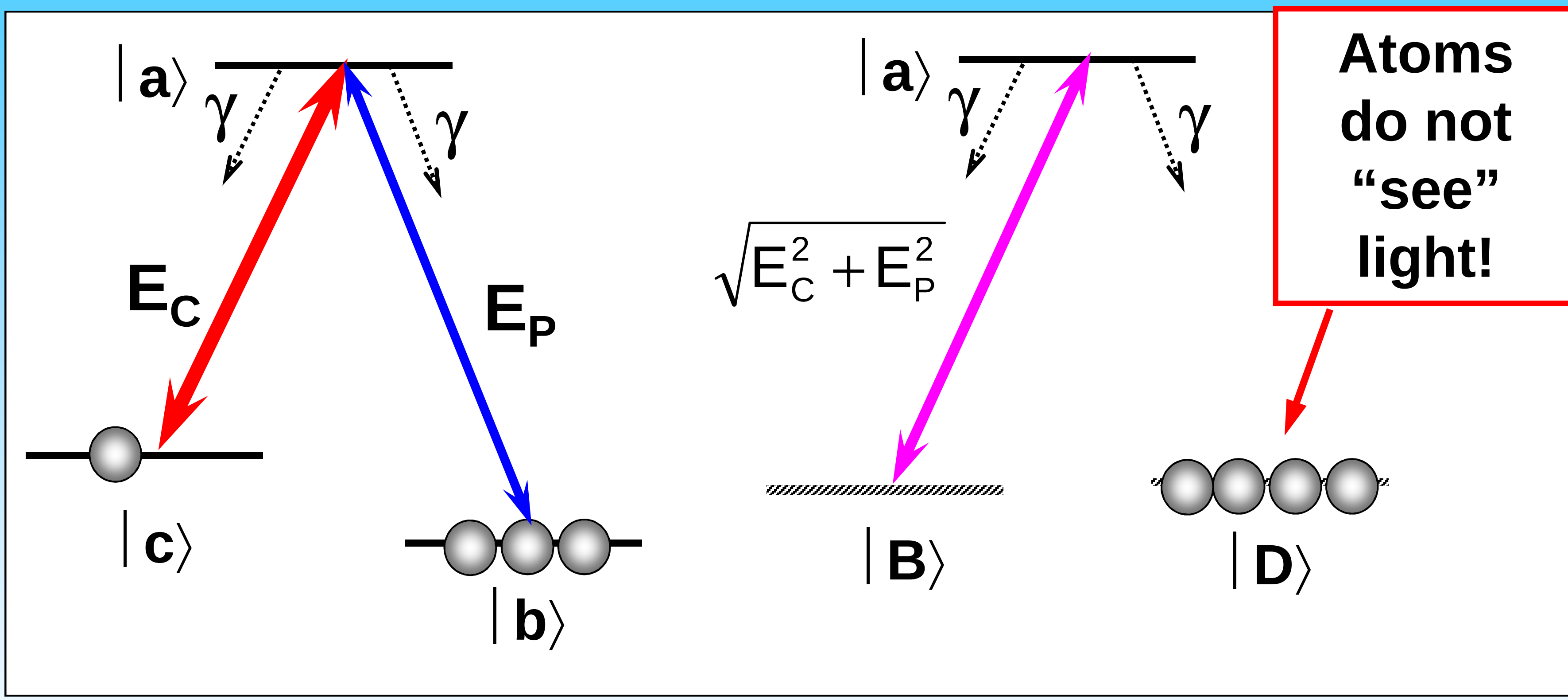
Electromagnetically Induced Transparency (EIT)



Bright and dark states:

