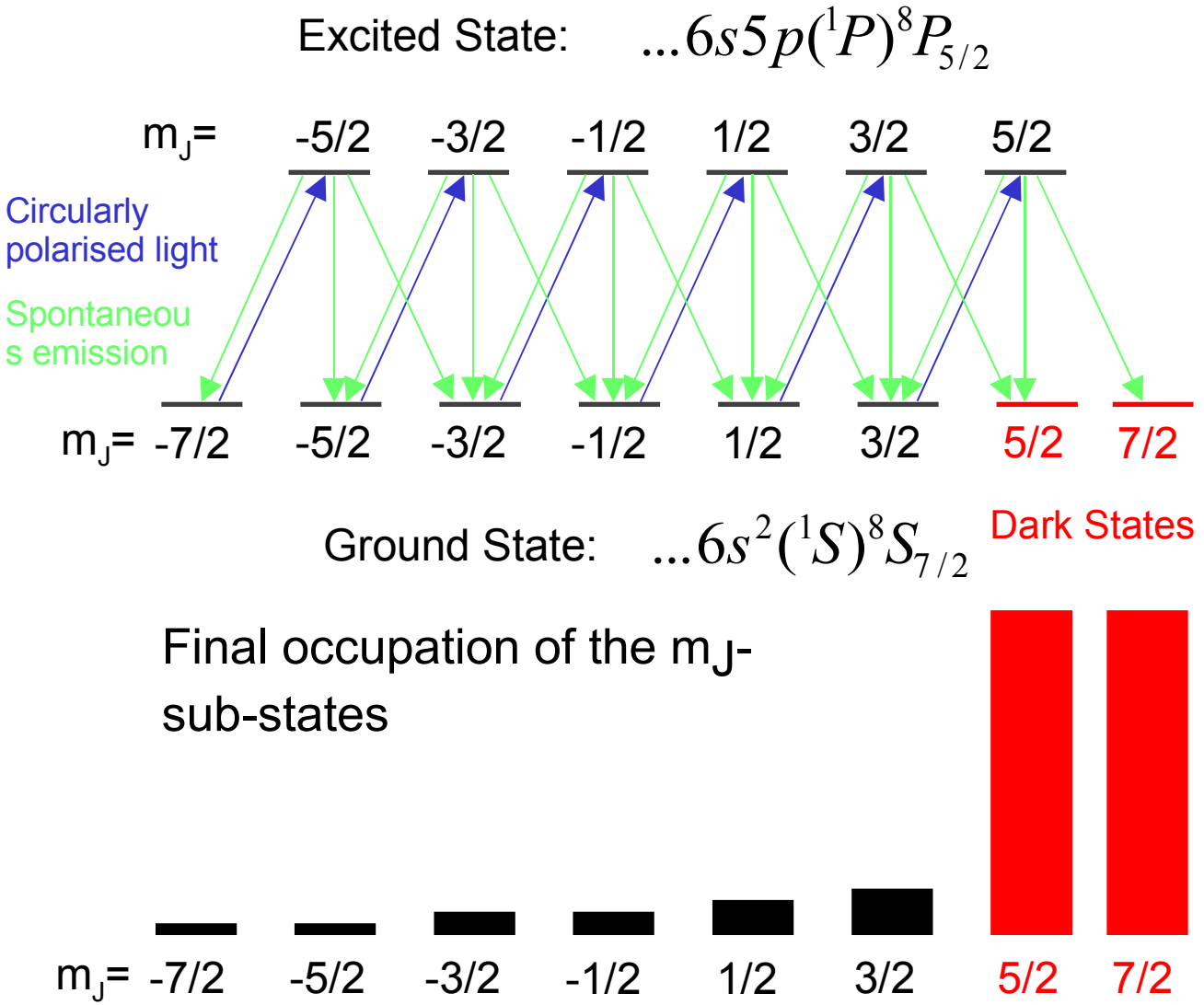
Combining laser light with synchrotron radiation

Part 6

Hyperfine structure

Examples of experiments combining synchrotron radiation with lasers

Optical Pumping into an Oriented Ground State



Hyperfine structure

The electron angular momentum J couples to the nuclear spin I to a total angular momentum F

Laser radiation easily resolves the hyperfine splitting

Not the L,m_L but the F, m_F eigenstates are pumped:

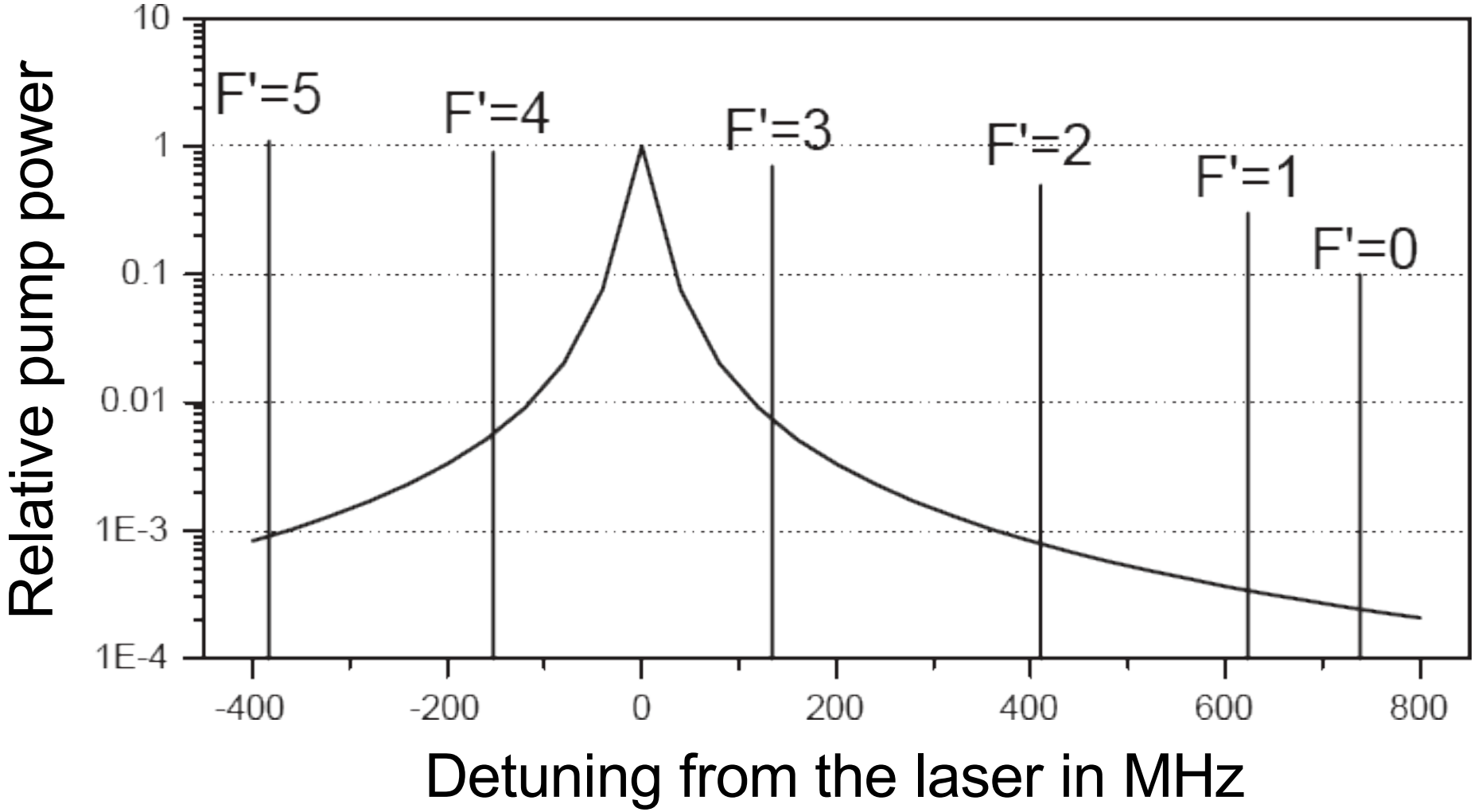
F,m_F

$$|6,6\rangle = \left| m_J = \frac{7}{2}, m_I = \frac{5}{2} \right\rangle$$

$$|6,5\rangle = \frac{1}{2}\sqrt{\frac{5}{3}} \left| m_J = \frac{7}{2}, m_I = \frac{3}{2} \right\rangle + \frac{1}{2}\sqrt{\frac{7}{3}} \left| m_J = \frac{5}{2}, m_I = \frac{5}{2} \right\rangle$$

