atomic physics at ERL

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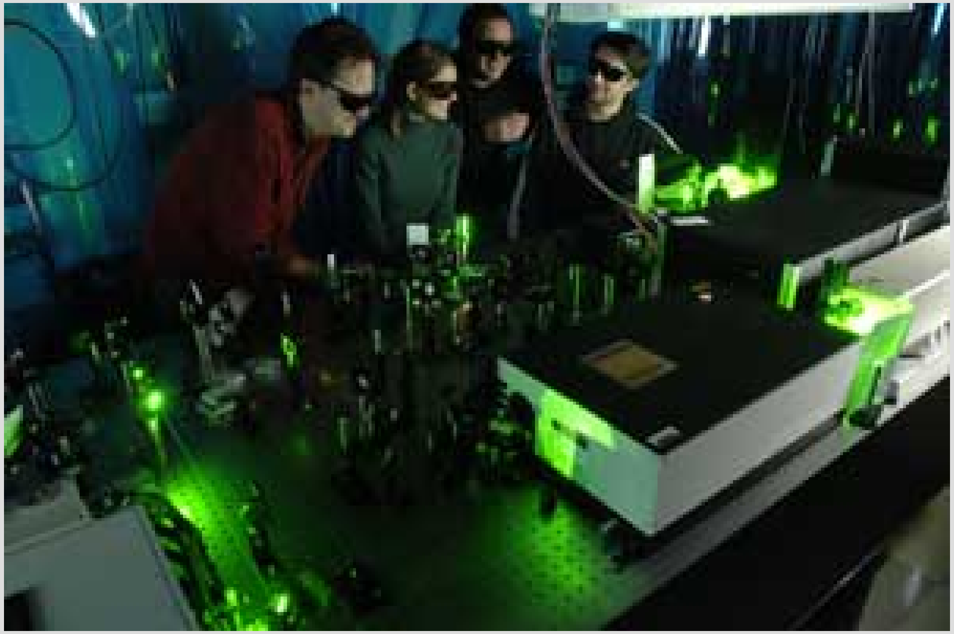
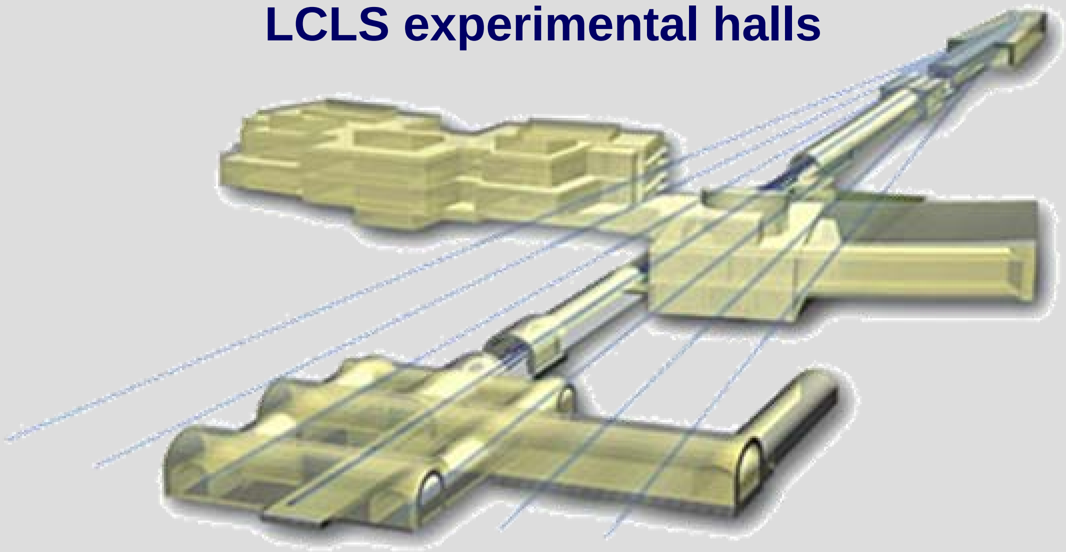
Cornell ERL workshop
June 14-15-2006



- fundamental studies of intense laser-atom interactions
- generation and application of attosecond pulses
- ultra-fast optical engineering