$$|B\rangle = \frac{E_P|b\rangle + E_C|c\rangle}{\sqrt{E_P^2 + E_C^2}}$$

$$|D\rangle = \frac{E_C|b\rangle - E_P|c\rangle}{\sqrt{E_P^2 + E_C^2}}$$

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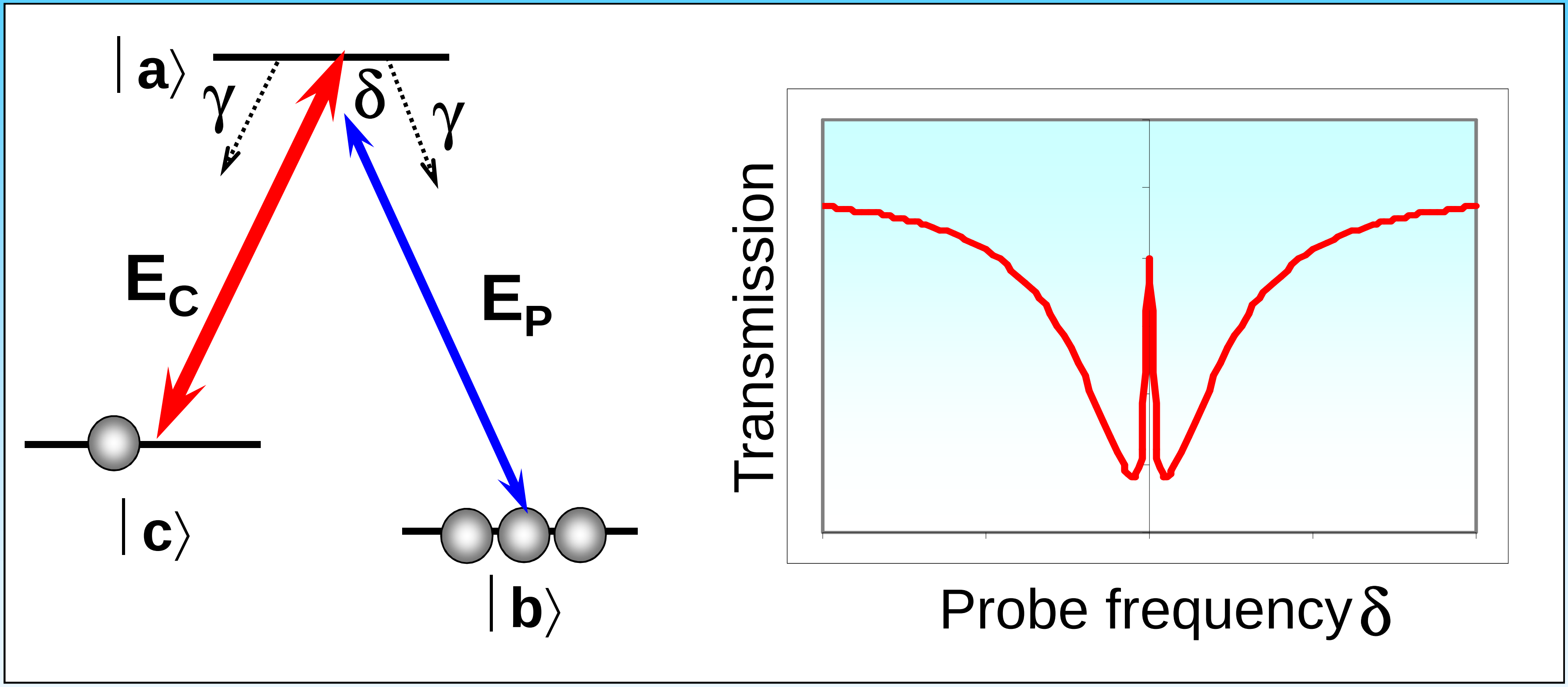
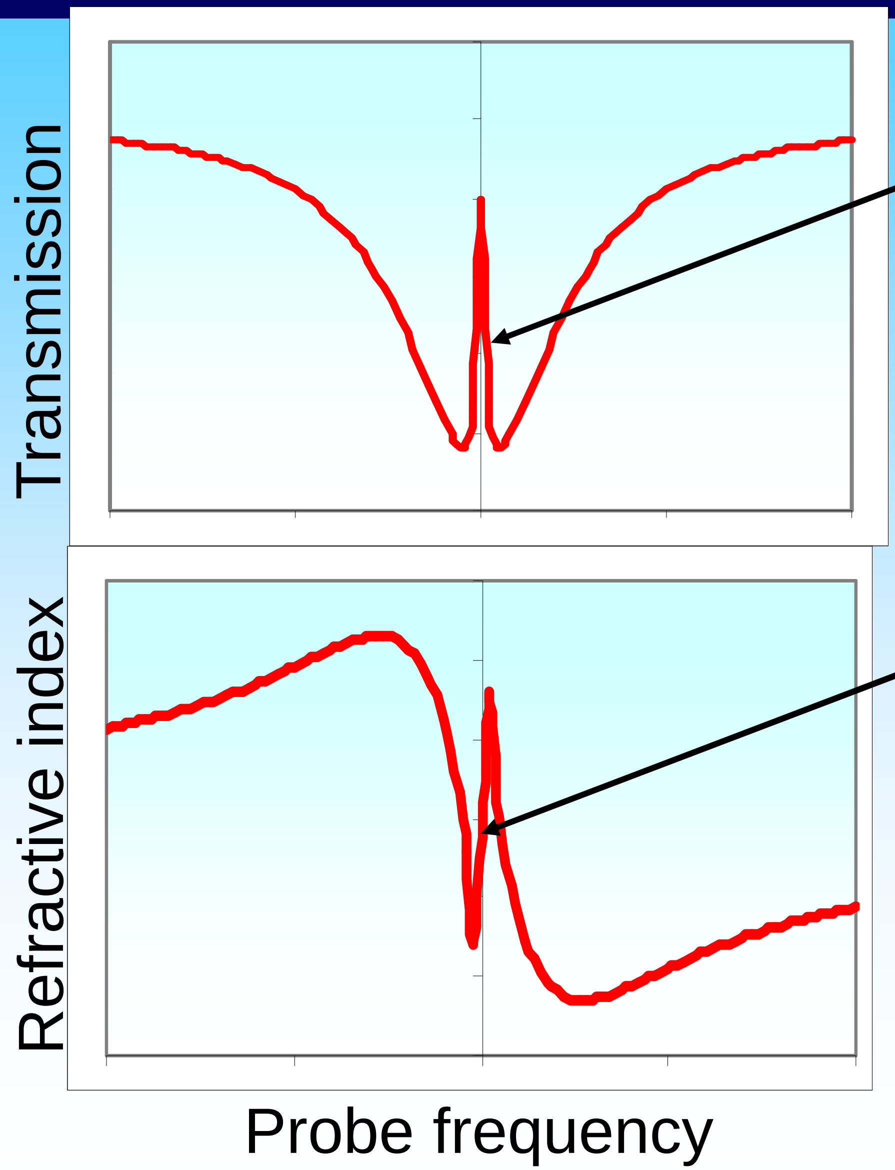


