Scope of the Lecture

1. Stimulated transition rates, x-sections, line-shapes
2. Nonradiative decay
3. Resonant energy transfer
4. Strongly coupled levels
5. Gain and absorption saturation
6. Spectral and spatial hole-burning
7. Amplified spontaneous emission

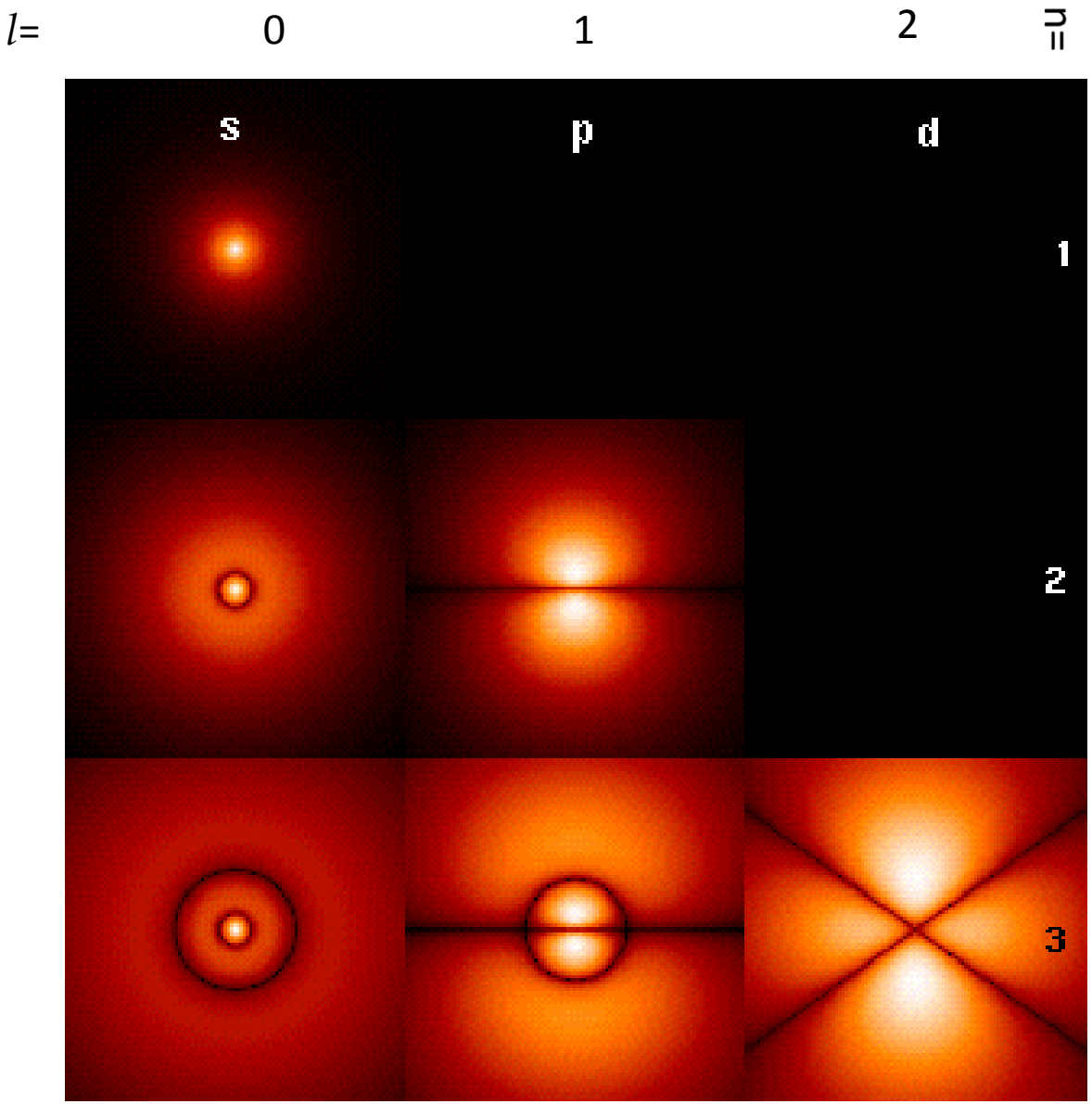
Reading: Ch 2.6, 2.7, 2.8, 2.9*

Electronic configurations

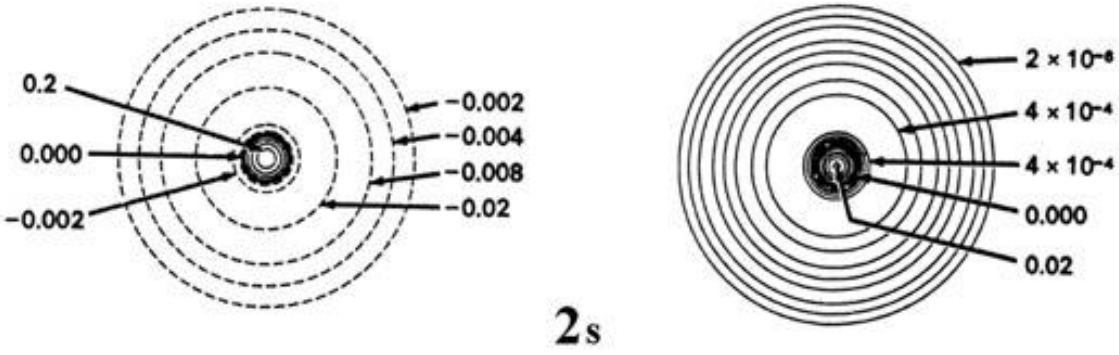
1A											2A	3A	4A	5A	6A	7A	8A
1 **H** $1s^1$											4 **Be** $2s^2$	5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	2 **He** $1s^2$
3 **Li** $2s^1$	4 **Be** $2s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	10 **Ne** $2s^22p^6$
11 **Na** $3s^1$	12 **Mg** $3s^2$	3B	4B	5B	6B	7B	8B			1B	2B						18 **Ar** $3s^23p^6$
19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $3d^14s^2$	22 **Ti** $3d^24s^2$	23 **V** $3d^34s^2$	24 **Cr** $3d^54s^1$	25 **Mn** $3d^54s^2$	26 **Fe** $3d^64s^2$	27 **Co** $3d^74s^2$	28 **Ni** $3d^84s^2$	29 **Cu** $3d^{10}4s^1$	30 **Zn** $3d^{10}4s^2$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $4d^15s^2$	40 **Zr** $4d^25s^2$	41 **Nb** $4d^45s^1$	42 **Mo** $4d^55s^1$	43 **Tc** $4d^55s^2$	44 **Ru** $4d^75s^1$	45 **Rh** $4d^85s^1$	46 **Pd** $4d^{10}$	47 **Ag** $4d^{10}5s^1$	48 **Cd** $4d^{10}5s^2$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
