Two-Color and High-Field Processes

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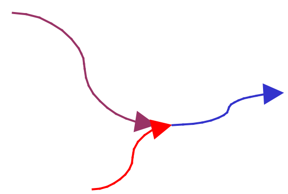


{ background -> speculations -> some numbers }

- atom-field interaction : pert. theory -> high field

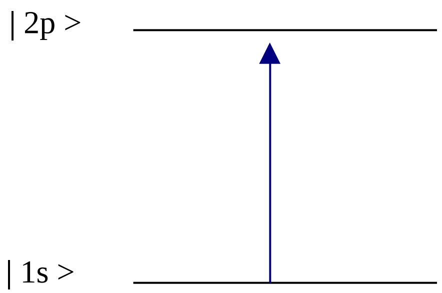
  (atomic structure ?)

- detectors and time-filters

- numbers for an experiment : 2 γ absorption

Atom -Field Interaction in Perturbation Theory

(transition rate, W)



Atom -Field Interaction in Perturbation Theory

Expansion parameter (κ)

$$\kappa = W^{(n+1)\gamma} / W^{n\gamma} = [d_{ij} \cdot E_L / h\delta\omega]^2 << 1 \text{ perturbation theory}$$

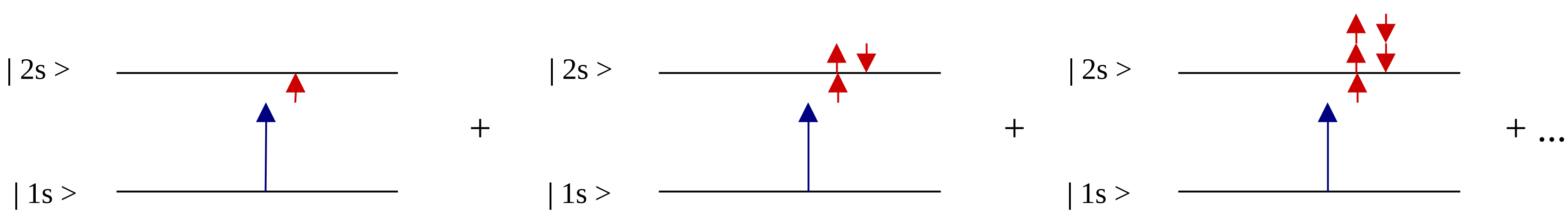
$\kappa \sim 1$ for $E_{laser} << E_{atomic}$

$\kappa \sim 1$ for : $h\delta\omega$ 1eV; $d_{ij} \sim e\eta a_o$; $E \sim 2 \cdot 10^{10}$ V/m {$I = 5 \cdot 10^{13}$ W/cm^2}

$E_{atomic} = e/a_o^2 \sim 5 \cdot 10^{11}$ V/m {$I \sim 3.5 \cdot 10^{16}$ W/cm^2}

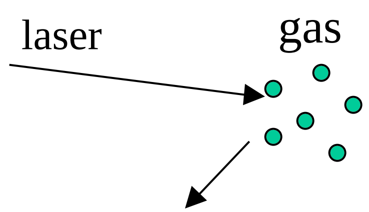
when $\kappa \sim 1$

account for higher order processes; possibility for interferences



An inconvenient picture for the interaction; A better picture ??

(> a decade of previous work)

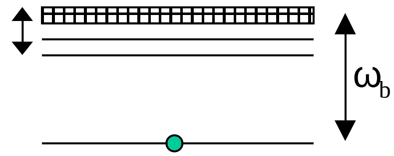


Direct energy level shifts

(stark shifts)