Width of EIT peak is determined by **control field intensity**, but limited by **spin coherence lifetime**

Slow light via Electromagnetically Induced Transparency (EIT)



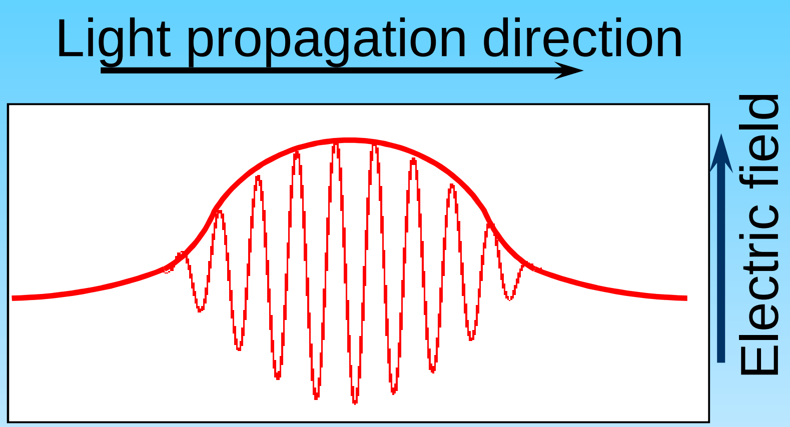
Narrow transmission resonance

$$\gamma_{EIT} \propto \frac{E_C^2}{\gamma} \frac{1}{\sqrt{N\lambda^2 L}}$$

Steep dispersion

$$\omega \frac{dn}{d\omega} >> 1$$

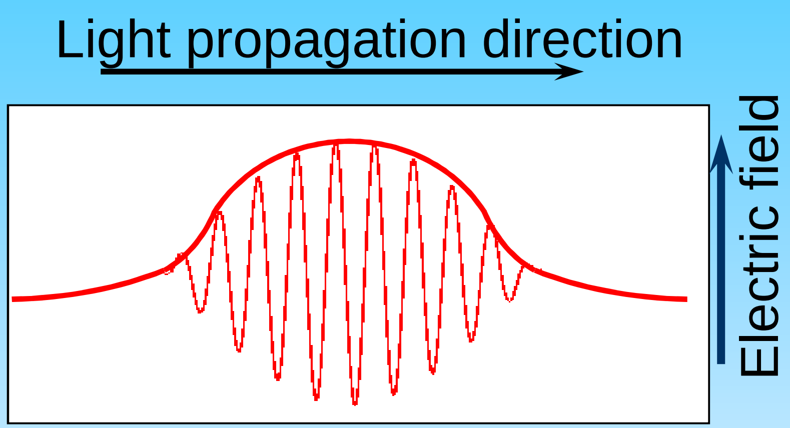
Group velocity manipulation



Group velocity

$$v_g = \frac{d\omega(k)}{dk} = \frac{c}{n + \omega \frac{dn}{d\omega}}$$

Group velocity manipulation



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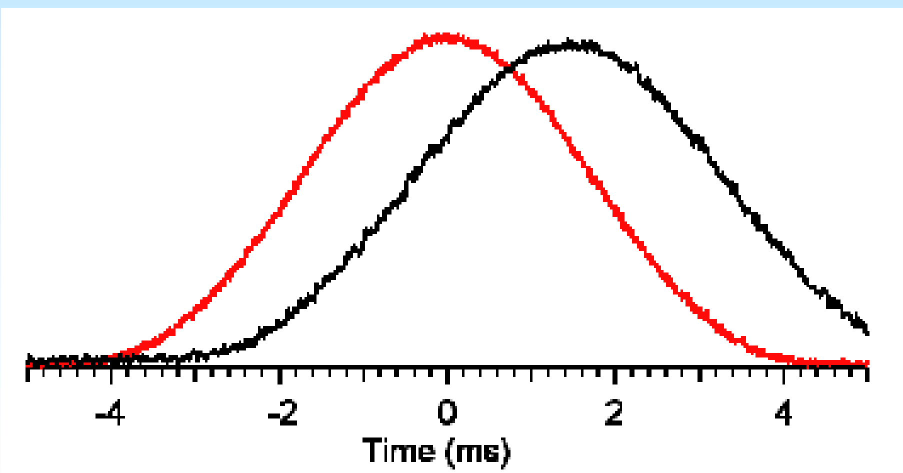
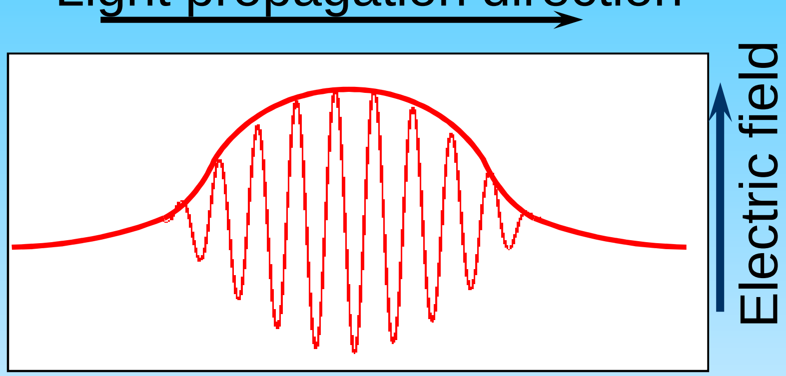