55 **Cs** $6s^1$	56 **Ba** $6s^2$	57 ***La** $5d^16s^2$	72 **Hf** $5d^26s^2$	73 **Ta** $5d^36s^2$	74 **W** $5d^46s^2$	75 **Re** $5d^56s^2$	76 **Os** $5d^66s^2$	77 **Ir** $5d^76s^2$	78 **Pt** $5d^96s^1$	79 **Au** $5d^{10}6s^1$	80 **Hg** $5d^{10}6s^2$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
87 **Fr** $7s^1$	88 **Ra** $7s^2$	89 †**Ac** $6d^17s^2$	104 **Rf** $6d^27s^2$	105 **Db** $6d^37s^2$	106 **Sg** $6d^47s^2$	107 **Bh**	108 **Hs**	109 **Mt**	110	111	112	Unknown	114	Unknown	††116	Unknown	††118

*	58 **Ce** $4f^26s^2$	59 **Pr** $4f^36s^2$	60 **Nd** $4f^46s^2$	61 **Pm** $4f^56s^2$	62 **Sm** $4f^66s^2$	63 **Eu** $4f^76s^2$	64 **Gd** $4f^75d^16s^2$	65 **Tb** $4f^96s^2$	66 **Dy** $4f^{10}6s^2$	67 **Ho** $4f^{11}6s^2$	68 **Er** $4f^{12}6s^2$	69 **Tm** $4f^{13}6s^2$	70 **Yb** $4f^{14}6s^2$	71 **Lu** $4f^{14}5d^16s^2$
†	90 **Th** $6d^27s^2$	91 **Pa** $5f^26d^17s^2$	92 **U** $5f^36d^17s^2$	93 **Np** $5f^46d^17s^2$	94 **Pu** $5f^67s^2$	95 **Am** $5f^77s^2$	96 **Cm** $5f^76d^17s^2$	97 **Bk** $5f^97s^2$	98 **Cf** $5f^{10}7s^2$	99 **Es** $5f^{11}7s^2$	100 **Fm** $5f^{12}7s^2$	101 **Md** $5f^{13}7s^2$	102 **No** $5f^{14}7s^2$	103 **Lr** $5f^{14}6d^17s^2$