AMOP at the LCLS

LCLS experimental halls



- AMOS team located in the near-hall
- initial experimental end-station on soft x-ray beamline (0.8-2 keV)
- scientific thrust: fundamental strong-field interactions at short wavelengths

contrast: long and short wavelength strong-field physics

ponderomotive potential is everything at long wavelengths

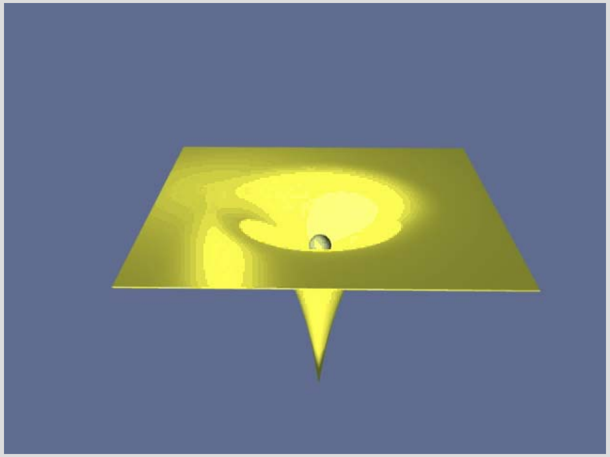
- electron ponderomotive energy (au):

  $U_p = I/4\omega^2$
- displacement:

  $\alpha = E/4\omega^2$
- PW/cm^2 titanium sapphire laser:

  U_p ~ 60 eV & α ~ 50 au

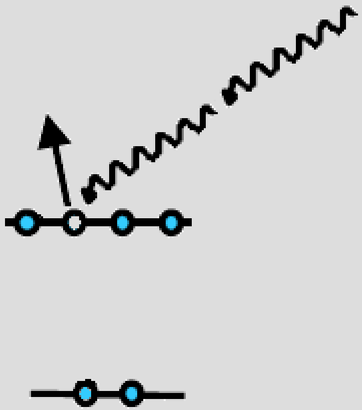
e^- in Coulomb + laser fields

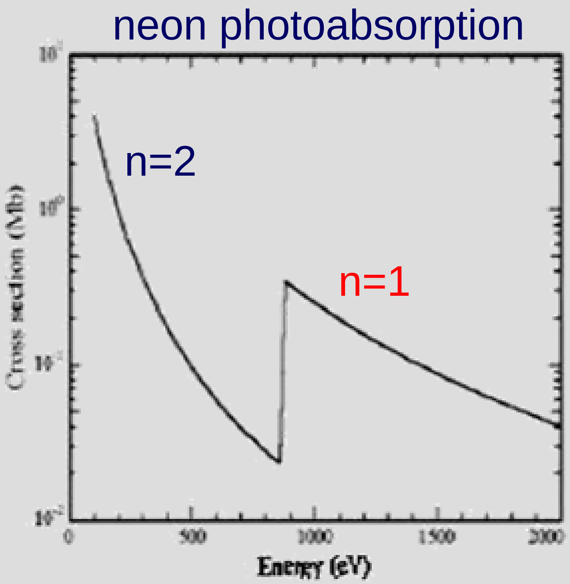


for LCLS @ 10^3 PW/cm^2 U_p & α are zero!
and even more zero for the ERL!!

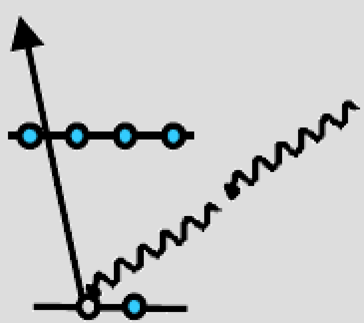
contrast: long and short wavelength strong-field physics