v_g=50m/s

"Slow" light

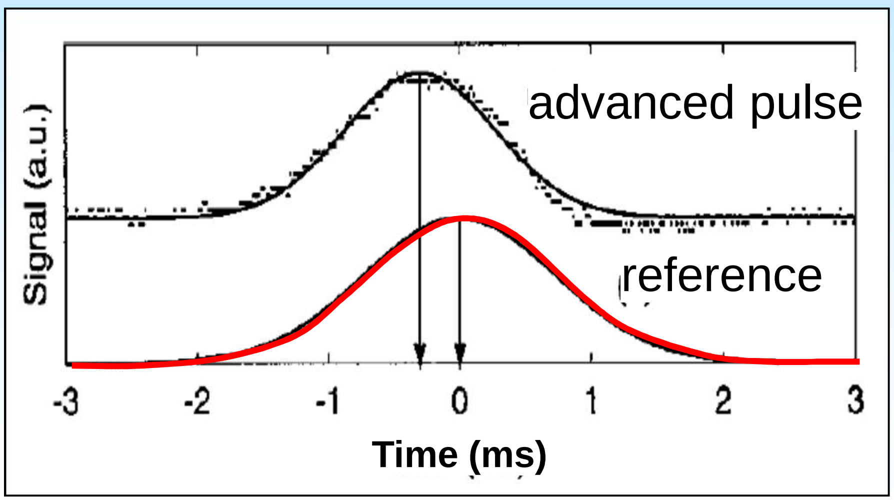
$$\omega \frac{dn}{d\omega} >> 1 \quad v_g << c$$