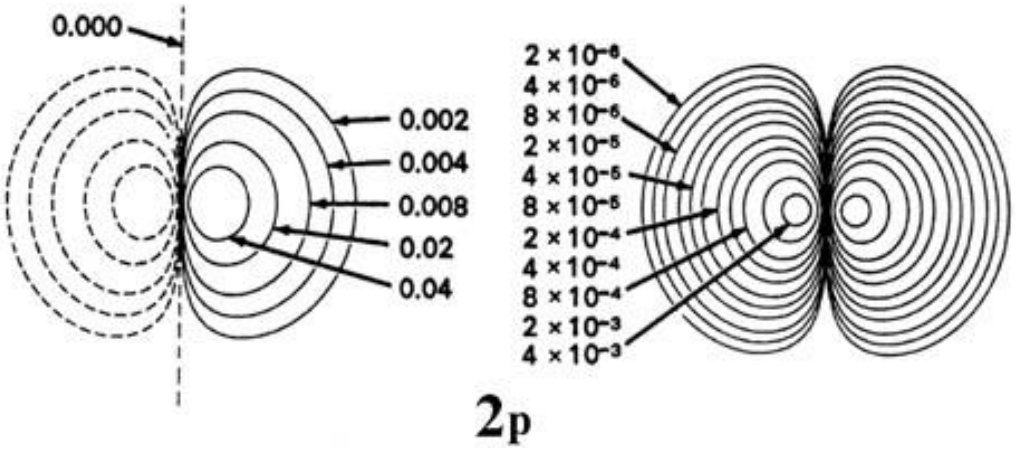
Atomic Orbitals

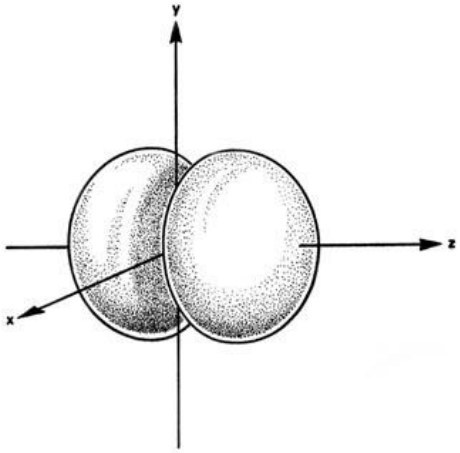


Wavefunction: $\psi_n(r)$ **Charge density:** $\int \psi_n^*(r)\psi_n(r)dr$



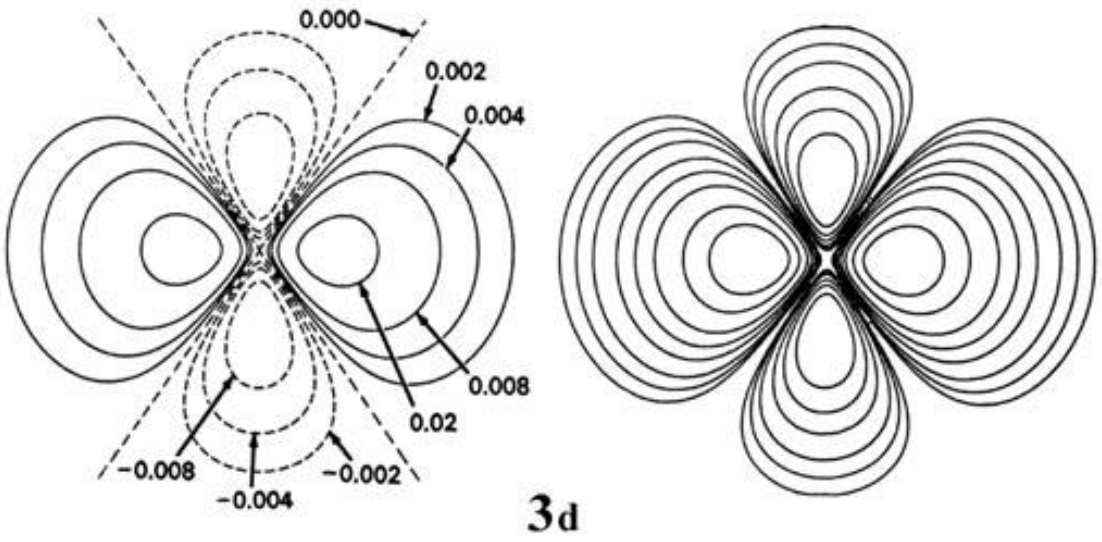
Even parity
l=0



