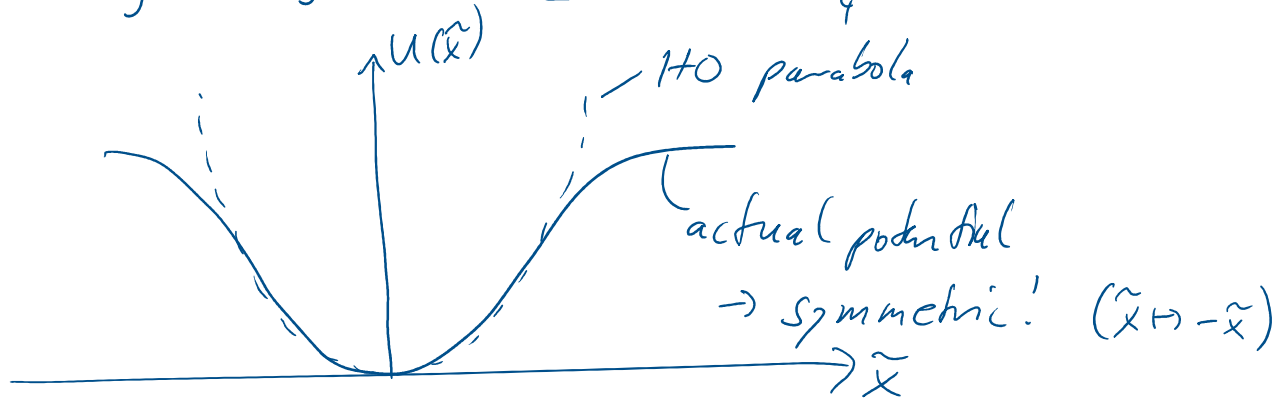


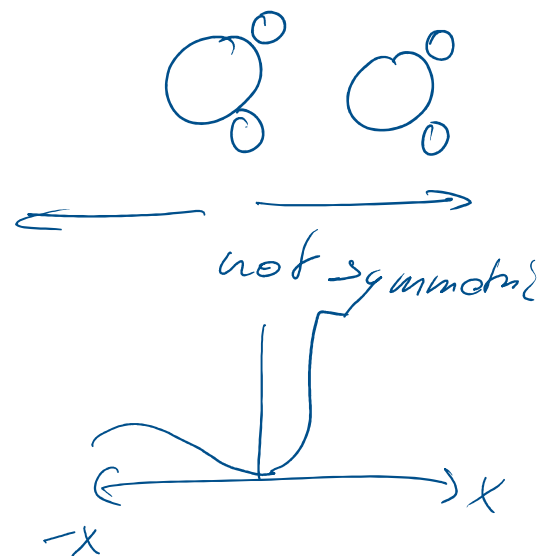
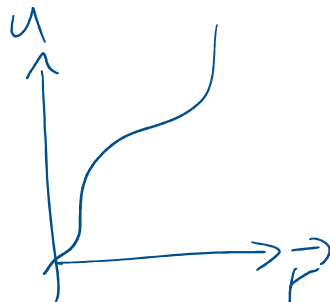
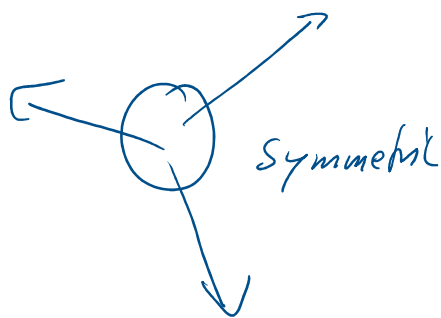
NLO in centro symmetric materials,
 (glasses, gases, liquids, some crystals)

$$\tilde{F}_{restorng} = -m\omega_0^2 \tilde{x} + b m \tilde{x}^3 + \dots \quad \text{Boyd (1.4.33)}$$

$$U(\tilde{x}) = -\int \tilde{F}_{restorng} d\tilde{x} = \frac{1}{2} m \omega_0^2 \tilde{x}^2 - \frac{1}{4} b m \tilde{x}^4 + \dots$$



Symmetric 3D: same potential for \vec{F} and $-\vec{F}$



$$\vec{F}_{\text{restonly}} = -m\omega_0^2 \vec{r} + mb \underbrace{(\vec{r} \cdot \vec{r}) \cdot \vec{r}}_{\text{radial direction}}$$

