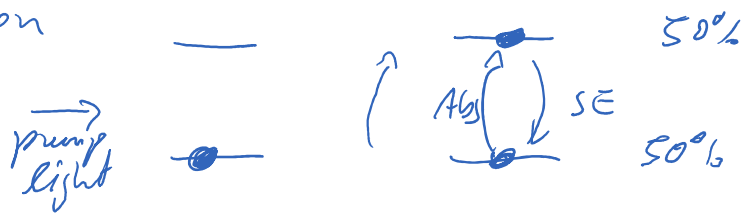


Q&A:

① Why does a laser need at least 3 energy levels

1) Inversion



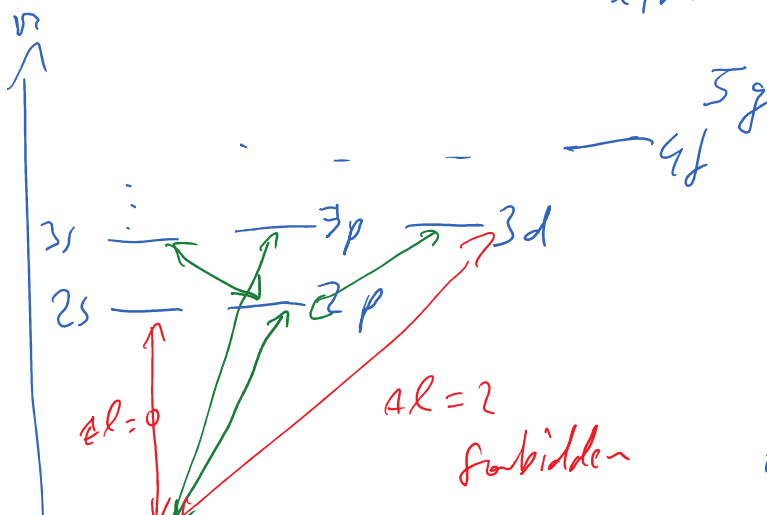
no inversion is possible by pumping on a 2-level system

3) ≥ 3 levels or more \Rightarrow separate pump & lasing transitions



② selection rules

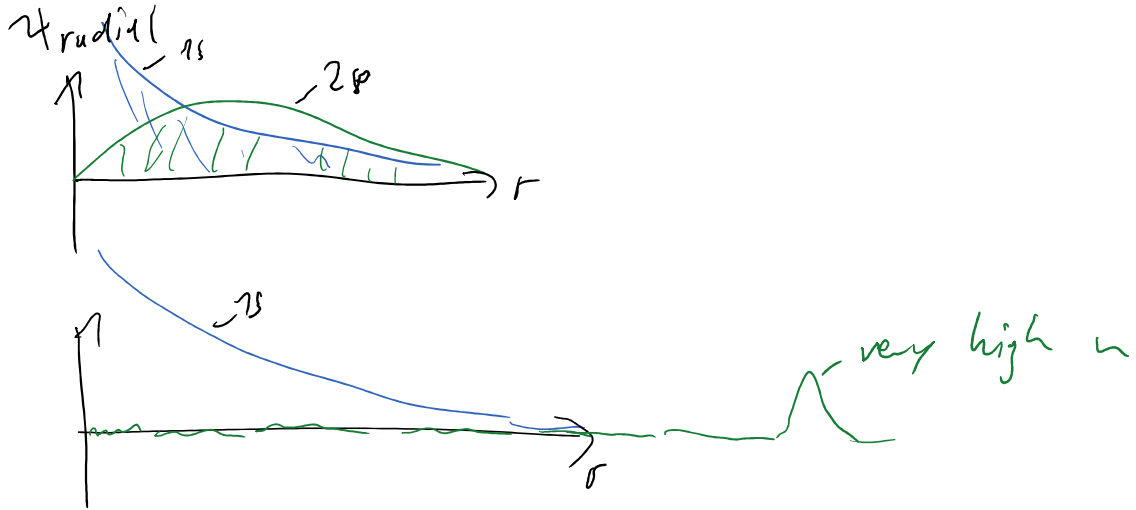
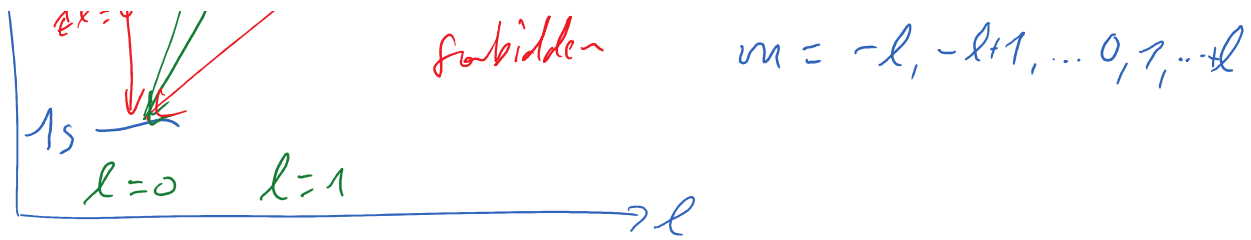
H-atom in SE : n radial part
 l, m angular part



