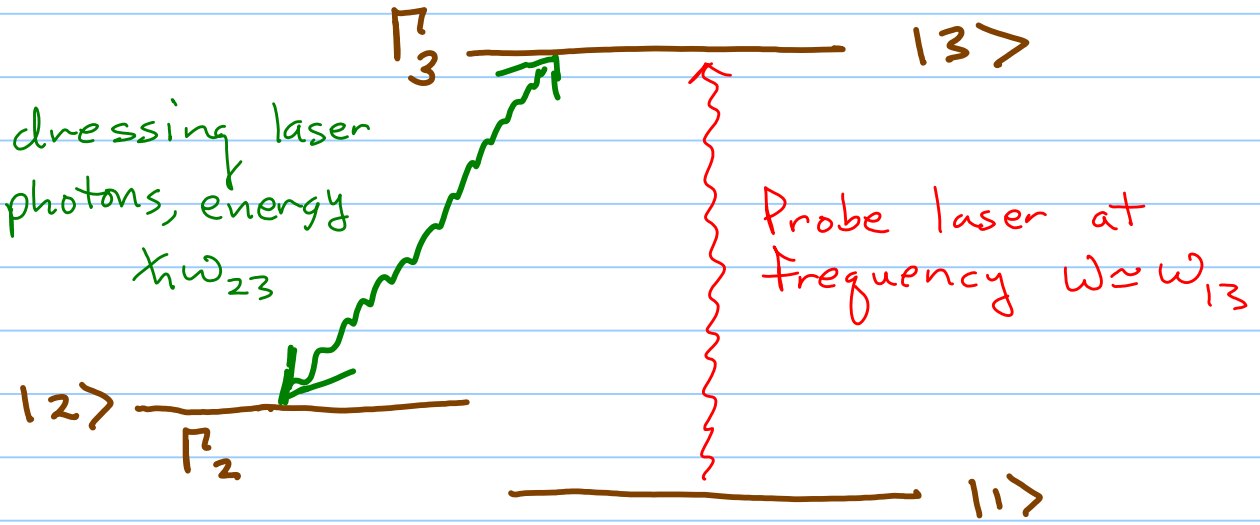
An exotic example: SLOW LIGHT

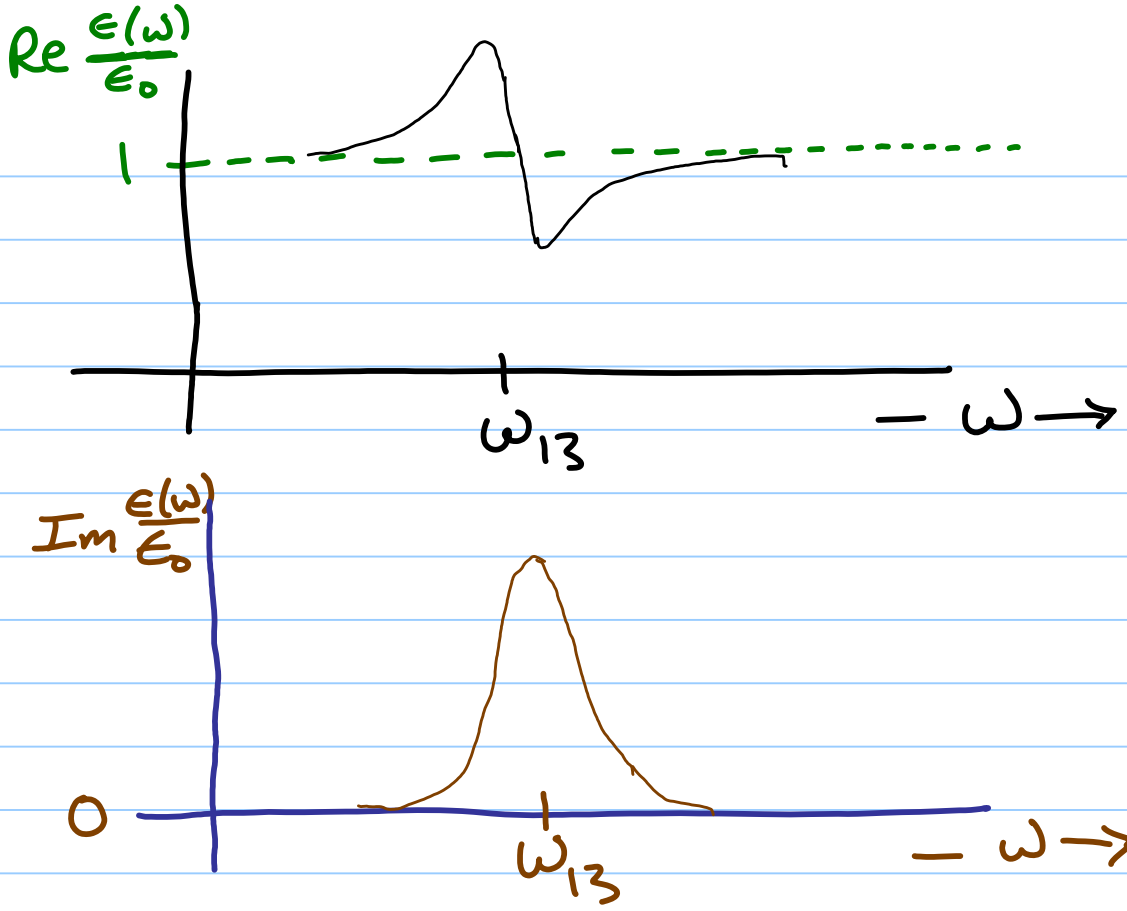
Idea - One can utilize "Photon Dressing" to modify the index of refraction at certain frequencies

Reference: Hau et al. Nature 397, 594 (1999)
≃ 1,800 citations to date!