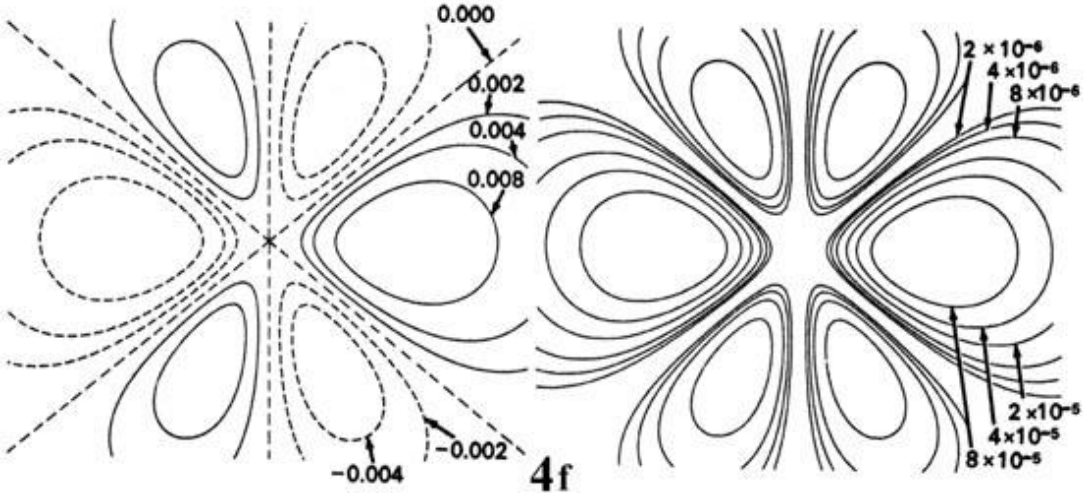


Odd parity
l=1

Wavefunction: $\psi_n(r)$ **Charge density:** $\int \psi_n^*(r)\psi_n(r)dr$

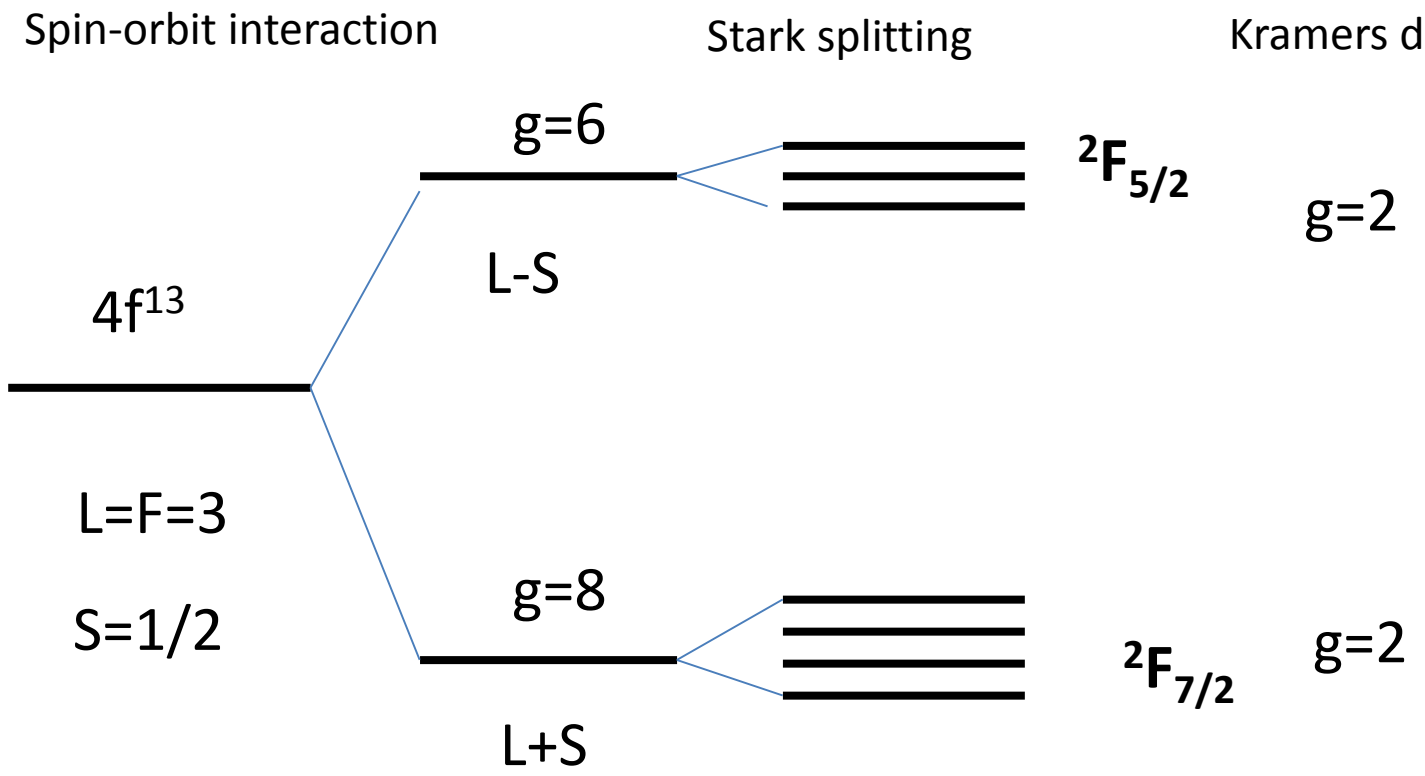


Even parity
l=2



Odd parity
l=3

Yb^{3+} active ion