Group velocity manipulation



Group velocity

$$v_g = \frac{d\omega(k)}{dk} = \frac{c}{n + \omega \frac{dn}{d\omega}}$$



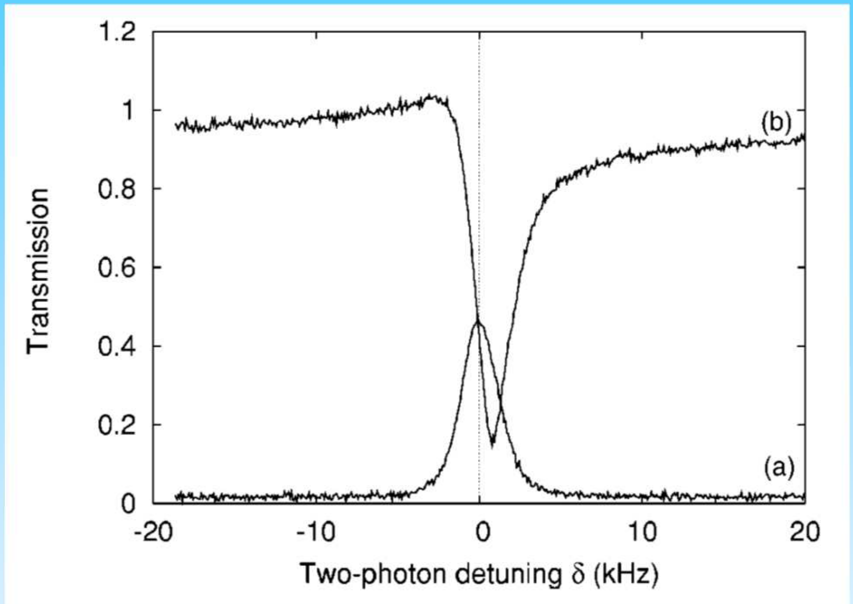
v_g=-180m/s

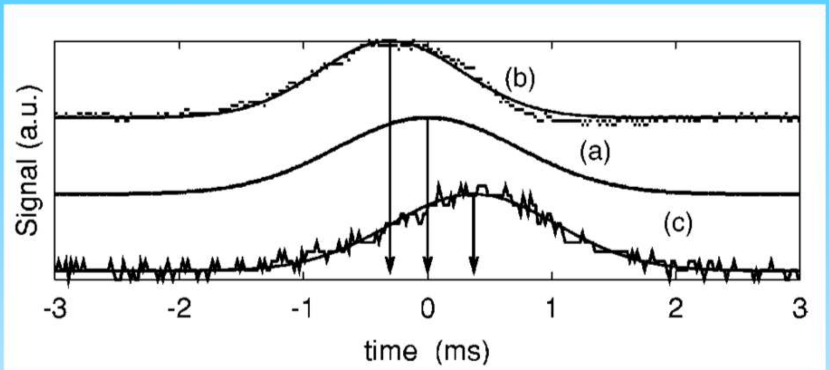
“Fast” light

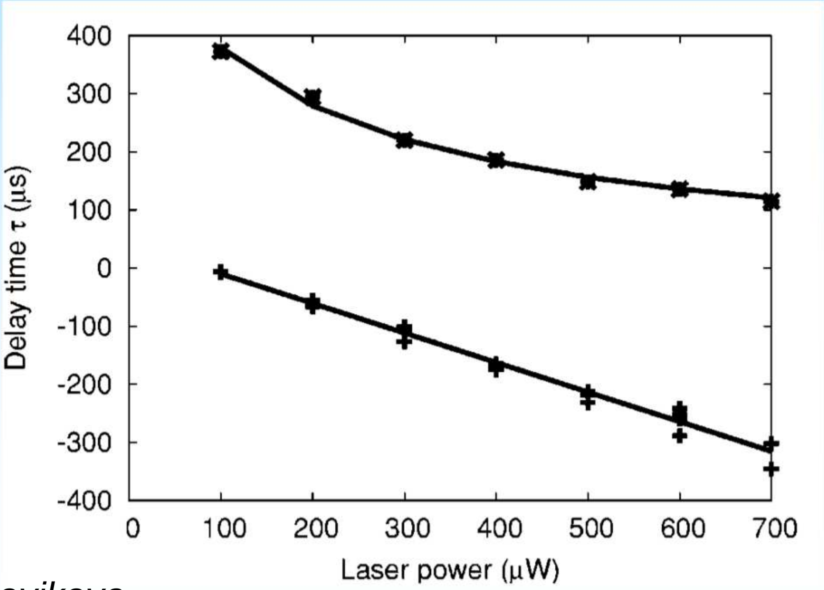
$$\omega \frac{dn}{d\omega} < 0$$

v_g>c or v_g<0

Group velocity manipulation

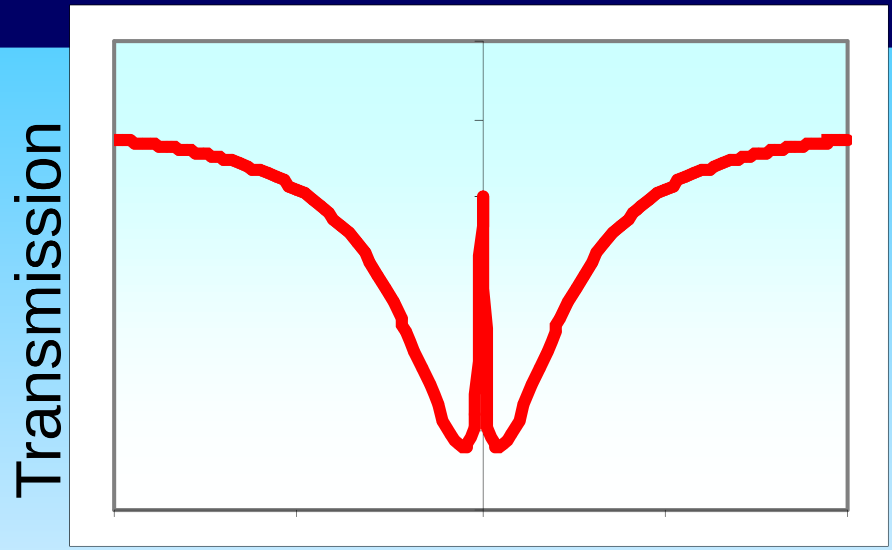


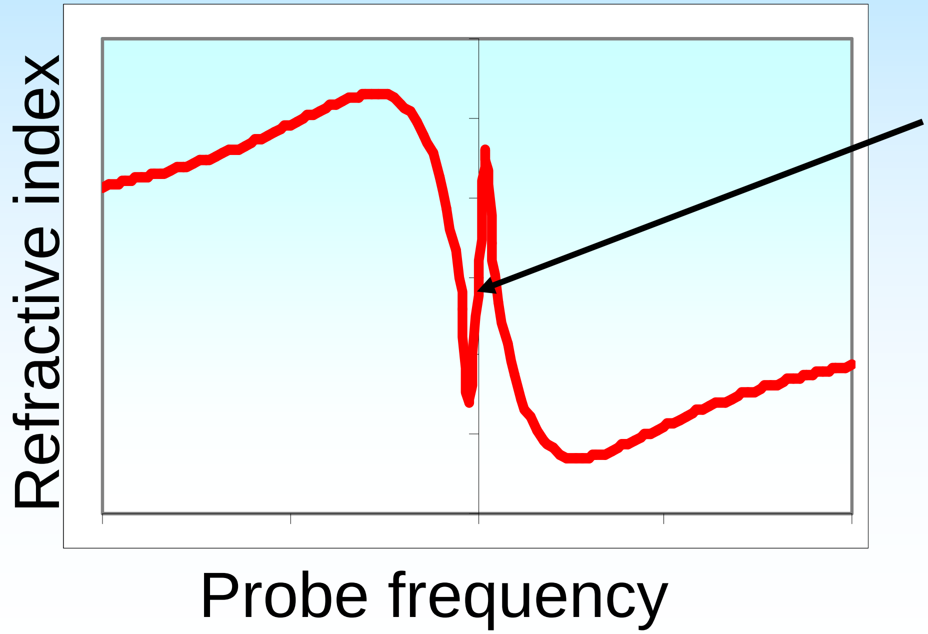




Eugeniy E. Mikhailov, Vladimir A. Sautenkov, Irina Novikova, and George R. Welch
Phys. Rev. A 69, 063808 (2004)