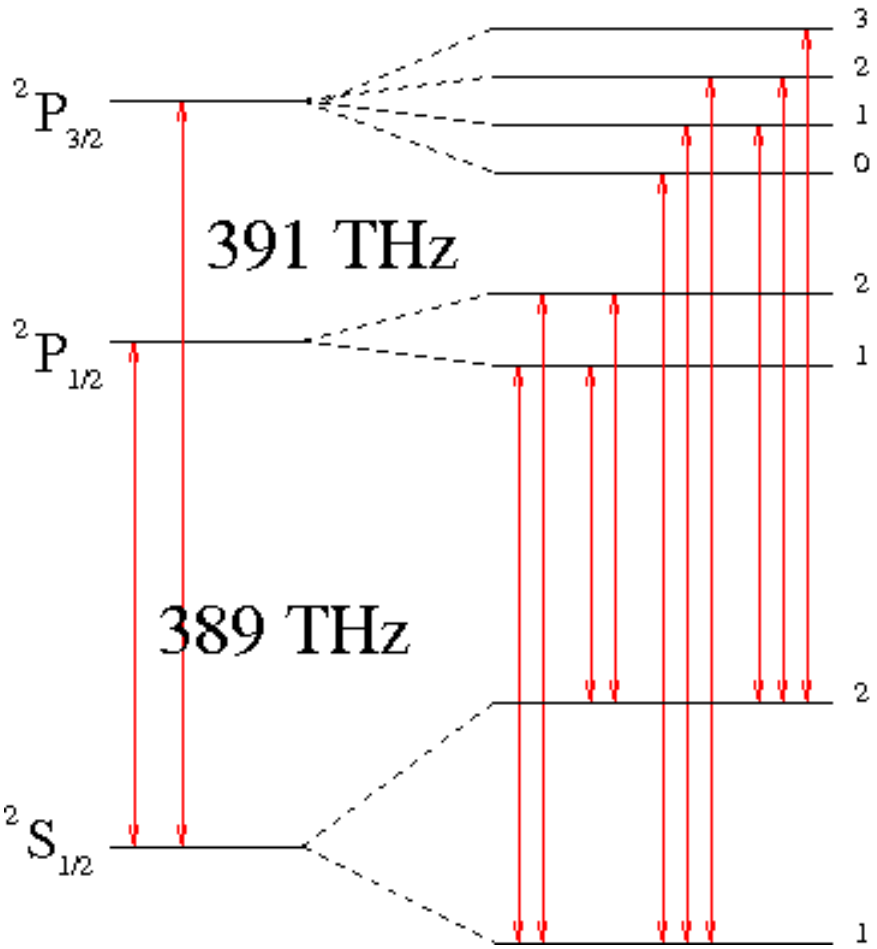
$$|5,5\rangle = \frac{1}{2}\sqrt{\frac{7}{3}} \left| m_J = \frac{7}{2}, m_I = \frac{3}{2} \right\rangle - \frac{1}{2}\sqrt{\frac{5}{3}} \left| m_J = \frac{5}{2}, m_I = \frac{5}{2} \right\rangle$$

Laser pumping of all Hyperfine States



Lorentzian linewidths of the atoms allow for pumping of all states

Potassium hyperfine structure



1.6 eV

0,1 μeV

2 μeV

Isotope	Mass	Abundance	Spin	Mag Moment
^{23}Na	22.989767	100%	3/2	2.21752

Isotope	Mass	Abundance	Spin	Mag Moment
^{39}K	38.963707	93.2581%	3/2	+0.39146
^{40}K	39.963999	0.012%	4	-1.298
^{41}K	40.961825	6.7302%	3/2	+0.21487

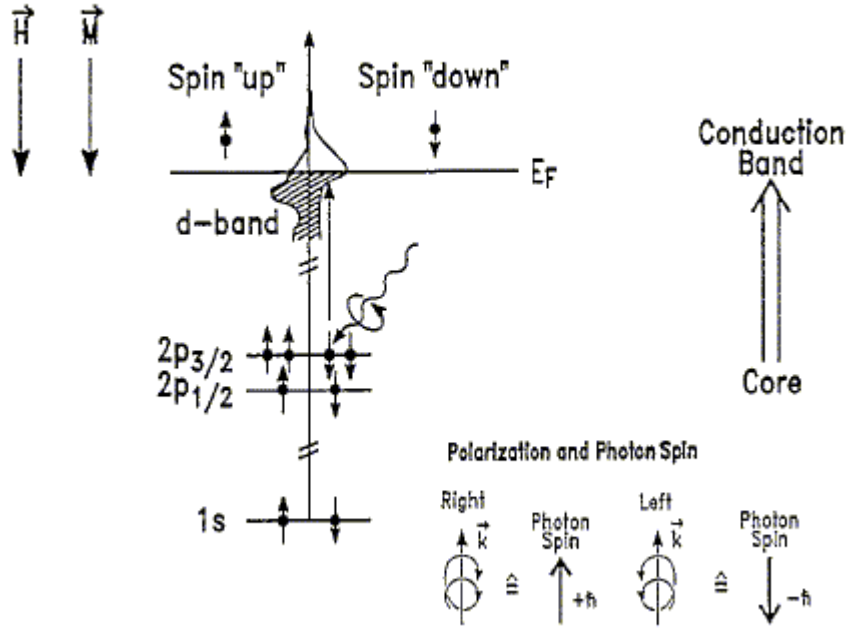
Isotope	Mass	Abundance	Spin	Mag Moment
^{85}Rb	84.911794	72.17%	5/2	+1.35302
^{87}Rb	86.909187	27.83%	3/2	+2.7512

Isotope	Mass	Abundance	Spin	Mag Moment
^{133}Cs	132.905429	100%	7/2	+2.579

Orientation in solid systems: Ferromagnetism

In the ferromagnets Fe, Co, and Ni the magnetic moments of the atoms are oriented.

Can be probed with
X-ray Magnetic Circular Dichroism (XMCD)



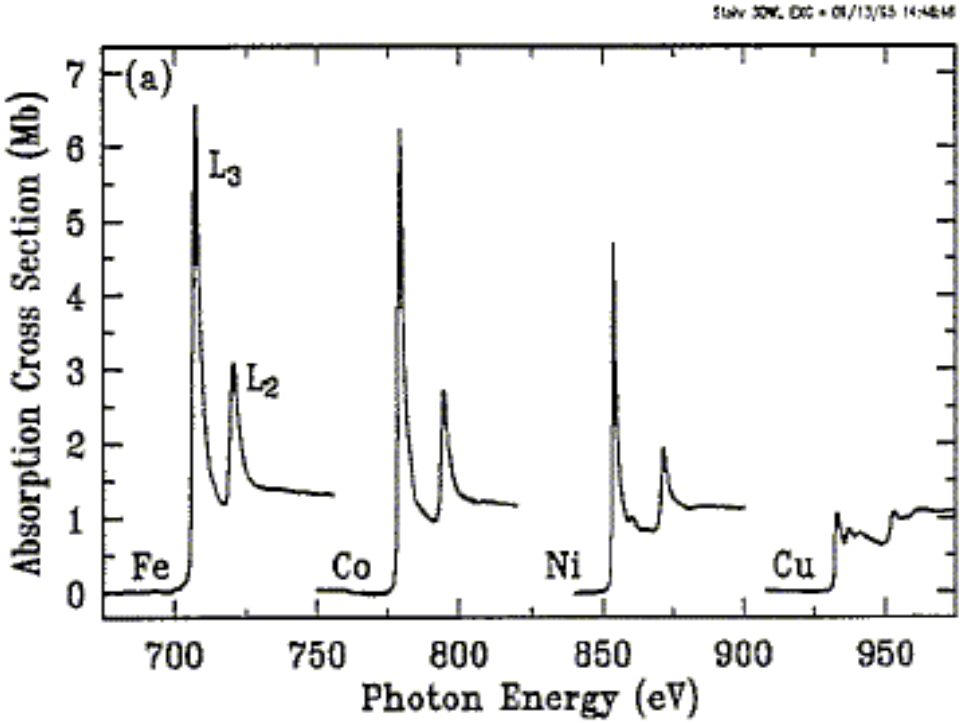
X-ray absorption spectroscopy

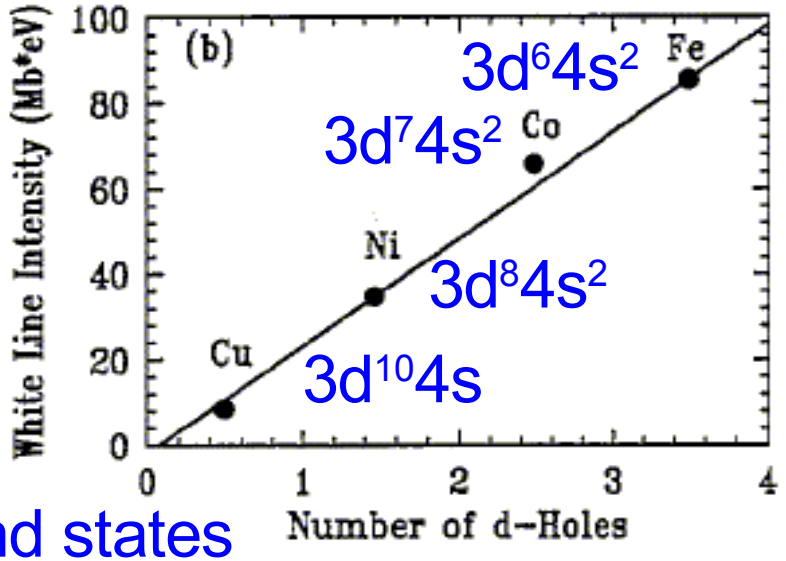
Excitation of a core electron into the conduction band

