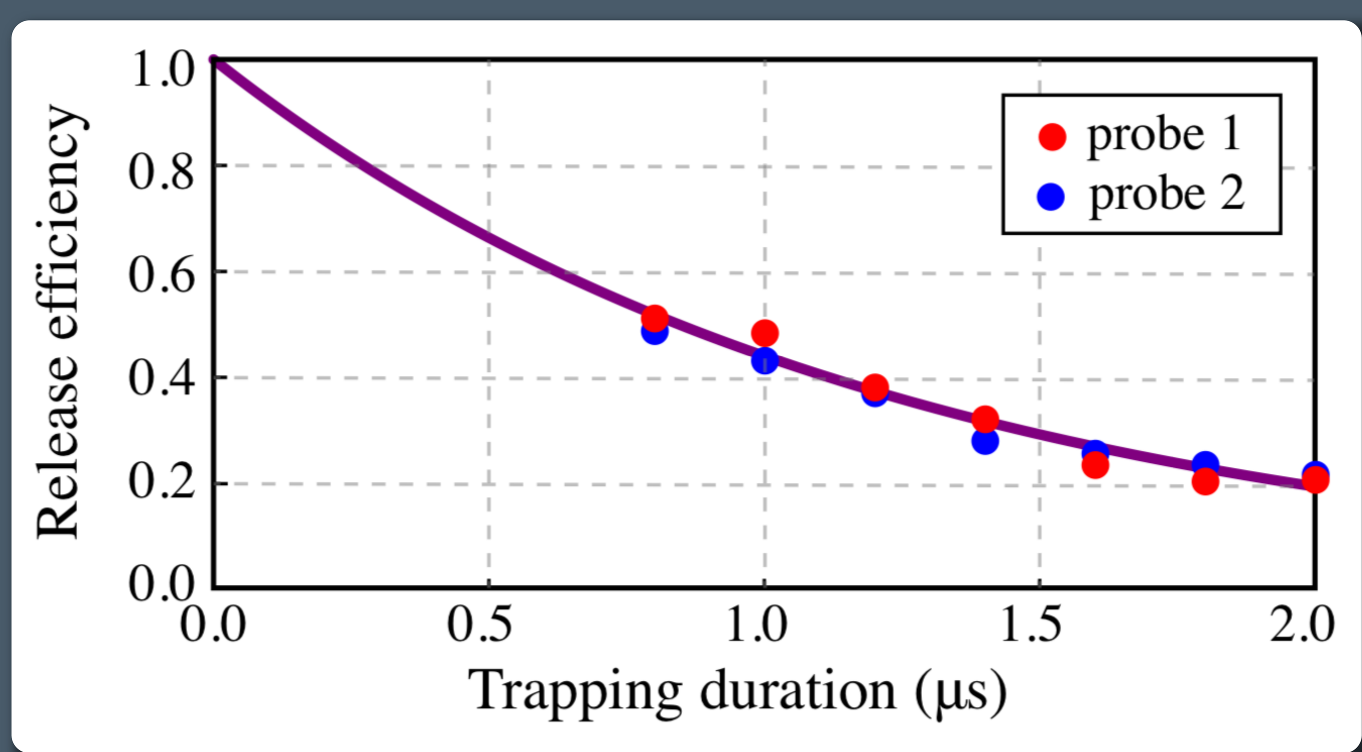
3.6 to 5.6 μs → Simultaneous EIT storage (only FWC)

probe 1 eff.=80.8% probe 2 eff.=59.1%

5.6 to 6.6 μs → Simultaneous SLP trapping (FWC & BWC)

probe 1 eff.=39.7% probe 2 eff.=24.9%

Release efficiency & Q-factor



Characteristic dissipation time = 1.22 μs for probe 1 and 2

SLP trapping process is an analogy of optical cavity

→ Effective Q-factor of simultaneous SLP trapping = 2.9×10^9

N-atom cooperativity estimates the atom-photon coupling

$\{g, \kappa, \Gamma\} = 2\pi\times\{0.24, 0.13, 5.8\}\ MHz$

$C_N \sim 8\times10^6$

→ larger N-atom cooperativity than recent cavity QED results

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