Slow light in EIT





Group velocity

$$v_g \propto \frac{8\pi}{3N\lambda^2}\frac{E_C^2}{\gamma}$$

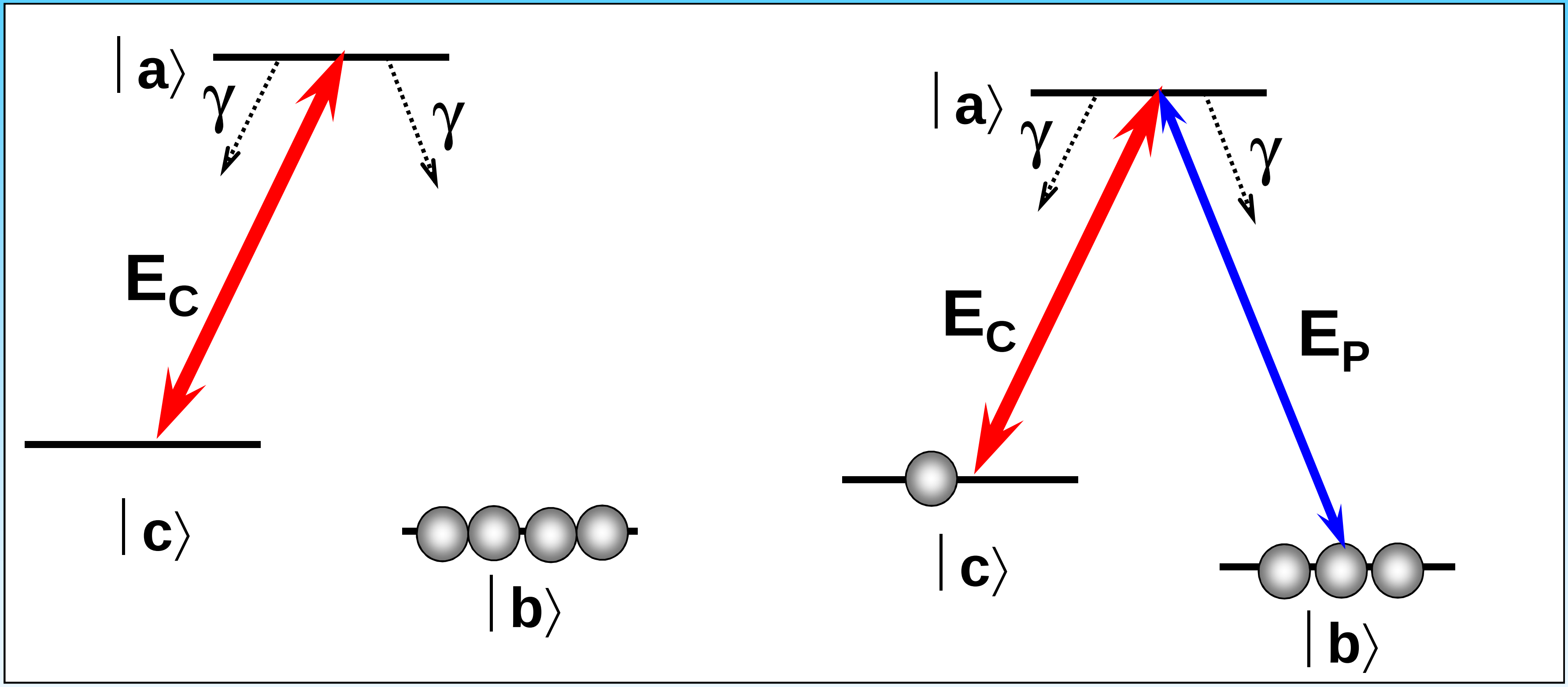
What happens when control field goes to **zero**?

Steep dispersion in EIT

$$\omega\frac{dn}{d\omega} >> 0$$

means **controllable** slow group velocity

Coupling of a probe pulse and a spin wave



Dark state:

$$|D\rangle = \frac{E_C|b\rangle - E_P|c\rangle}{\sqrt{E_P^2 + E_C^2}}$$

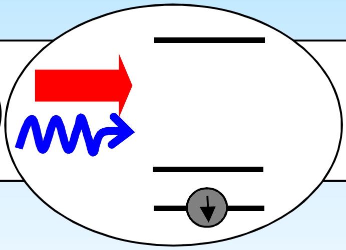
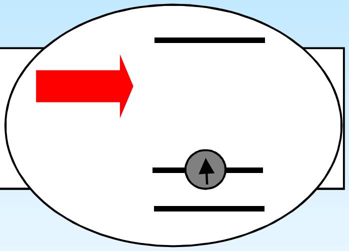
Light-atoms interaction: dark-state polariton