L_3: $2p_{3/2}$

L_2: $2p_{1/2}$

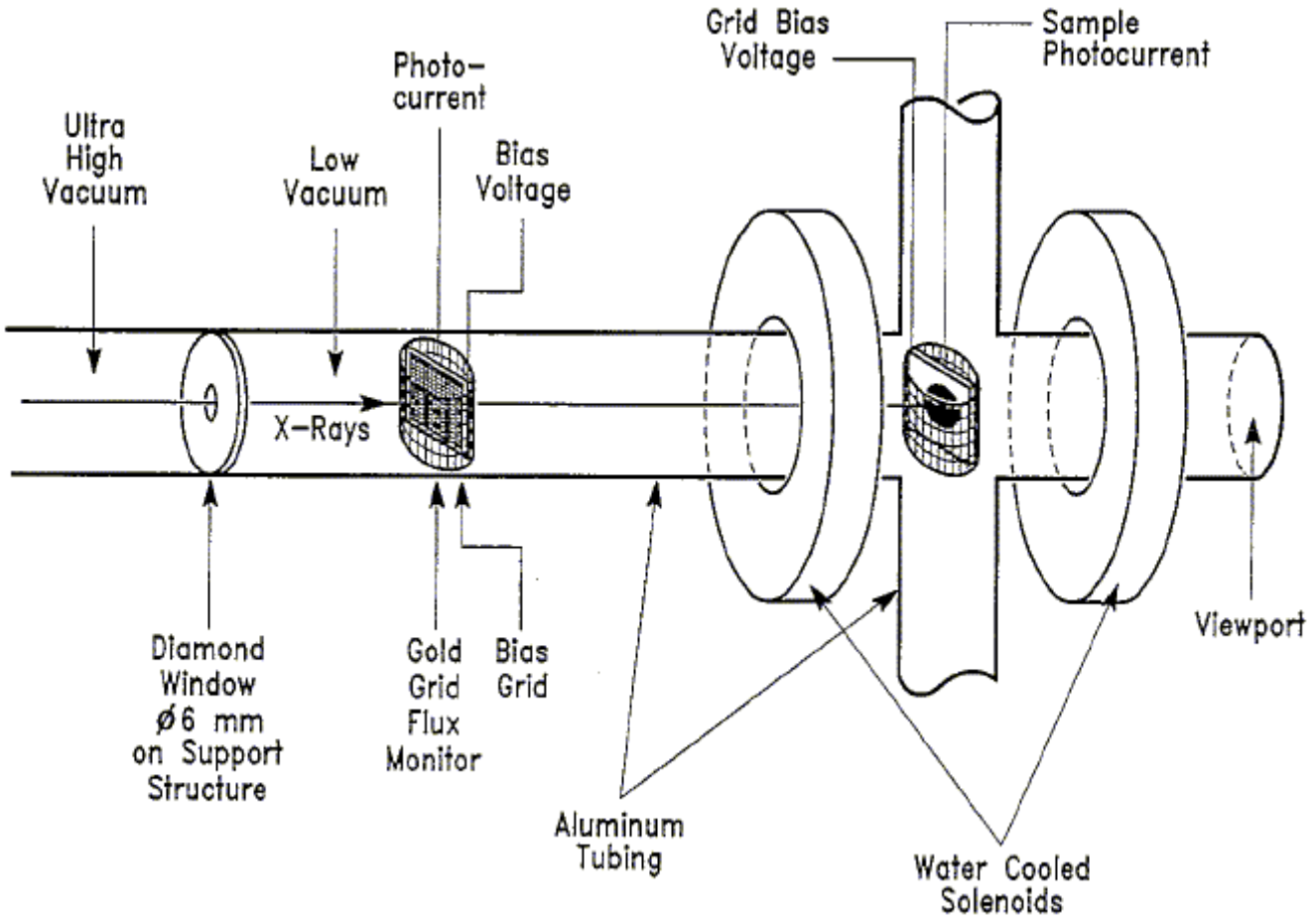
Intensity proportional to the number of d-Holes in the conduction band