$\delta E \sim U_p$

$\delta E = U_p(\omega/\omega_b)^4 << U_p$



$U_p = [e(eE/m\omega^2)/4] \cdot E$

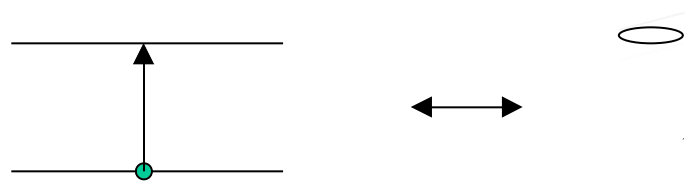
1 eV @ 1μm, 10^{13} W/cm^2

Indirect energy level shifts

(changes in nuclear screening)

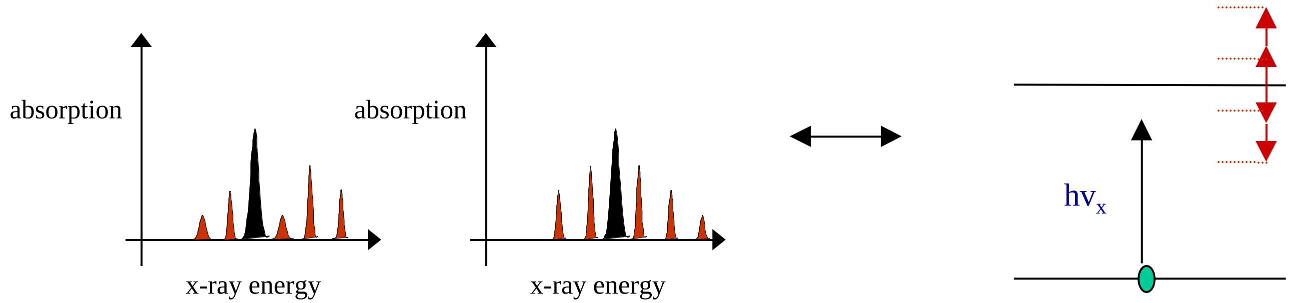
|2p >

|1s >



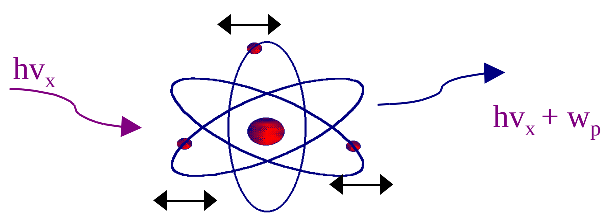
Dressing of states

(virtual states)



Collective excitations ??

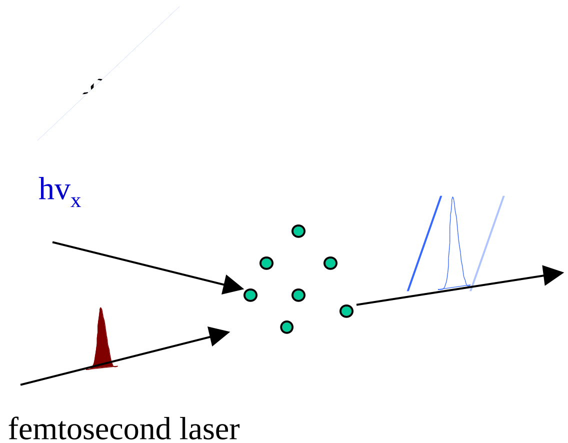
(oscillations of electron cloud)