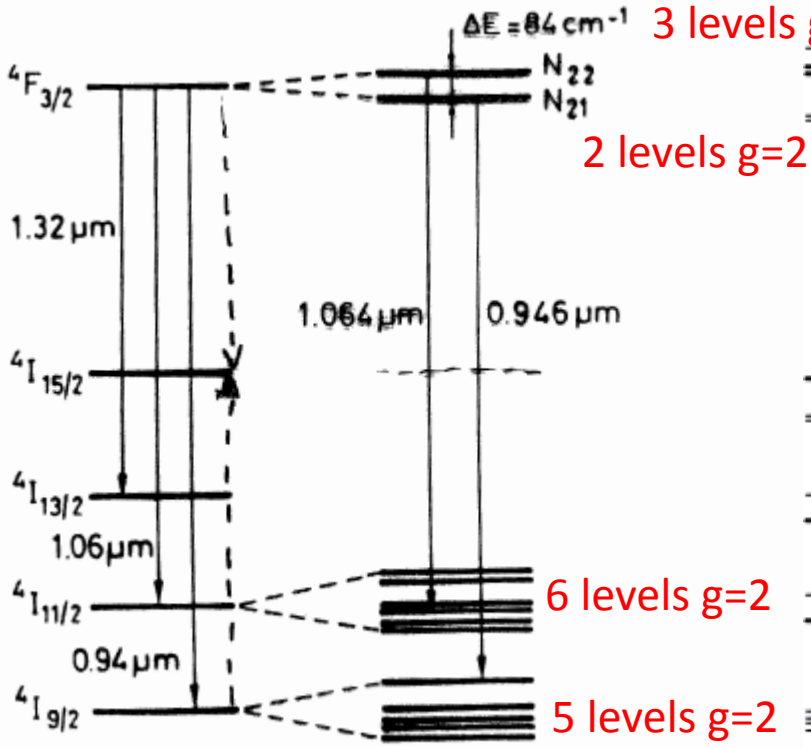


$^{2S+1}L_J$ **J=L±S** g=2J+1

$$L = \sum l; \quad S = \sum s$$

Stark splitting of degenerate states in crystals

Nd^{3+}: $4f^3$



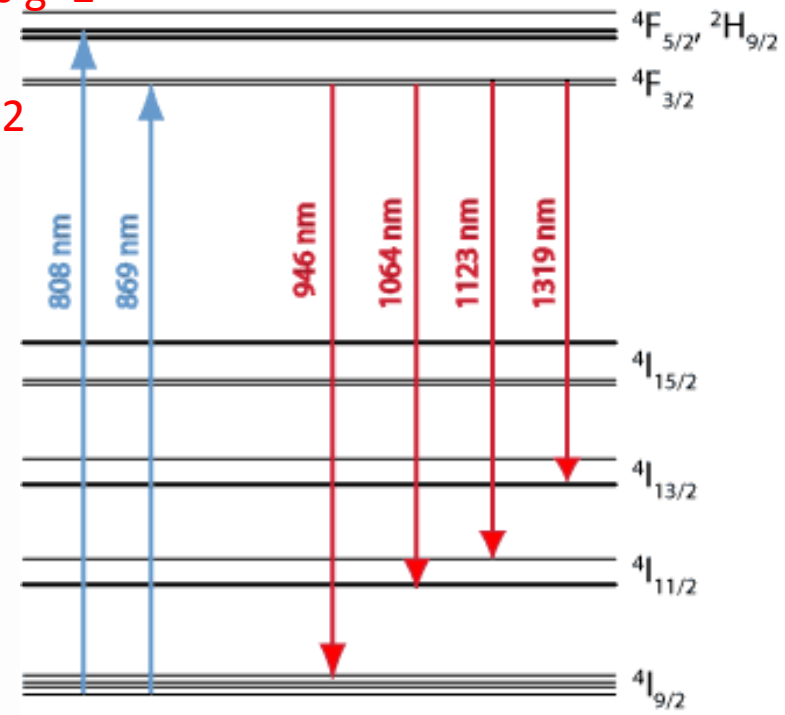
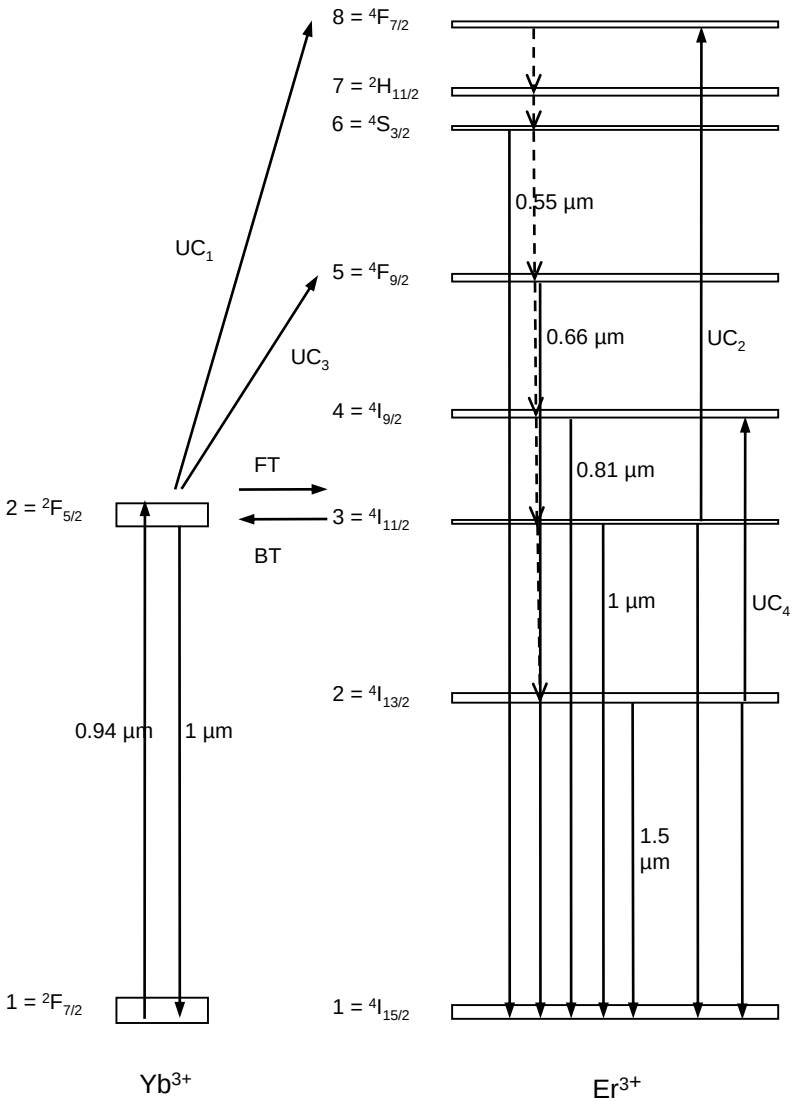