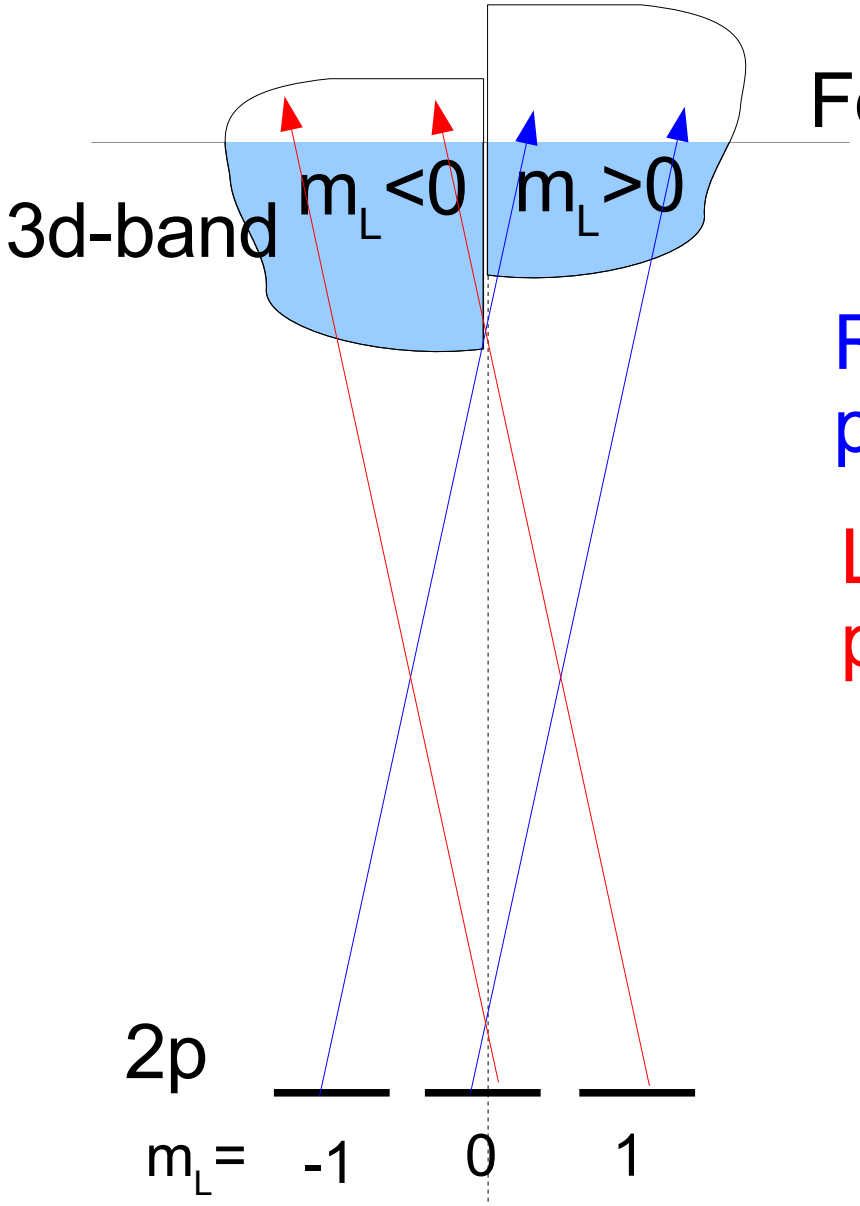


Atomic ground states

XMCD Experimental Setup



Orbital magnetic moment



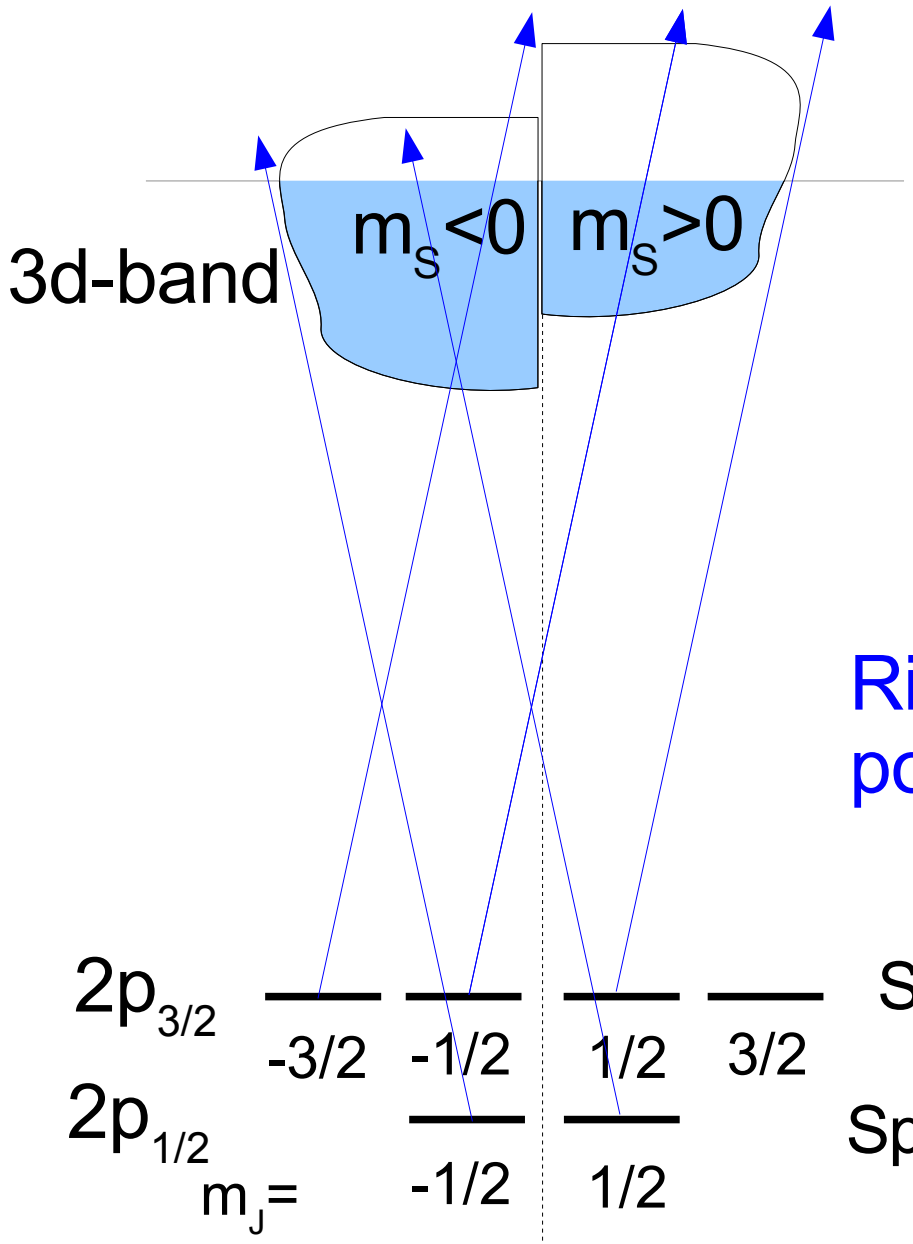
Right handed polarized x-rays

Left handed polarized x-rays

The difference between the absorption of right and left handed circular x-rays gives information about the angular magnetism.

$$I_{rhp}-I_{Lhp} \propto \langle m_L \rangle$$

Spin magnetic moment



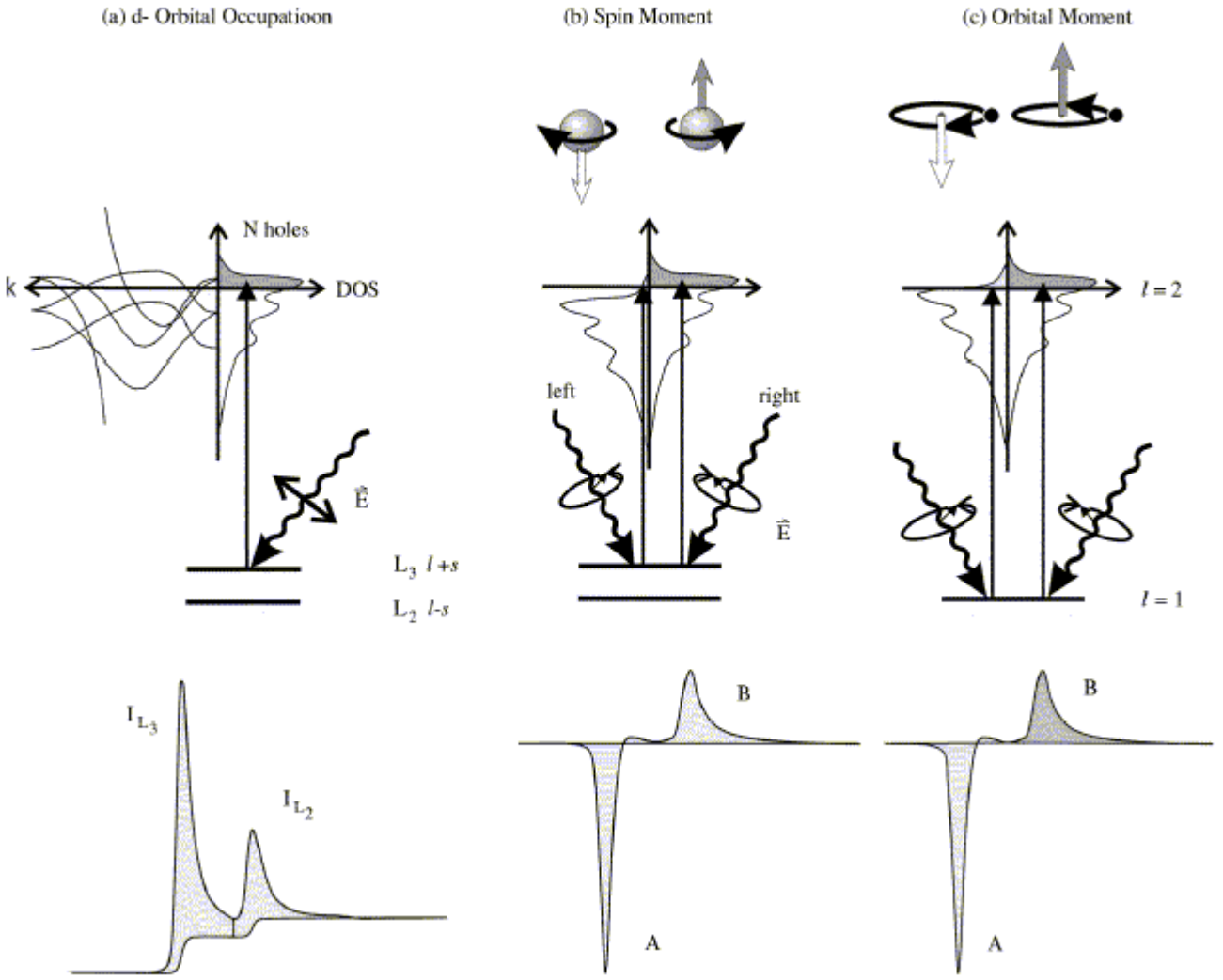
The weighted difference of the hyperfine signals gives the spin magnetic moment.

Right handed polarized x-rays

Spin parallel to orbit

Spin anti-parallel to orbit

XMCD-Overview

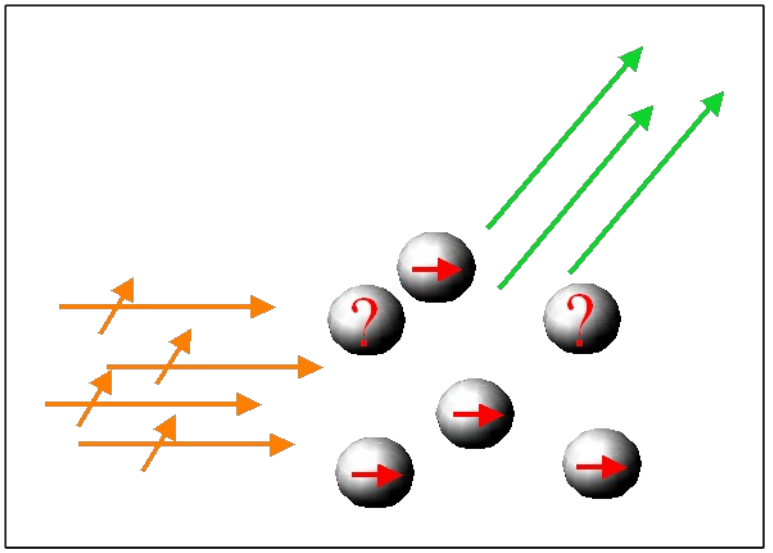


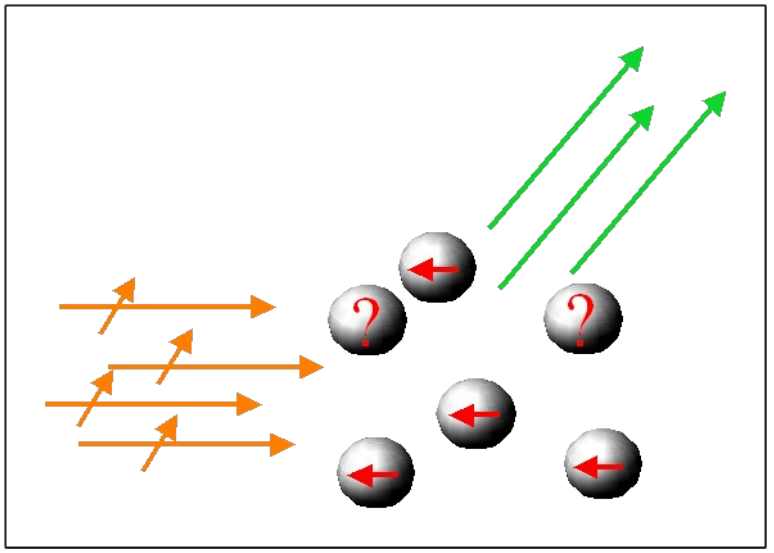
Linear Dichroism in Photoemission

A magnetic field would disturb the electron emission!