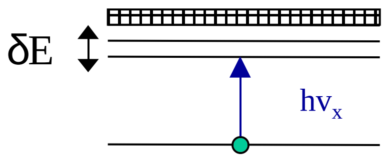


$hw_p \sim 100$ ev

for ~ 10 e in a_o^3

Time-filter via Stark shifts

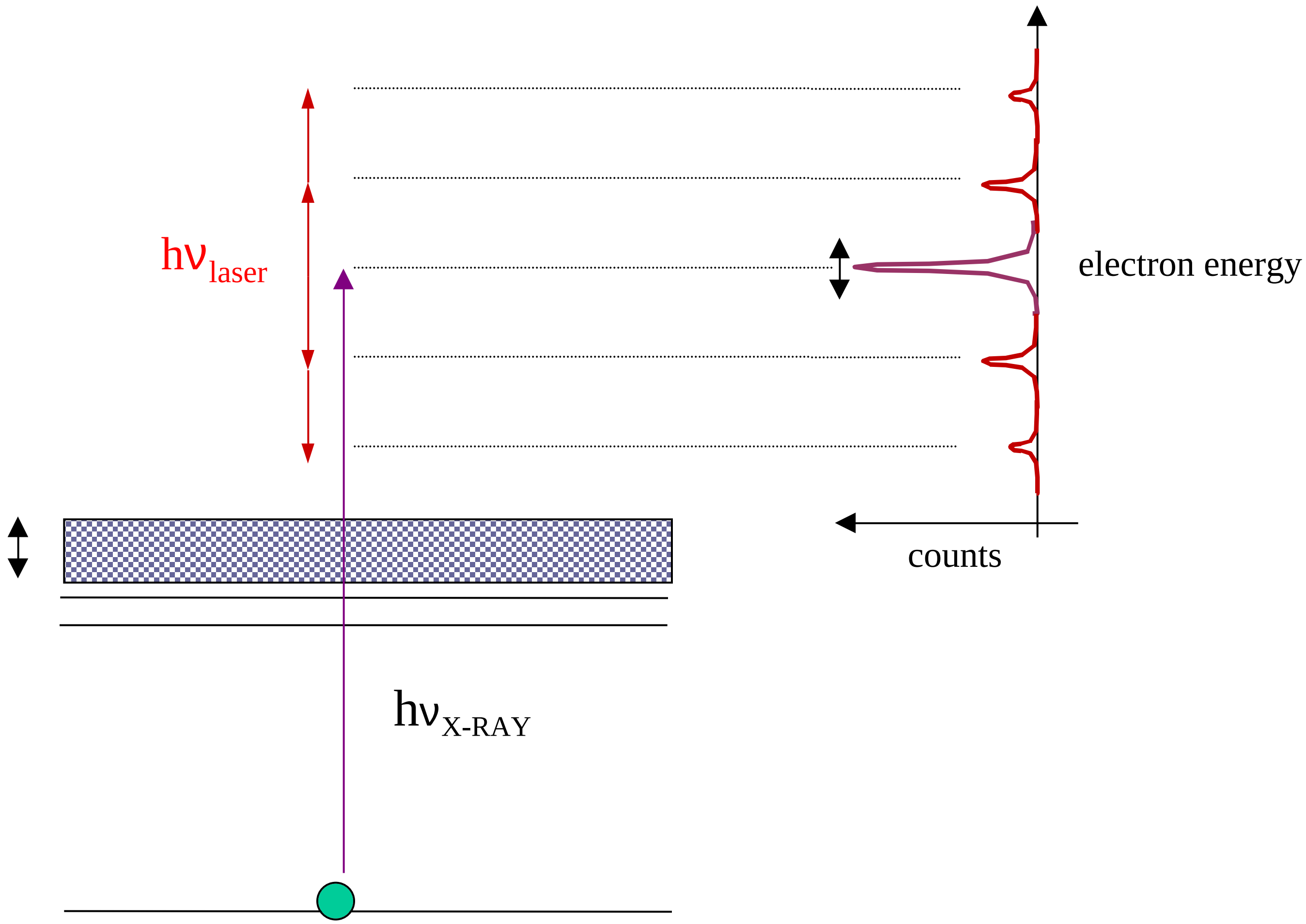




absorption probability = NσL ~ 1 @ 1 atm, $10^{-19}cm^2$, L=1 cm

Continuum scattering