$$\hat{\Psi} = \cos\theta\ \hat{E}_P - \sin\theta\ \sqrt{N}\hat{\sigma}_{bc}$$

M. Fleischhauer and M.D. Lukin
PRL 84, 5094 (2000)

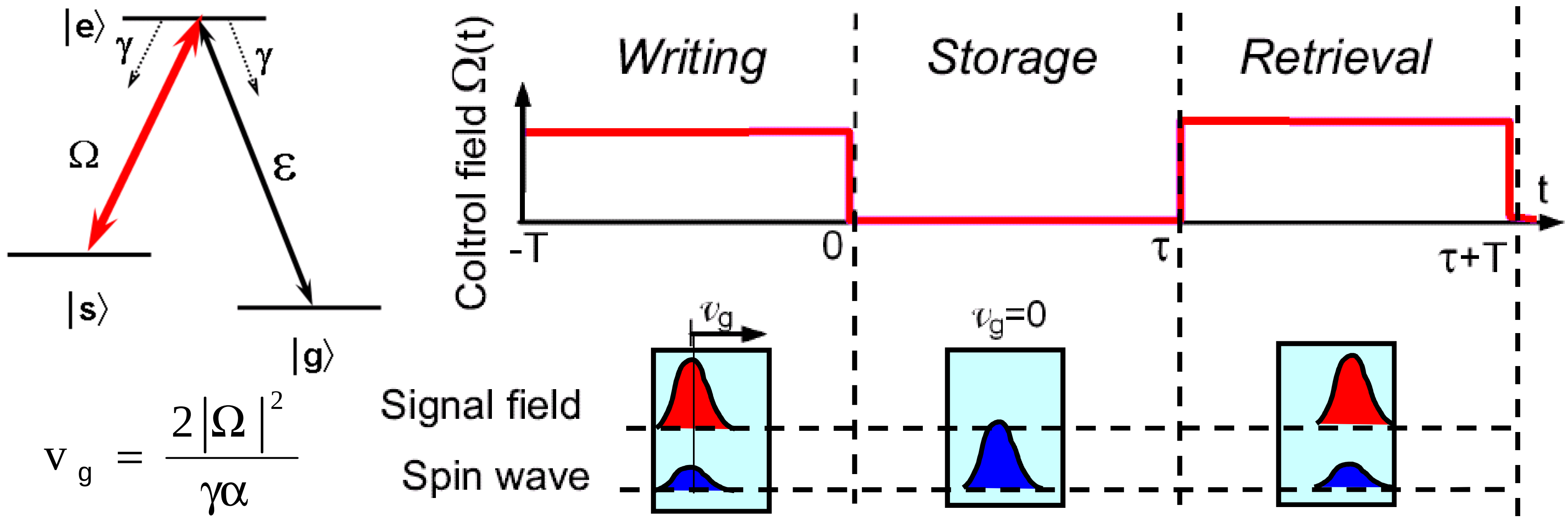
Photons of the probe field

Excitations of the spin wave

$\hat{\Psi} = \cos\theta$  $-\sin\theta$ 

$$\cos\theta = \sqrt{\frac{v_g}{c}} \propto E_C$$

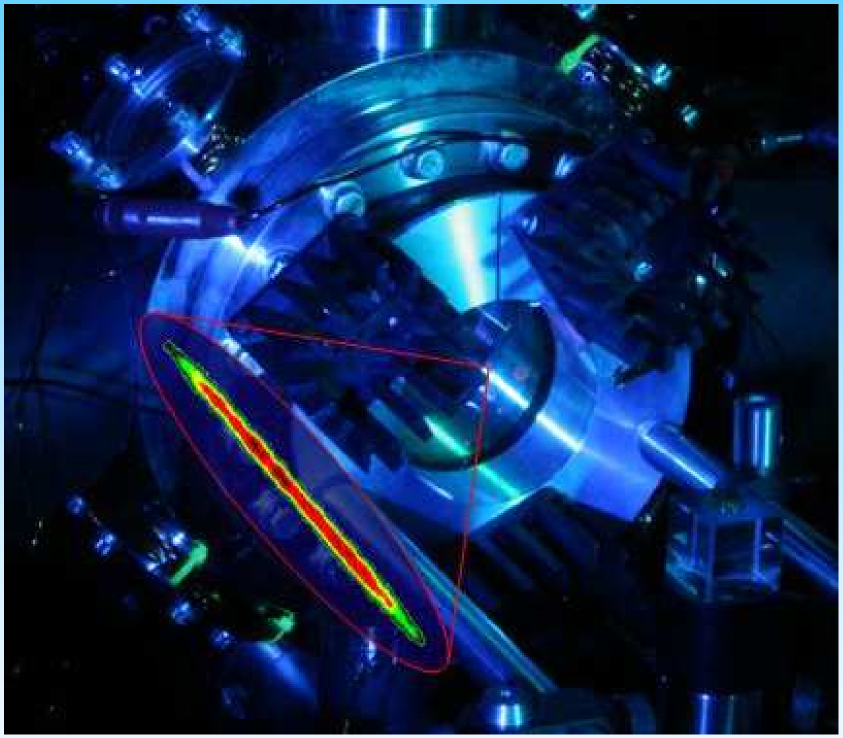
Quantum memory for photons



$$v_g = \frac{2|\Omega|^2}{\gamma\alpha}$$

Ideal memory operation

How long does the dark state live?