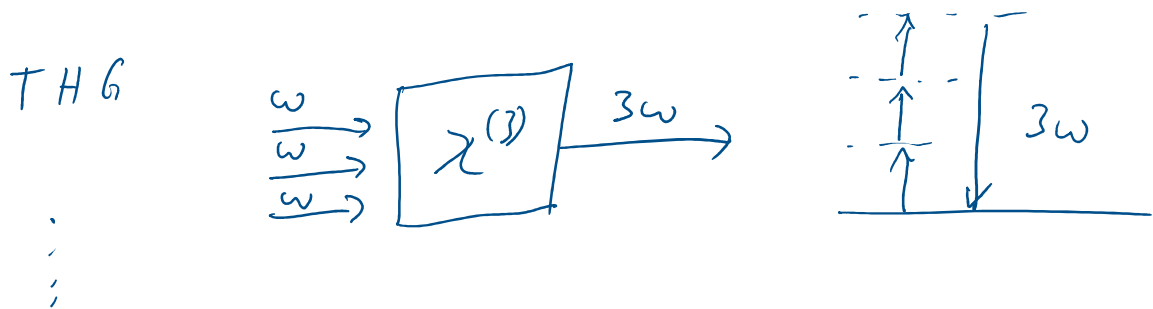
$$\ddot{\vec{r}} + 2\gamma \dot{\vec{r}} + \omega_0^2 \vec{r} - b(\vec{r} \cdot \vec{r})\vec{r} = -e \vec{E}(t)/m$$

$$\vec{E} = \vec{E}_1 e^{-i\omega_1 t} + \vec{E}_2 e^{-i\omega_2 t} + \vec{E}_3 e^{-i\omega_3 t} + \text{c.c.}$$

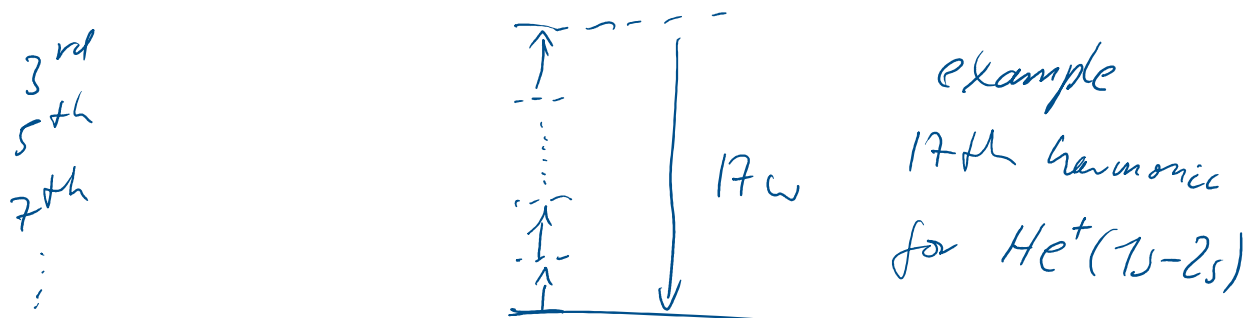
Same perturbation theory as before (1.4.39 ff)

→ no $\chi^{(2)}$, only $\chi^{(3)}$

This 3rd order nonlinear susceptibility $\chi^{(3)}$ is responsible for



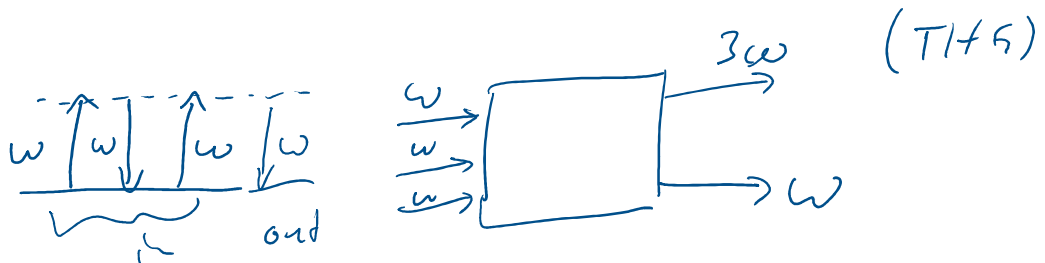
HHG (odd orders)



HHG done in gas jet \rightarrow much higher damage threshold
 Ar, Xe, Kr

(just ionization \rightarrow no problem)