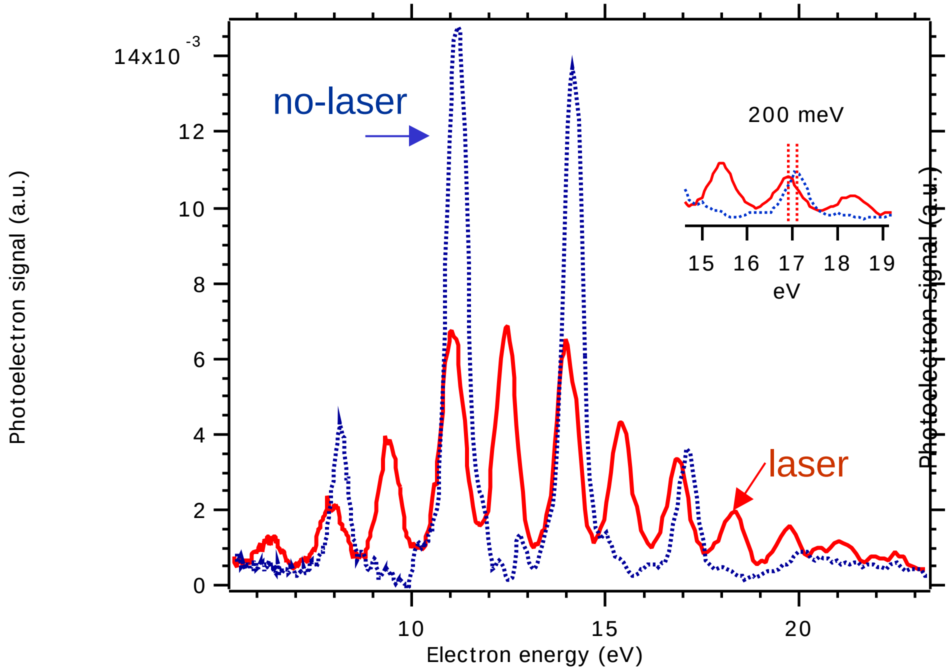
Look for laser induced modifications to XPS : (1) optical scattering and (2) AC stark shift



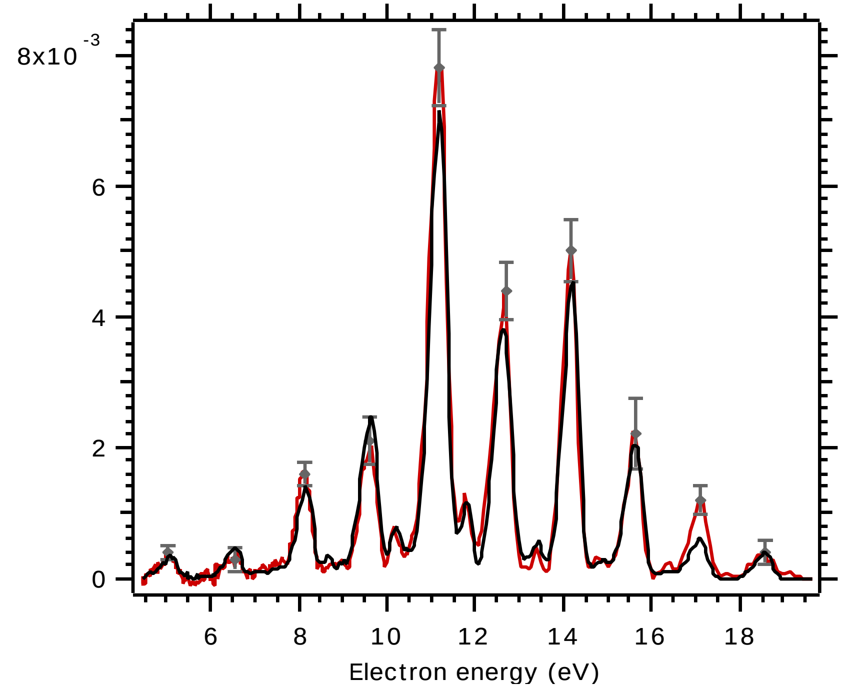
Advantage of this approach : no x-ray resonances => works for many x-ray wavelengths