$$n = 1, 2, 3, 4, \dots$$

$$l = 0, \dots, n-1$$

$$m = -l, -l+1, \dots, 0, 1, \dots, l$$



"allowed" transitions

↳ possible in electric Dipole transitions

$$\text{rate} \propto |e \vec{E}_0|^2 \left| \int \psi_2^* \vec{r} \cdot \vec{e}_{\text{rad}} \psi_1 d^3r \right|$$

↑
∝ intensity of laser

for $\vec{E}(t) = |\vec{E}_0| \text{Re}(e^{-i\omega t} \hat{e}_{\text{rad}})$

laser field

$$\vec{r} \propto Y_{l, l-1} \frac{\hat{e}_x + i \hat{e}_y}{\sqrt{2}} + Y_{l, 0} \hat{e}_z + Y_{l, l+1} \frac{-\hat{e}_x + i \hat{e}_y}{\sqrt{2}}$$

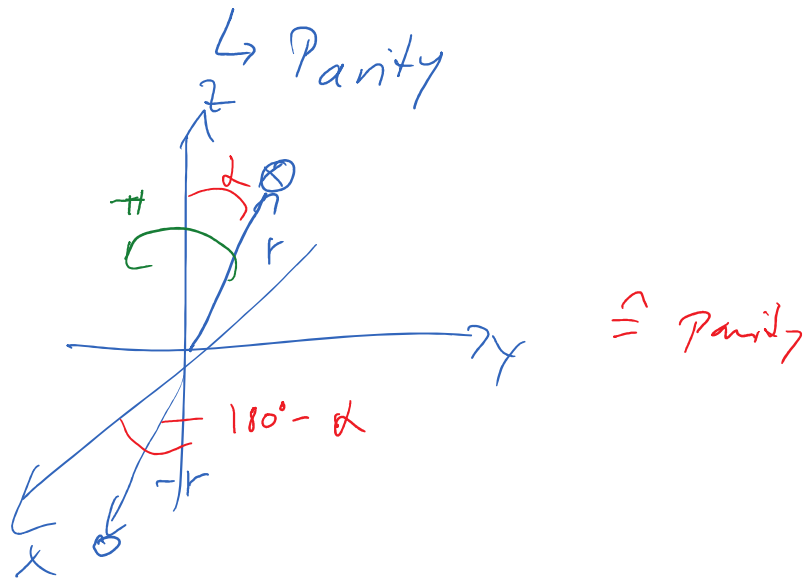
↑ ↑
π
σ⁺ polariz.

σ⁻

$$l = \pm 1$$

photon momentum = 1th k

$l = 0$ is forbidden



physics invariant under \hat{P}
(= same)

matrix elements same under \hat{P}

$$\hat{P} Y_{lm} = (-1)^l Y_{lm} \quad (2.41)$$

$$F_{ang} = \underbrace{(-1)^{l_2 + l_1 + 1}}_{= +1} F_{ang} \quad (2.42)$$

$$l_2 + l_1 + 1 = \text{even}$$

if $l_1 = l_2 \Rightarrow l_1 + l_1 + 1 =$
 $2l_1 + 1 = \underline{\text{always odd}}$

for $l_1 = l_2$ (2.42) become,

$$I_{\text{arg}} = -I_{\text{arg}}$$

only true for $I_{\text{arg}} = 0$

no transition possible

σ, π is related to Δm