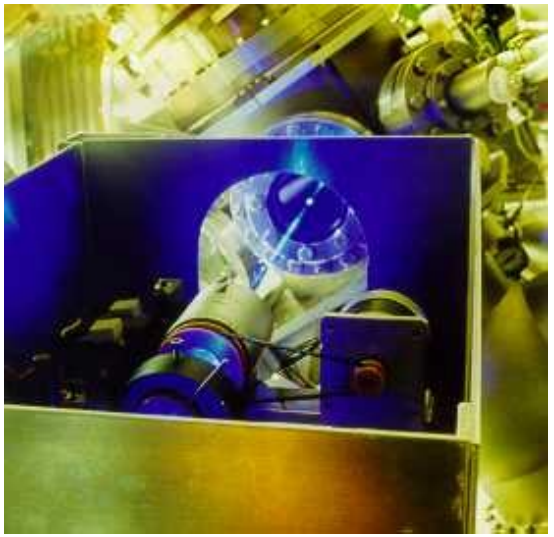
Lasers can be used for orienting the atoms

Linear Magnetic Dichroism in the Angular Distribution (LMDAD)





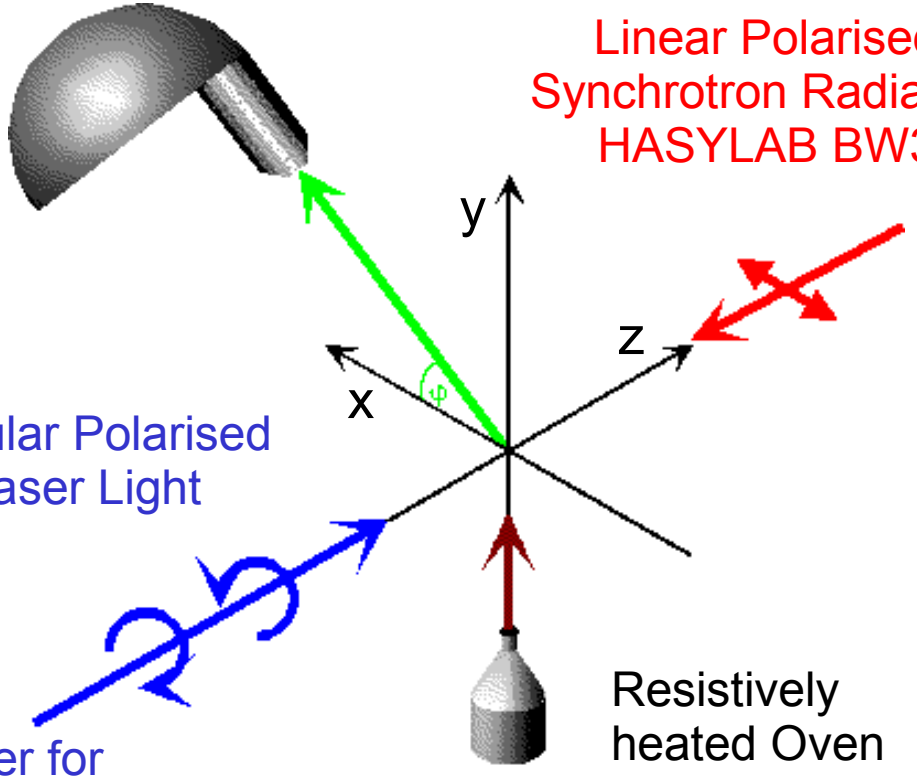
Setup in Hamburg



466 nm for Eu
429 nm for Cr
372 nm for Fe

Scienta SES200
Electron Analyser

Linear Polarised
Synchrotron Radiation
HASYLAB BW3



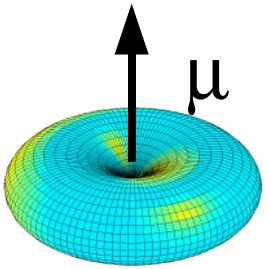
Circular Polarised
Laser Light

CW Dye Laser for
Optical Pumping

Resistively
heated Oven

Symmetry Considerations

Circular light orients the atoms



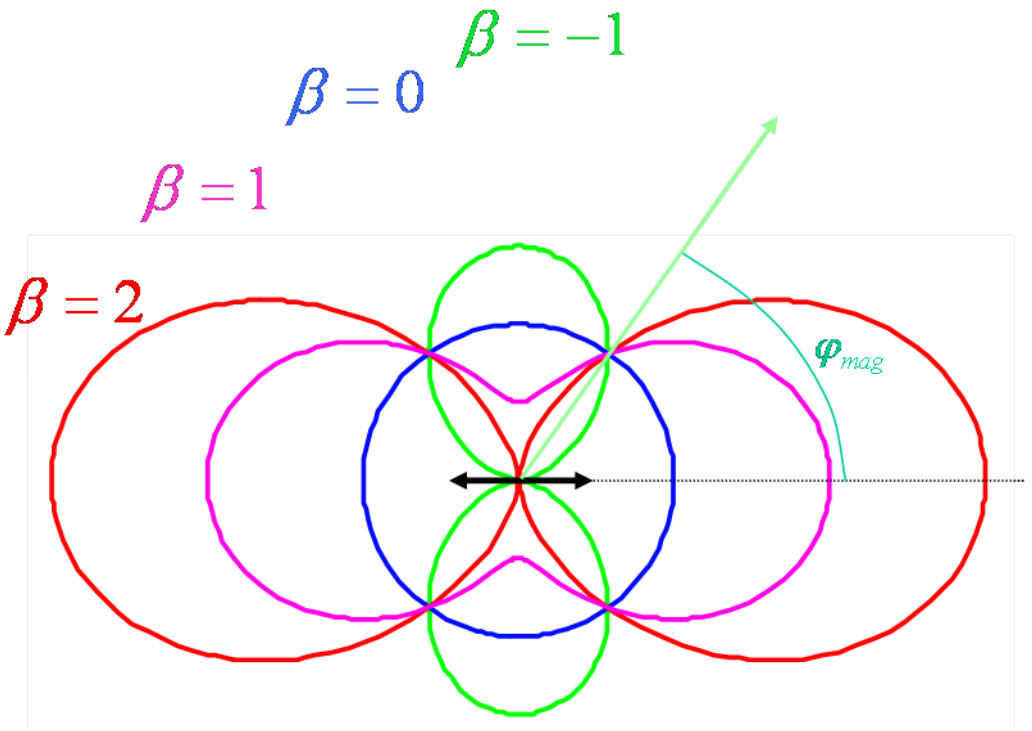
Photoemission by linearly polarized synchrotron radiation

Linear polarized light can be split into two circular components.