Continuum scattering experiments : data

Photoelectron Spectra



Comparison with theory



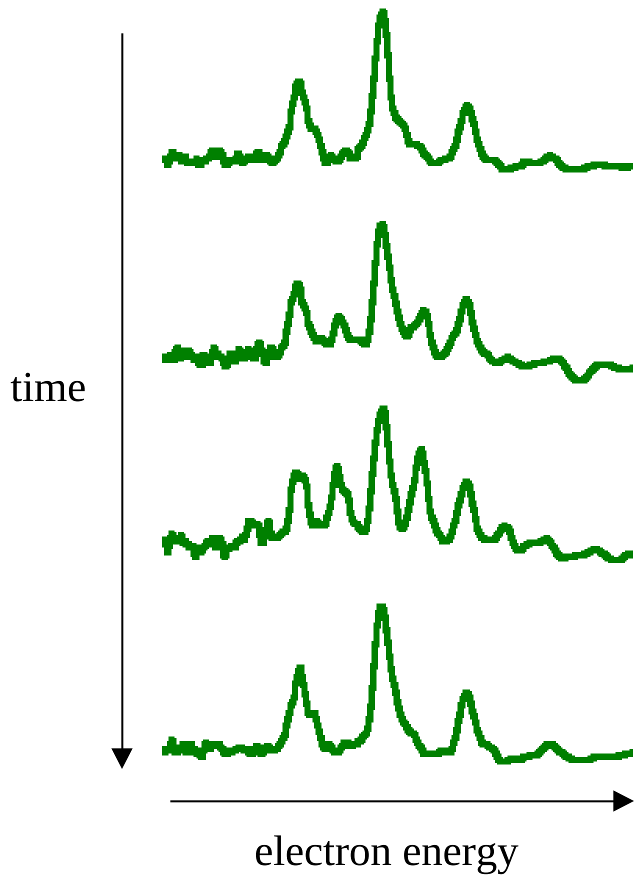
$$P \sim |\langle i|\, H' \,|f\rangle|^2$$

| i > = unperturbed atomic

| f > = exp[-it/h (p - eA/c)^2/2m]