also $\chi^{(3)}$: intensity-dependent refractive index

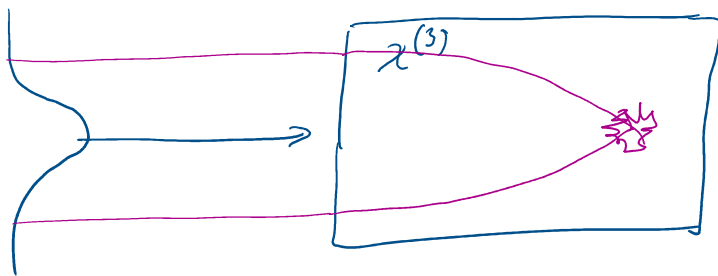


This leads to

$$n = n_0 + n_2 \cdot I$$

I intensity

$$n_2 = \frac{3}{2n_0^2 \epsilon_0 c} \chi^{(3)}$$

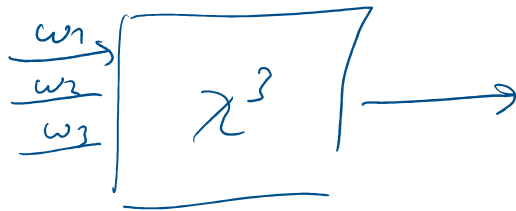


self-focusing of light

\rightarrow can lead to destruction of material

Other 3rd order interactions,

$$E = E_1 e^{-i\omega_1 t} + E_2 e^{-i\omega_2 t} + E_3 e^{-i\omega_3 t}$$

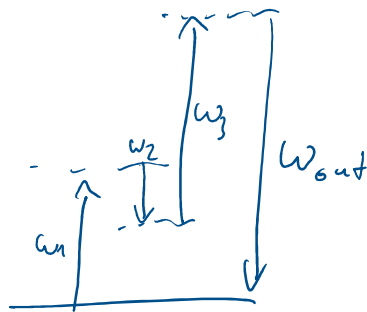


$$\omega_1 + \omega_2 + \omega_3$$

$$\omega_1 + \omega_2 - \omega_3$$

⋮

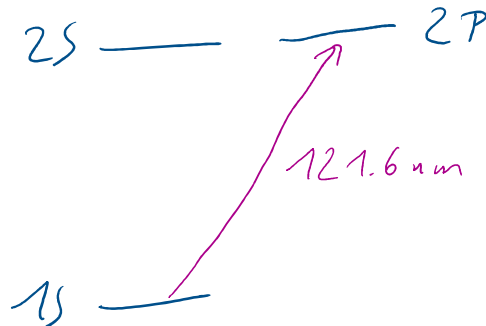
$\pm\omega_1 \pm \omega_2 \pm \omega_3$
 + all SHG
 + all SFG
 DFG



efficiency, damage threshold

example: Lyman- α laser 121.6nm

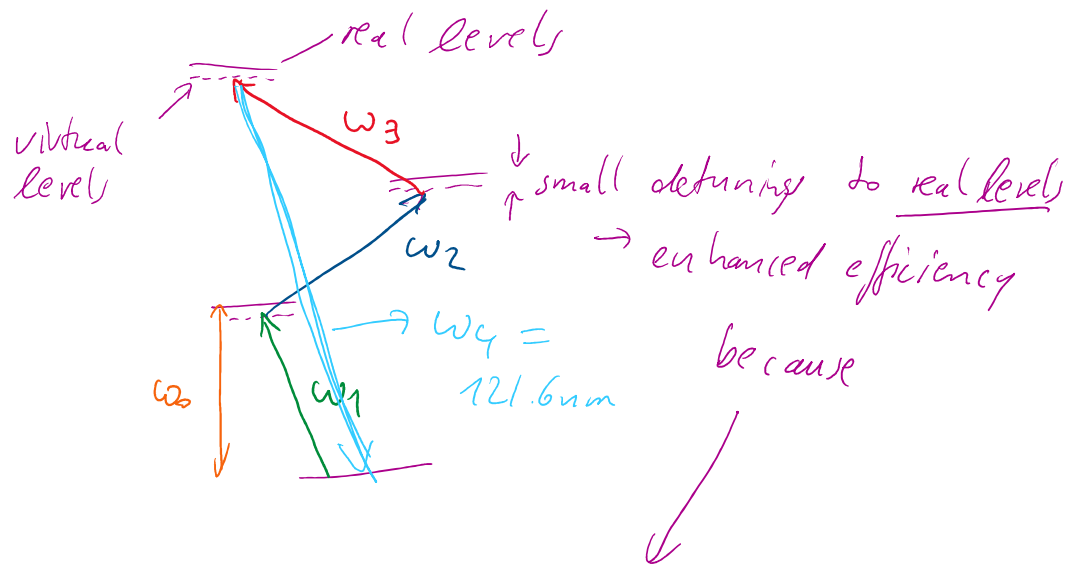
H



pulsed \rightarrow see ALPHA exp. @ CERN (H)

cw \rightarrow Jochen Walz

↓
4 wave-mixing in Hg vapour



$$D(\omega_i) = \underbrace{\omega_0^2 - \omega_i^2}_{\text{gets small}} - \gamma \omega_i$$

↑

in the denominator of $\chi^{(3)}$

4th homework option

SNLO

google

simulate NLO processes