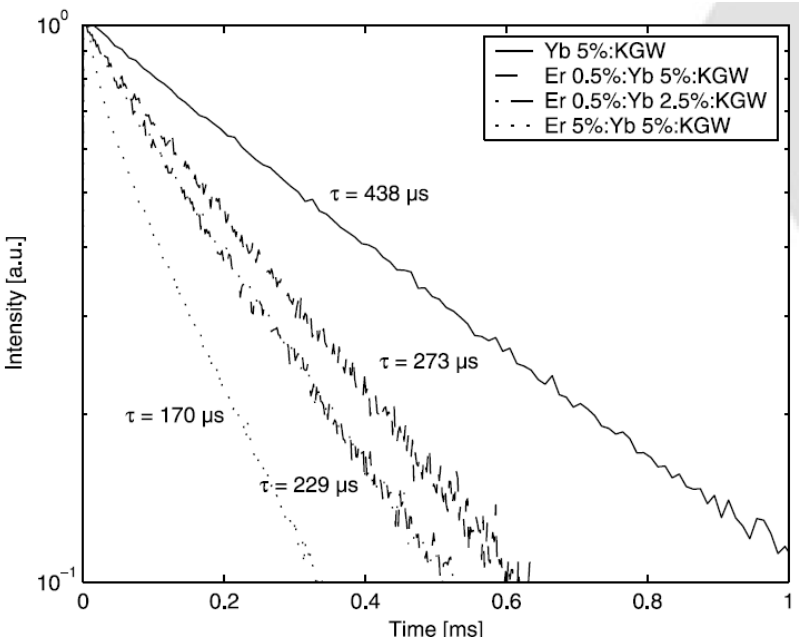
FIG. 2.15. Relevant energy levels for the $\lambda = 1.064$-μm laser transition of Nd:YAG laser.