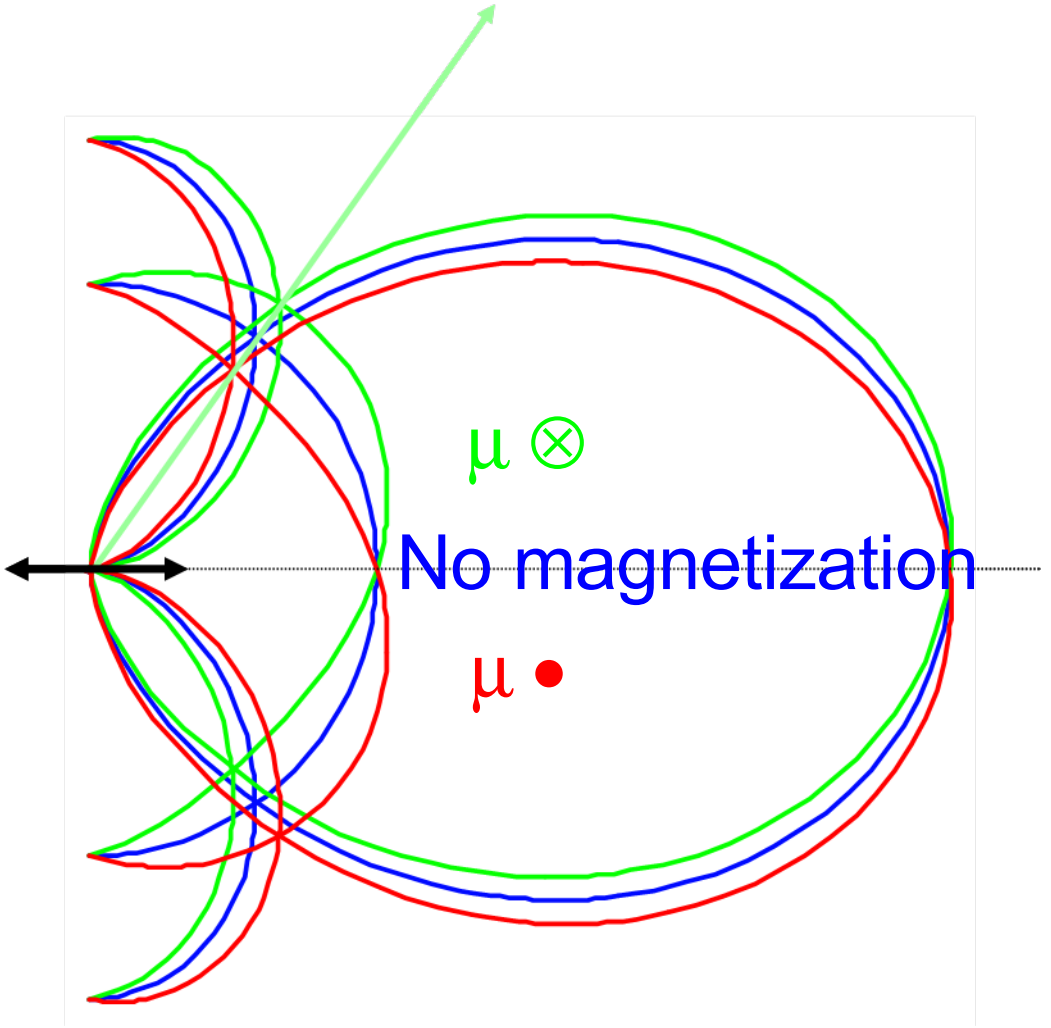
→ In absorption of total yield the CMD cancels out.

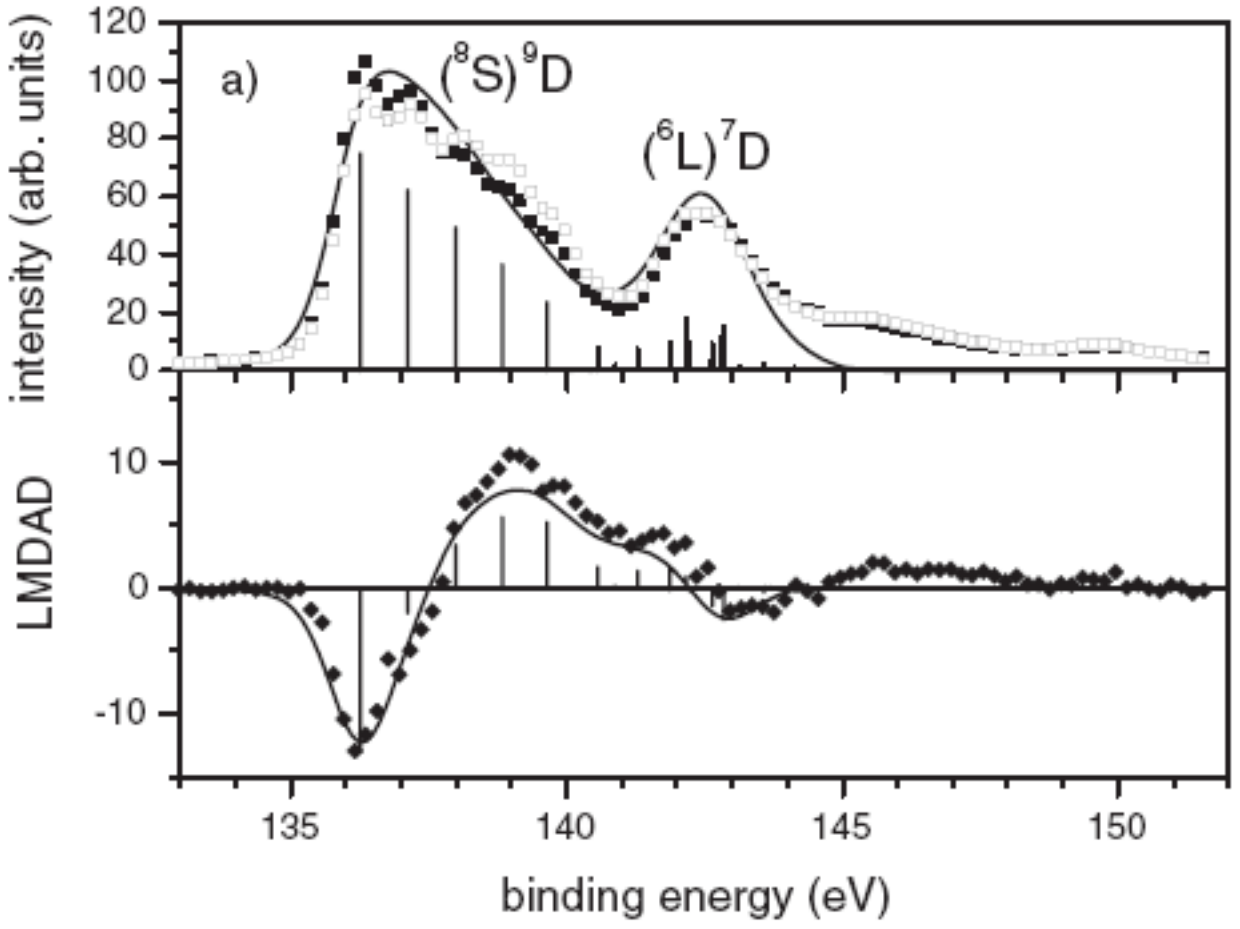
An effect is only seen in the angular distribution:

