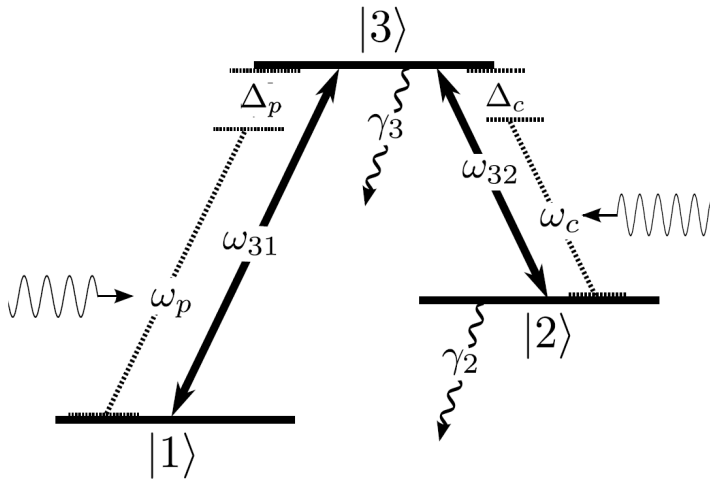
Rydberg atoms: Slow light

Udo Hermann, 02.07.2013

1 Three level system



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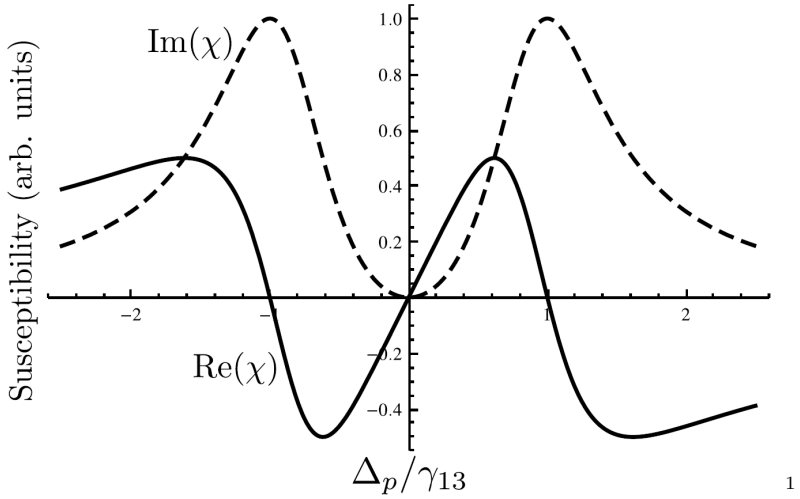
- Similar effects as in a two-level atom i.e. absorption (transition $|1\rangle$ - $|3\rangle$, "probe")
- Second transition: $|2\rangle$ - $|3\rangle$ ("coupling")
- Transition $|1\rangle$ - $|2\rangle$ is dipole forbidden
- New phenomena when a coupling laser is added to the already present probe laser: Electromagnetically induced transperency
- Absorption line (imaginary part of the susceptibility χ) has a dip in the centre



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2 Effects

2.1 Slow light

- Group velocity of light:

$$v_g = \frac{c_0}{n(\omega) + \omega \frac{\partial}{\partial \omega} n(\omega)} \tag{1}$$

- $n(\omega)$ depends on the real part of χ
- Quick change in the refractive index over the frequency leads to a slow group velocity
- There are approaches to decrease the speed of light to zero, the current status quo[2] is at 17 m/s

2.2 Population transfer

- Dark state: $|a^0\rangle = \cos\Theta\,|1\rangle - \sin\Theta\,|2\rangle\,, \tan\Theta = \frac{\Omega_p}{\Omega_c}$
- Adiabatic (slow) change of Θ leads to a population transfer of 100 %

3 Experiments

3.1 Interaction of slow photons

- Atoms are trapped in a dipole trap
- Coupling and probe beam are applied into the trap
- Beam waist is smaller than the Rydberg blockade radius
- One-dimensional alignment of Rydberg atoms
- Photons cannot avoid each other
- If two photons are at the same location, the EIT feature will be destroyed (and the photons will be absorbed)

4 Outlook

EIT offers several interesting topics for further research:

- Optical transistor
- Light storage
- Single photon source

[1] W. W. Erickson, Electromagnetically Induced Transparency
[2] L. V. Hau et al., Nature, Vol 397, 18 February 1999