- l configurations: $F_{3/2}$: ↓↓↑ $I_{9/2}$: ↓↓← $M_{15/2}$: ↓↓↓

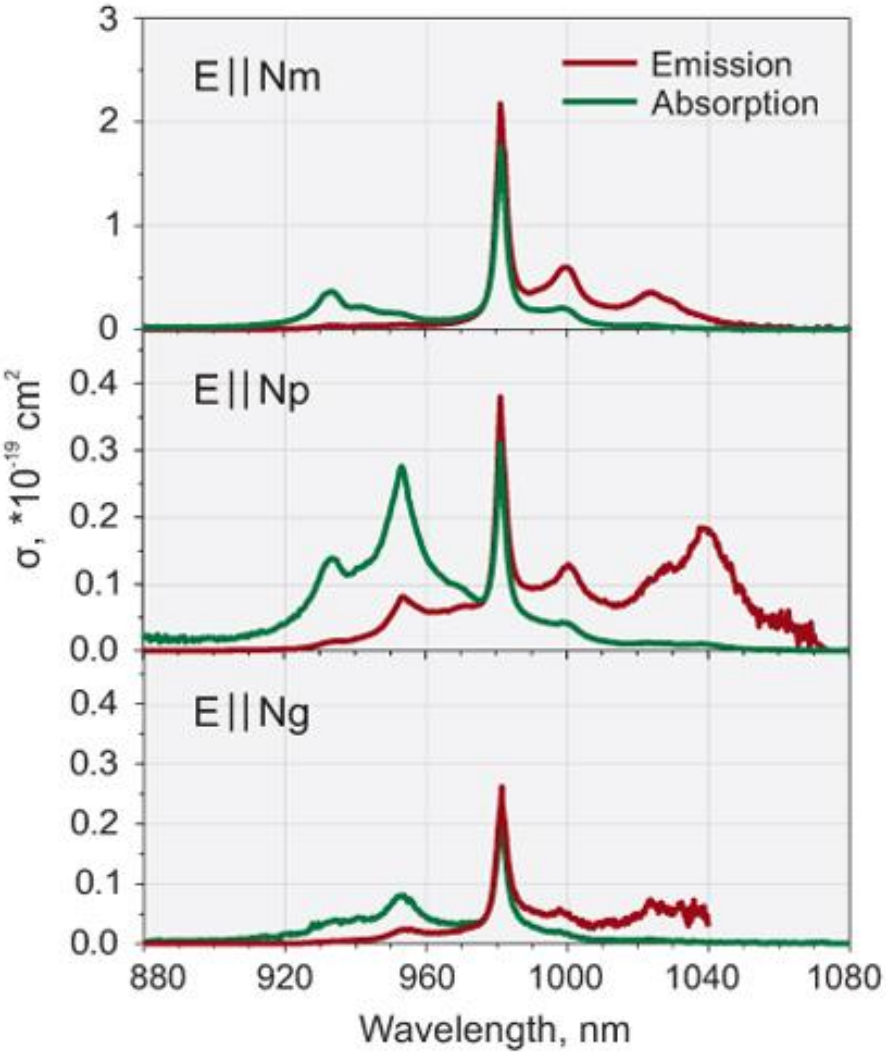
L=3 L=6 L=9

Er:Yb system: resonant excitation transfer





Absorption and emission in closely coupled level systems



$Yb:KY(WO_4)_2$

Saturation of homogeneously broadened line

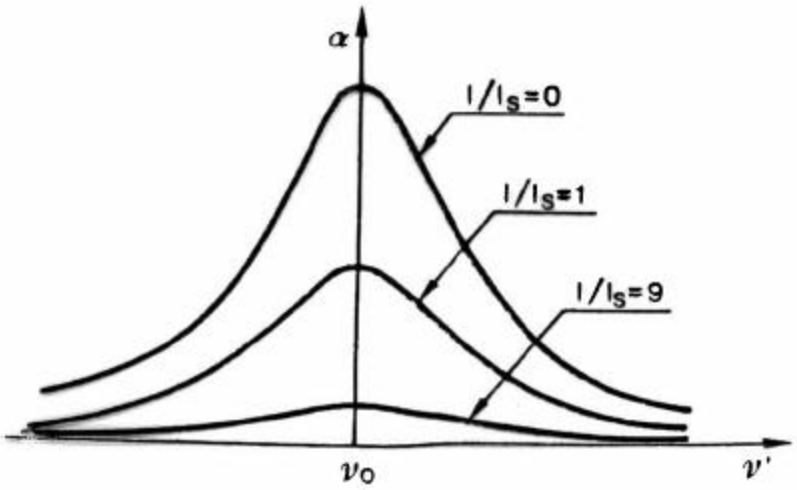
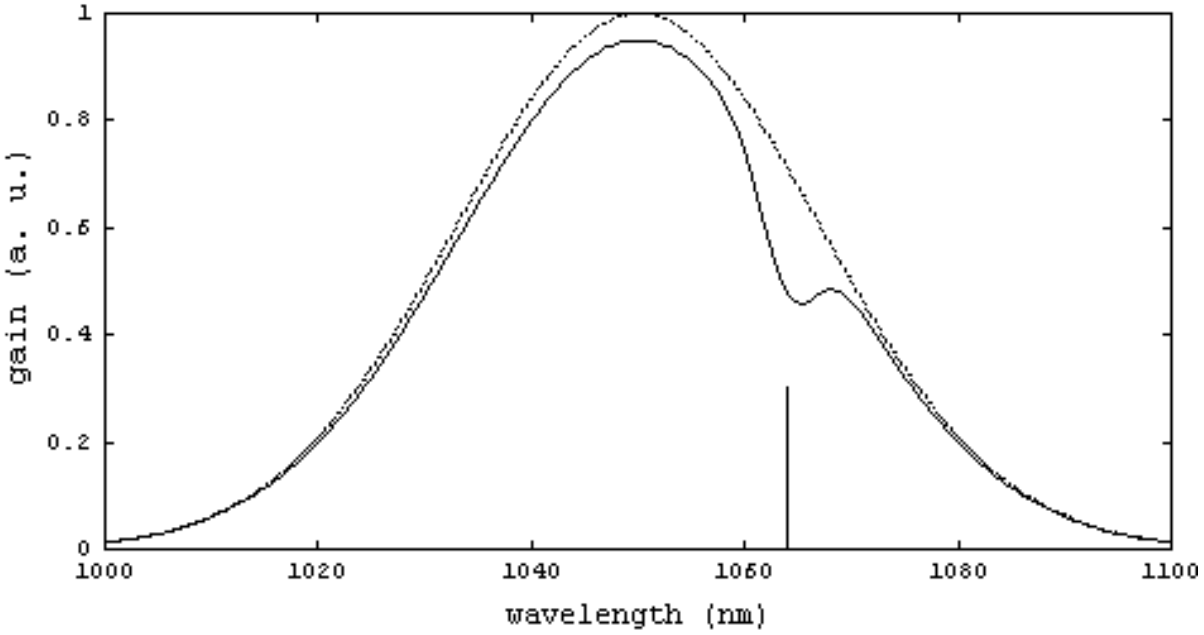