Angular Distribution of Photoelectrons

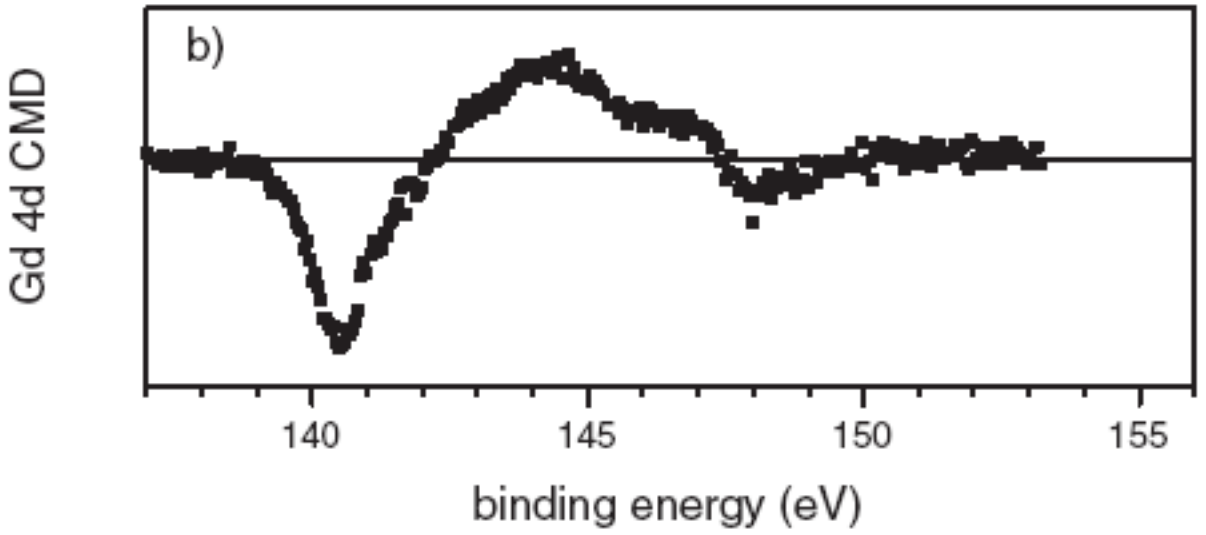


Modification by Linear Magnetic Dichroism





LMDAD in the
Eu 4d photoemission



Compared to solid
state gadolinium
magnetic dichroism

Dichroism Patterns

Orientation

Alignment

A_{10}

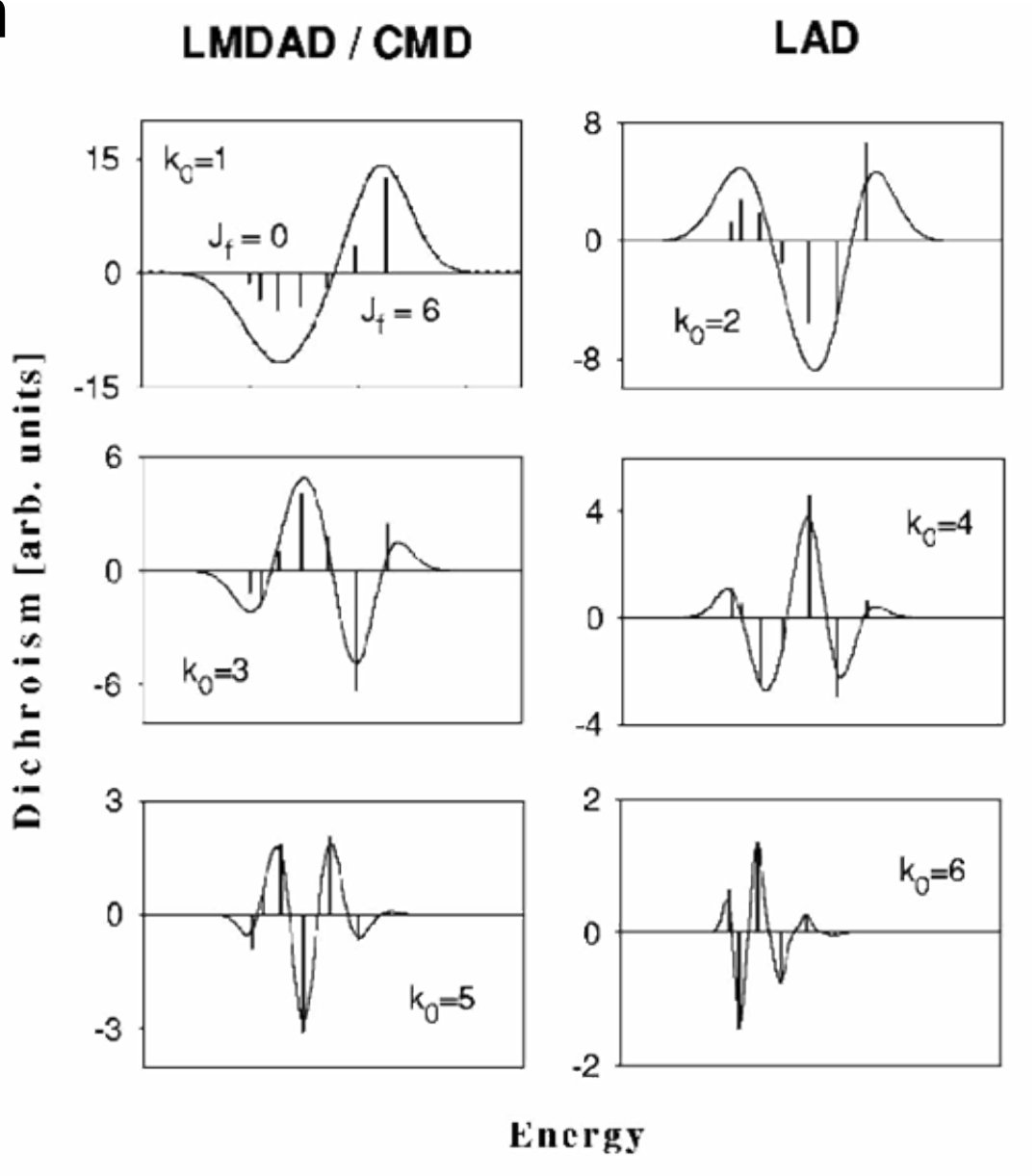
A_{20}

A_{30}

A_{40}

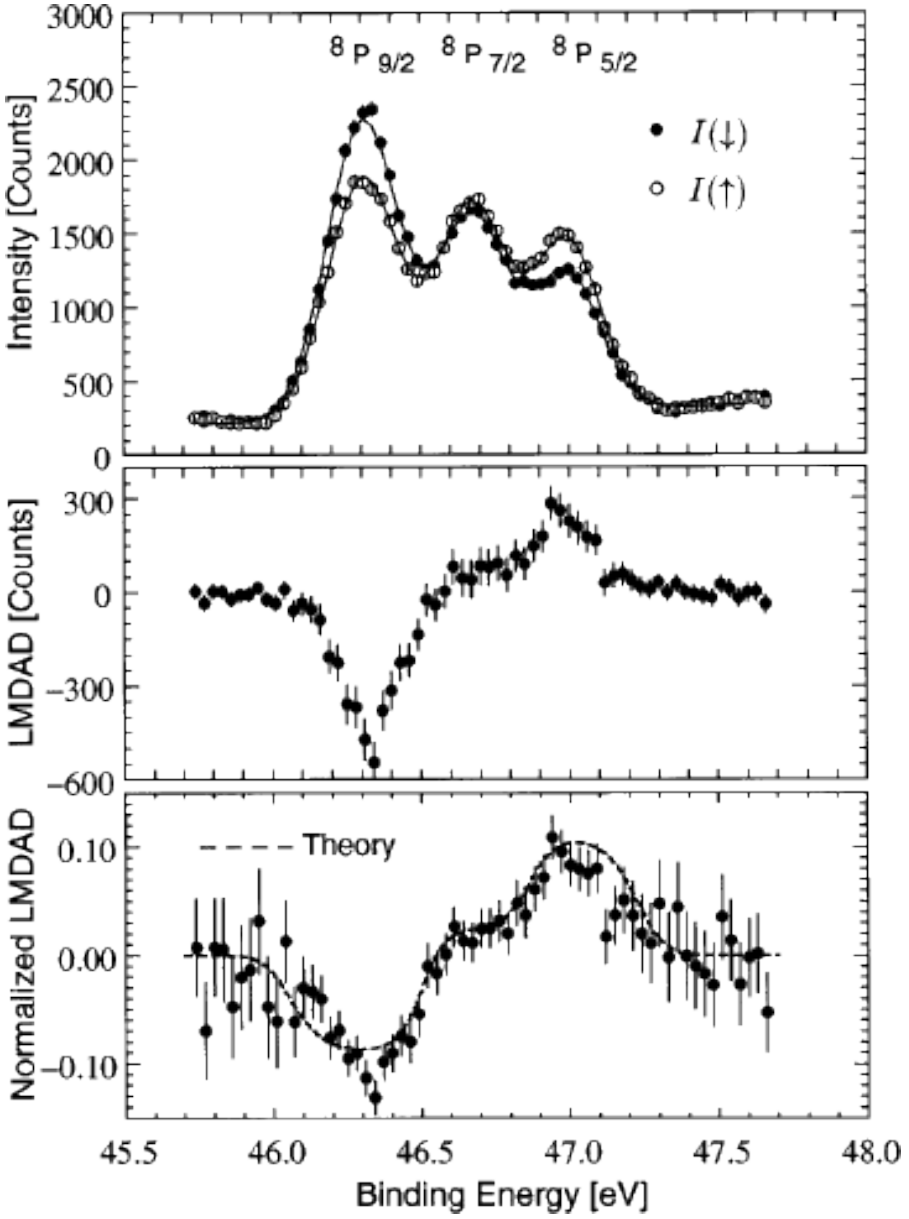
A_{50}

A_{60}