⇒ Consider a gas of 3-level atoms, in a situation where 2 levels are "dressed" by a dressing laser tuned to the resonant frequency of levels 2 and 3:



When no dressing laser is present, (no ω_{23}), we can ignore level 2, and we see a standard dispersion profile shown on the following figure:

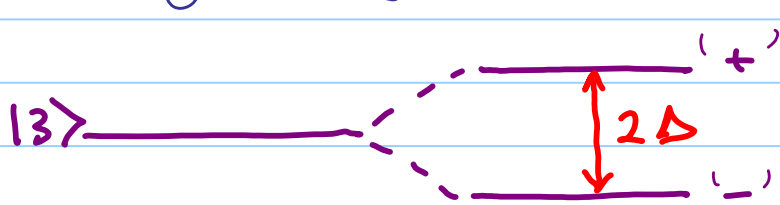


Now observe what happens when ω_{23} is turned on to modify state $|3\rangle$ into two photon-dressed levels.

$\Rightarrow$ These are 2 linear combinations,

$$|\Psi^{\pm}\rangle = \frac{1}{\sqrt{2}}\left\{ |N\hbar\omega_{23}\rangle|3\rangle \pm |(N+1)\hbar\omega_{23}\rangle|2\rangle \right\}$$

and these 2 levels are split by the Rabi frequency 2Δ,



this is called an Autler-Townes doublet

This changes the dielectric constant of the gas (for $\omega \simeq \omega_{13}$ probe light) into something like:

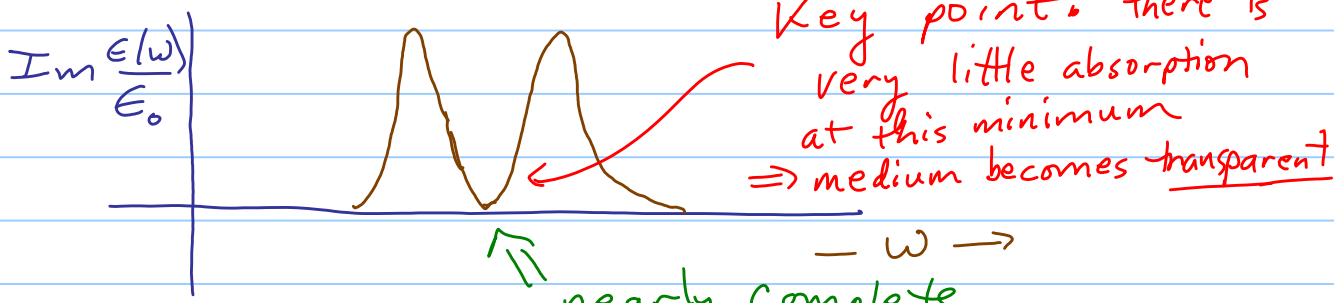
$$\frac{\epsilon(\omega)}{\epsilon_0} = 1 + \frac{S}{(\omega_{13}+\Delta)^2 - \omega^2 - i\gamma\omega} + \frac{S}{(\omega_{13}-\Delta)^2 - \omega^2 - i\gamma\omega}$$

$$= 1 + \frac{S\cdot[(\omega_{13}+\Delta)^2 - \omega^2 + i\gamma\omega]}{[(\omega_{13}+\Delta)^2 - \omega^2]^2 + \gamma^2\omega^2} + \frac{S[(\omega_{13}-\Delta)^2 - \omega^2 + i\gamma\omega]}{[(\omega_{13}-\Delta)^2 - \omega^2]^2 + \gamma^2\omega^2}$$

whereby the real & imaginary parts look like:

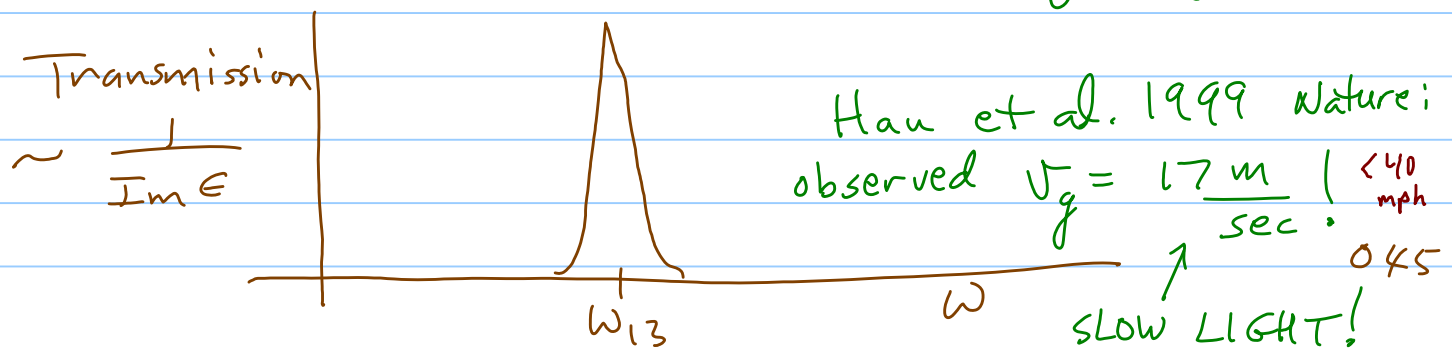
Recall $v_g = \frac{c}{n + \omega \frac{dn}{d\omega}}$

Note: large positive slope $\frac{dn}{d\omega}$ results in VERY slow group velocity!



Key point: there is very little absorption at this minimum ⇒ medium becomes transparent

⇑ nearly complete destructive interference, ⇒ almost no loss at this frequency!



Hau et al. 1999 Nature: observed $v_g = 17 \frac{m}{sec}$ (< 40 mph)

SLOW LIGHT!