FIG. 2.19. Saturation behavior of the absorption coefficient α versus frequency ν' for increasing values of intensity I of the saturating beam (homogeneous line).

Gain saturation in nonhomogeneous media



Spectral hole-burning

ASE Spectral narrowing

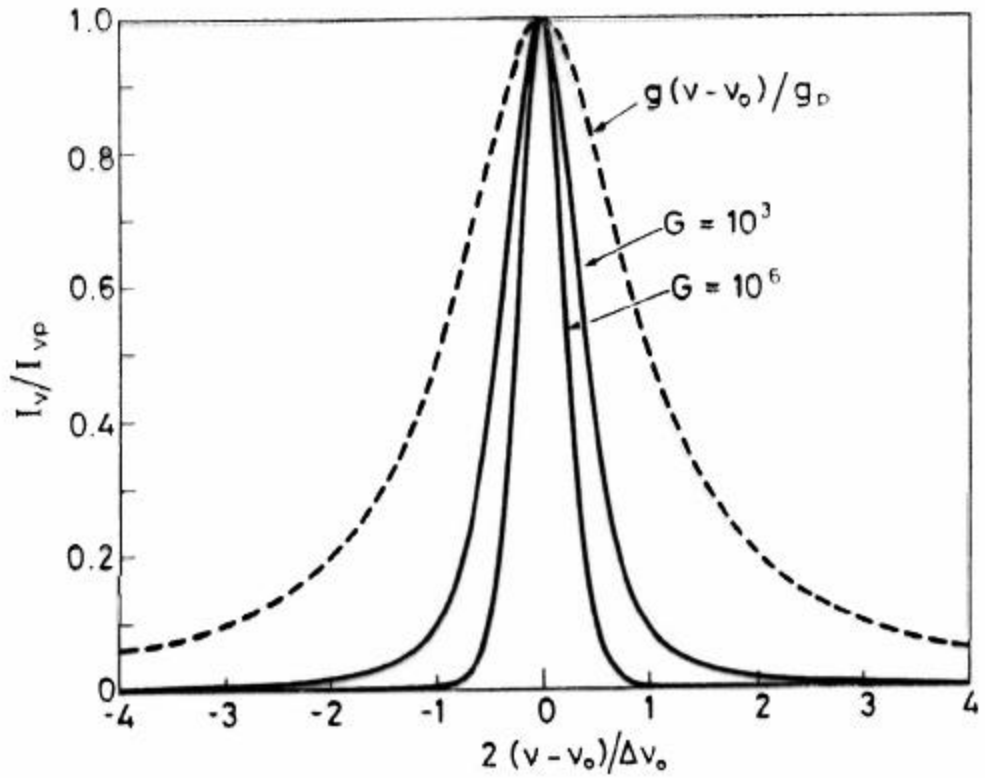


Fig. 2.24. Normalized ASE spectral emission at two different values of the peak, unsaturated, single-pass gain.

Main Keywords

Collisional and multiphonon relaxation
Elastic and inelastic collisions
Cross-relaxation, upconversion, excitation migration and trapping
Degeneracy of electronic levels
Thermalisation of strongly coupled levels
Saturation intensity, saturation fluence
Spectral hole-burning

Problems

2.5, 2.6, 2.8, 2.13, 2.14, 3.2, 3.3,3.4
Examples: 2.10, 3.1