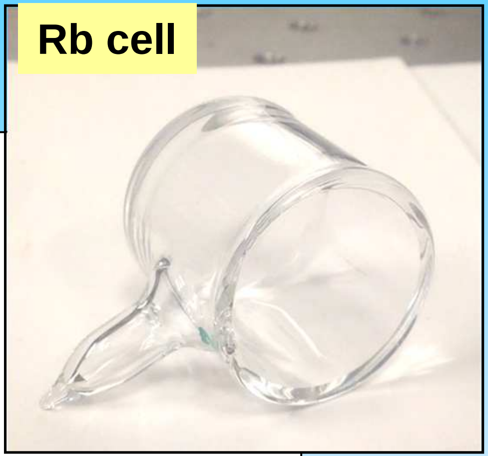
Cold atoms

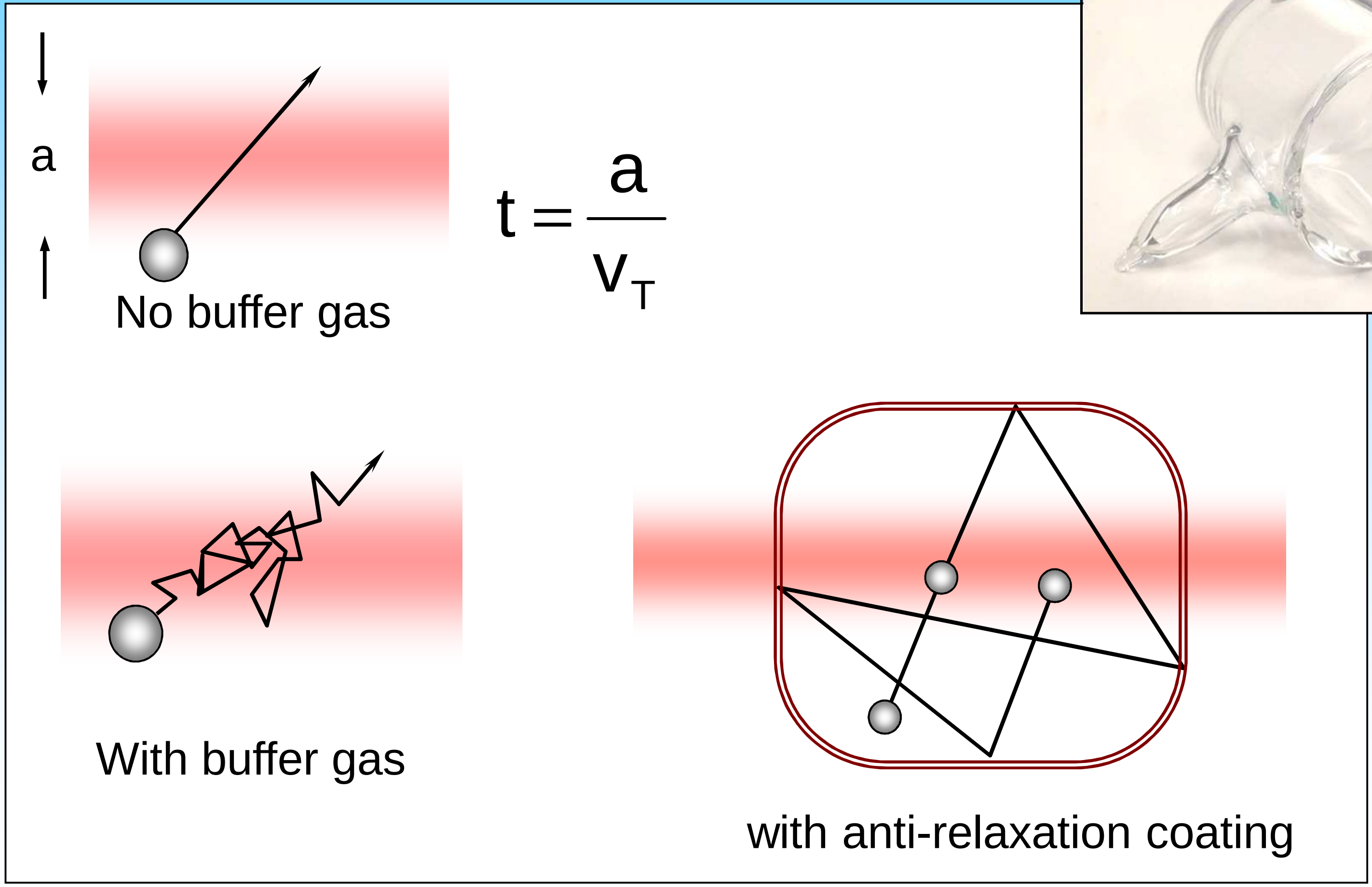
No Doppler broadening, but there may be difficulties due to
- uncompensated magnetic fields
- gravity
- insufficient number of atoms
- collisions between atoms

These are technical problems – if all are fixed, the ground state coherence was shown to live up to several seconds!

How long does the dark state live?

atoms fly away! $v_T \approx 400 m/s$





$$t = \frac{a}{v_T}$$

How long does the dark state live?