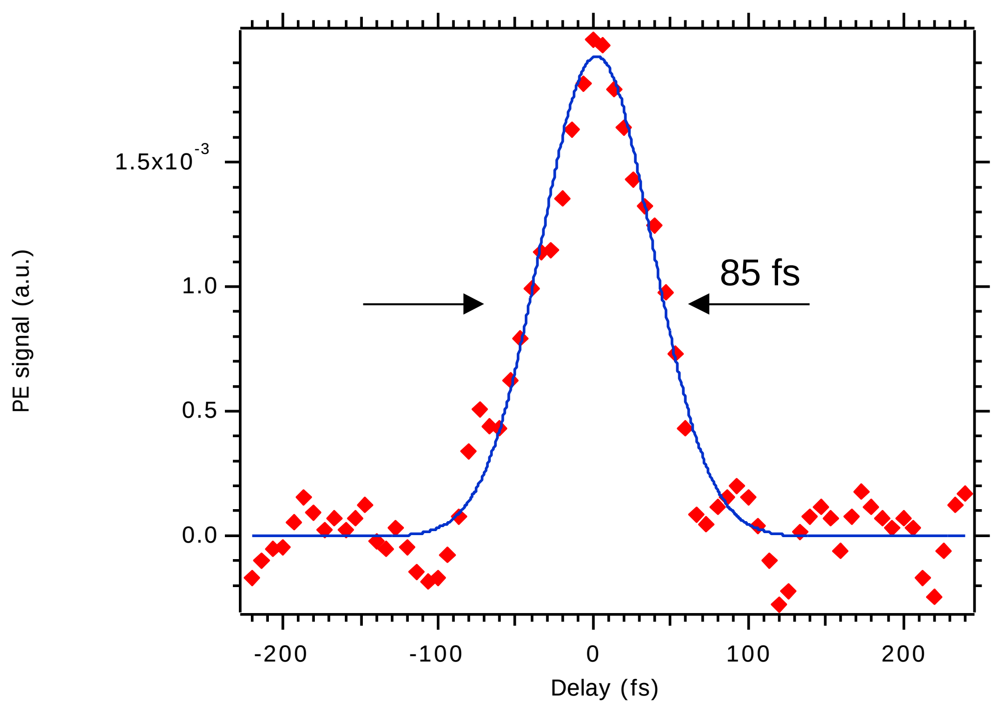
Continuum scattering experiments : data

Photoelectron Spectra vs time



Laser-VUV cross-correlation Measurement

50 fs VUV pulse



Two - photon absorption : Acquisition times

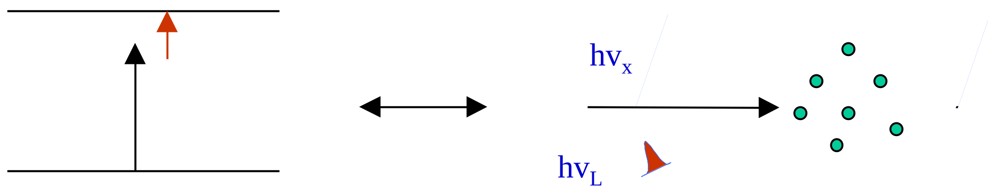
Beamline parameters

x-rays
- X-ray flux (5.3.1 bend) : 10^{12} γ/sec·0.1% BW => 10 γ /pulse·0.1% BW (100 fs)
- Rep. rate (1-10 KHz) : @ 5KHz => $5 \cdot 10^4$ γ /sec·0.1% BW in 100 fs

laser
- **E** = 1-10 mJ, 100 fs, r = 10 - 100 μm => $3 \cdot 10^{13}$ W/cm^2 < I < $3 \cdot 10^{16}$ W/cm^2

($1/30 < E_{laser}/E_{atomic} < 1$)

Direct detection

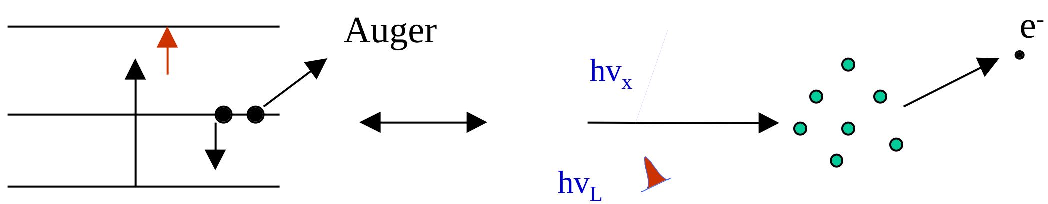


fractional absorption = **F** = $N L [\sigma_x (d_{ij}.E_L/2h\omega)^2]$

For : $N=10^{18}$/cc; L=1mm; $\sigma_x = 10^{-19}$cm^2; $(d_{ij}.E_L/2h\omega)^2 = 10^{-2}$; {$10^{12}$ W/cm^2; 4s4p}

F ~ 10^{-4} => S/N =1 in 0.5 h (QE=1)
= 3 in 5 h

(Indirect detection : background free)



Count Rate = R = $\varepsilon_{detection}$ ε_{auger} **F** (#γ_x/sec)

(0.1) (0.5) (10^{-4}) ($5\cdot10^4$ γ /sec·0.1% BW)

R = 15/min => 10% shot noise in ~10 min

Summary

- <u>Beamline capabilities (5.3.1)</u> :

  x-rays at 100 fs, $5 \cdot 10^4\ \gamma$ /sec·0.1% BW ⟶ backgnd free expts.

  laser at 100 fs, 10^{13} W /cm^2 - 10^{16} W /cm^2

- <u>High Field experiments</u> : fundamentals and applications