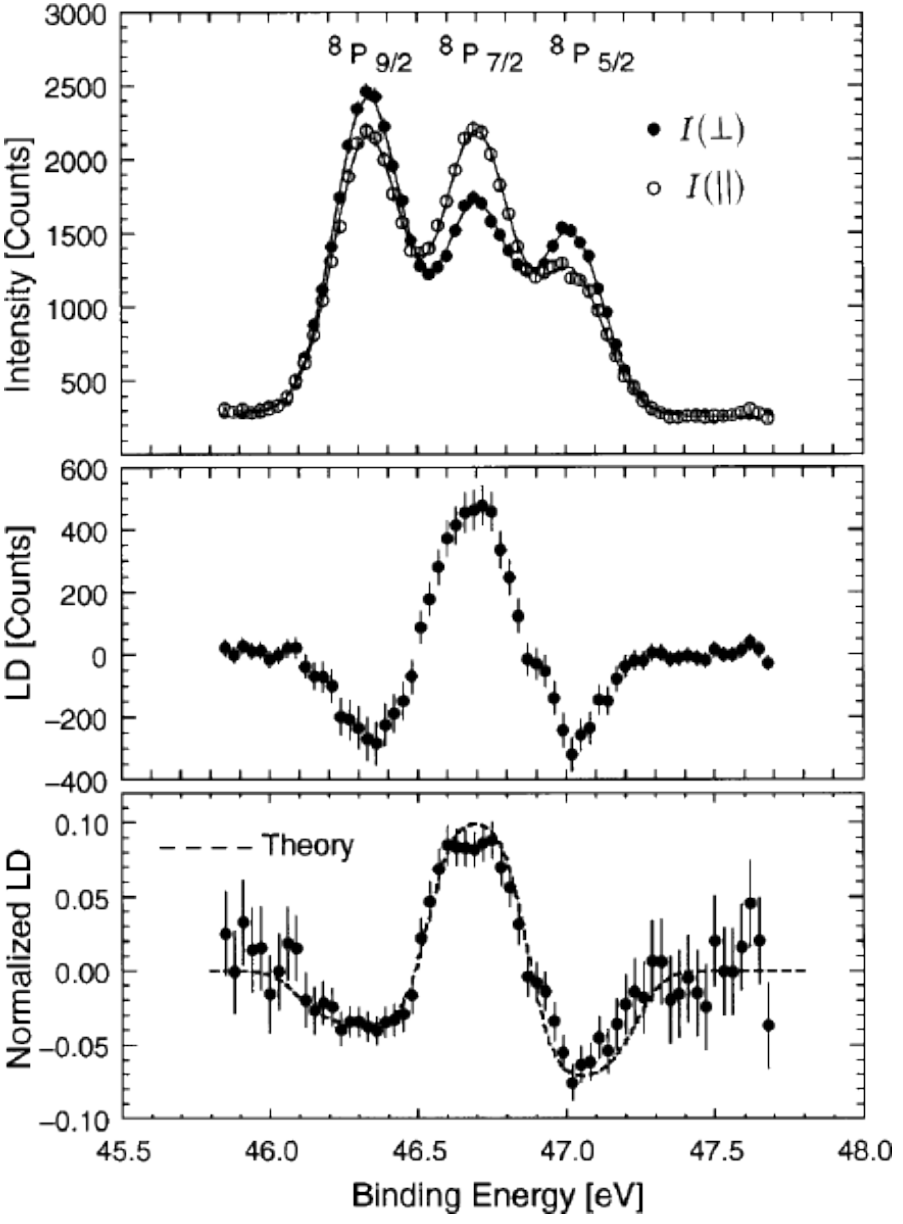


Cr 3p Dichroism Patterns

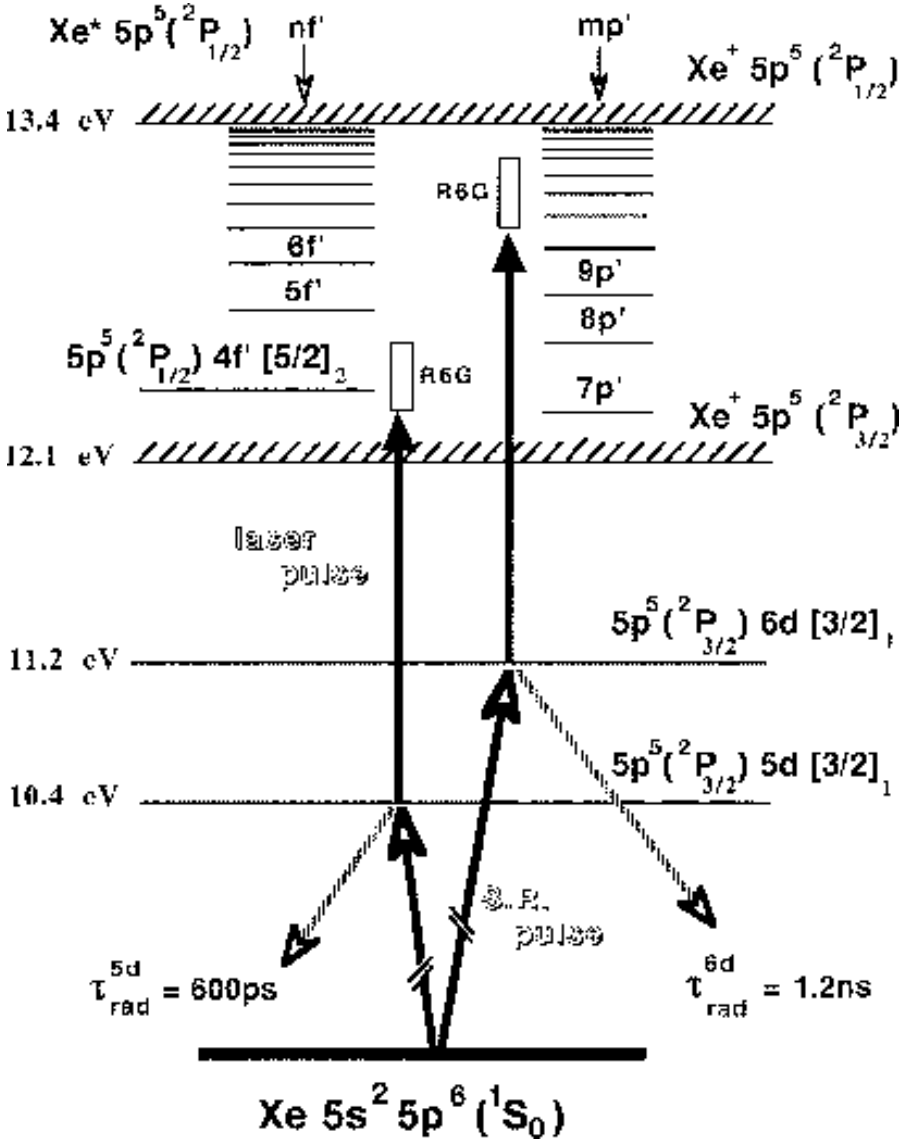
Orientation (LMDAD)



Alignment (LAD)



Two Photon experiments

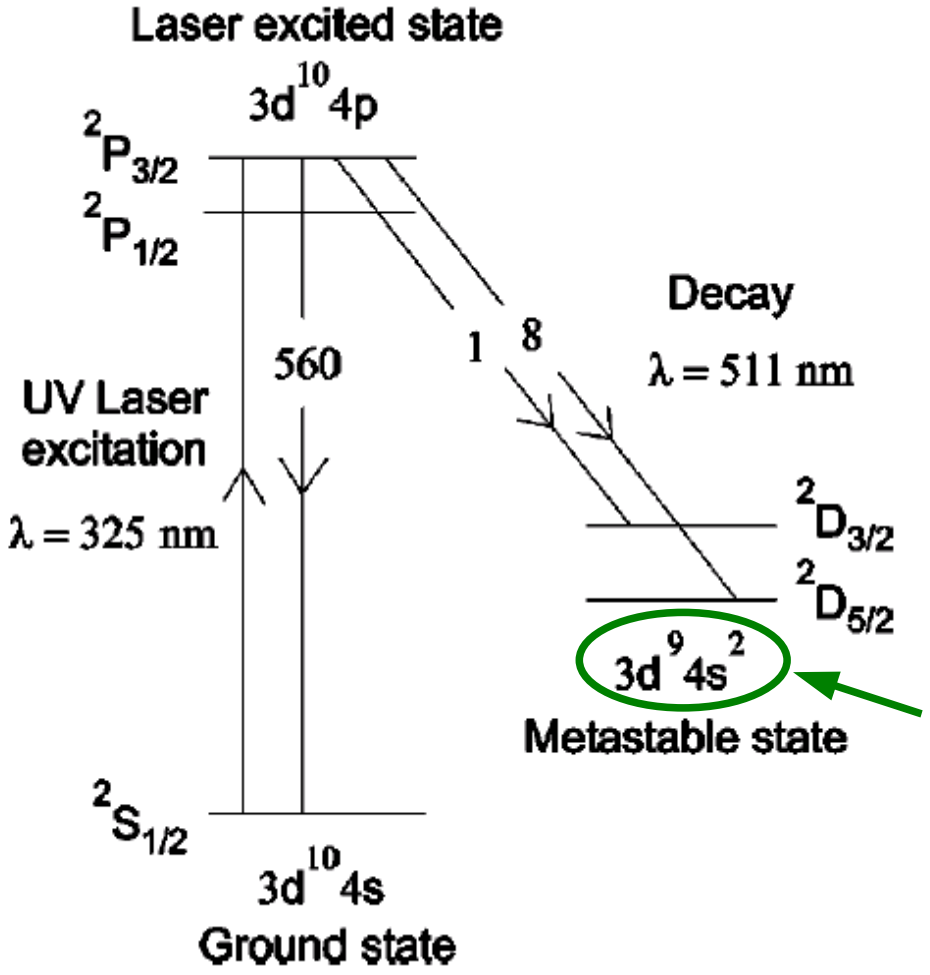


Xenon
two step excitation

M. Gisselbrecht, M. Marquette, M. Meyer

Laser Tailored Nickel like Copper

atomic Cu



Ni like open 3d-shell

A. Verweyen et al. Phys. Rev. A 60, R737 (1999)

Changings in the PE-Spectrum