- laser multiphoton ionization



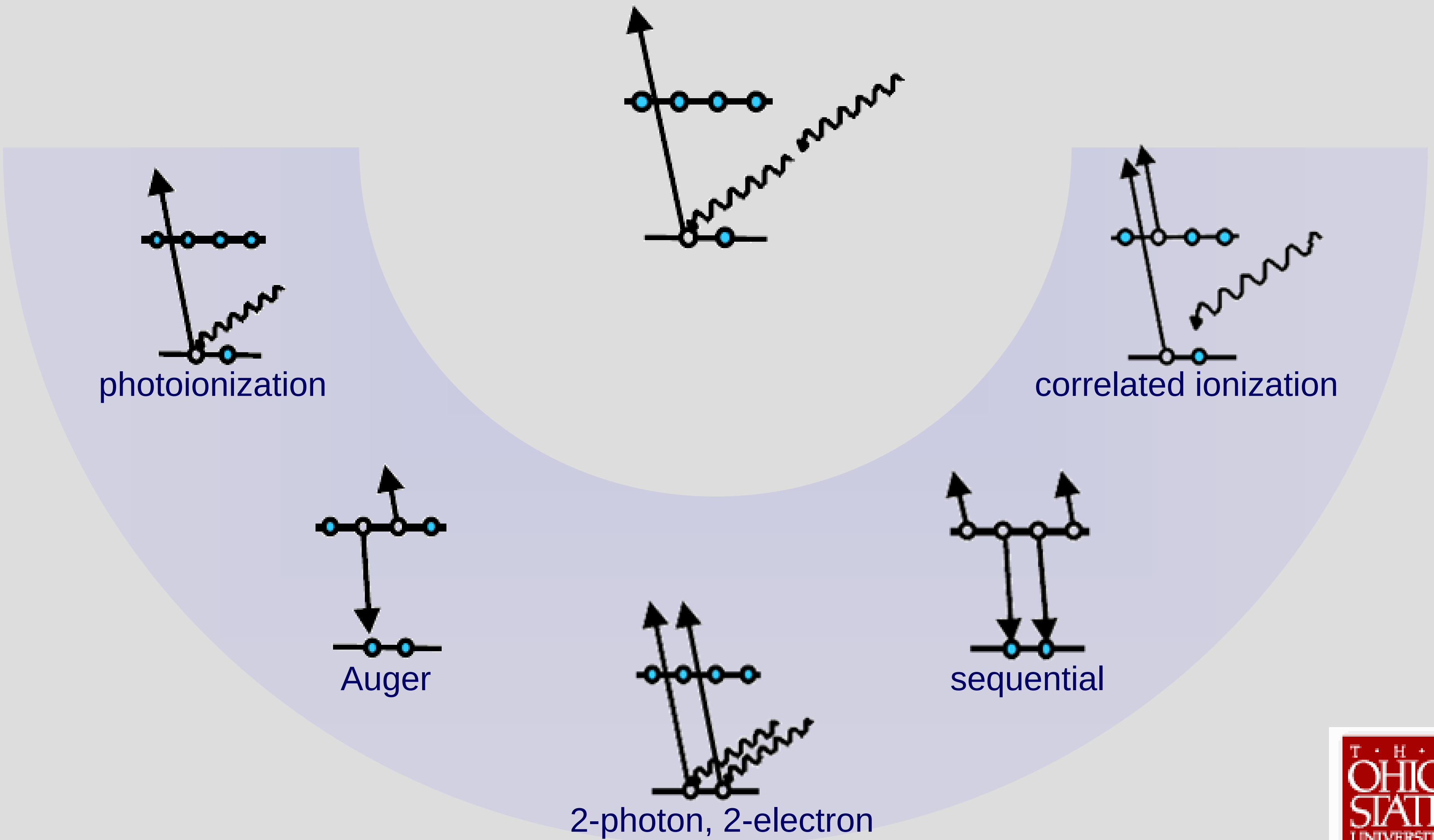


- x-ray multiphoton ionization

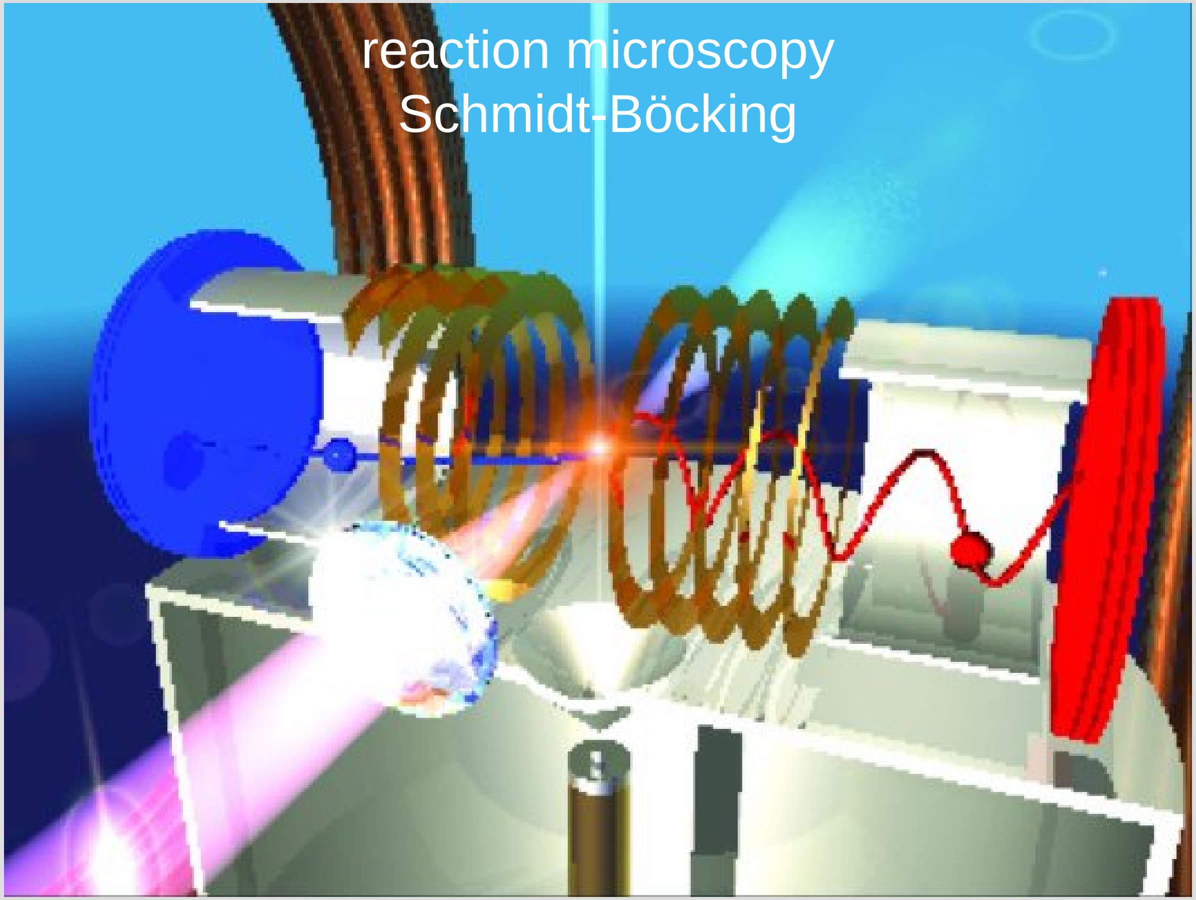


x-ray strong field experiment

x-ray multiphoton ionization



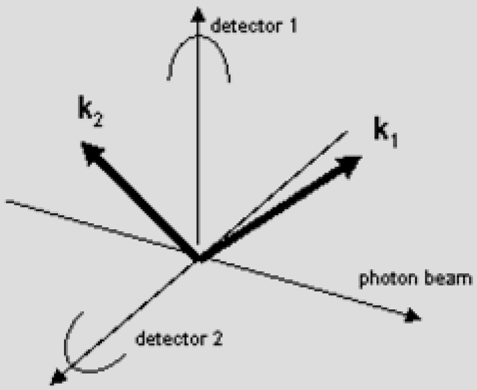
needle in the haystack: coincidence measurements



• detect by correlating particle-particle events

J. Ullrich *et al.,* JPB **30**, 2917 (1997)

coincidence measurement



true-to-false ratio:

$T/F = \eta_t C f / (\eta_1 C + N_1)(\eta_2 C + N_2)$

$\eta_{t,1,2}(\sigma,\theta,\varepsilon) \equiv$ detection coefficients

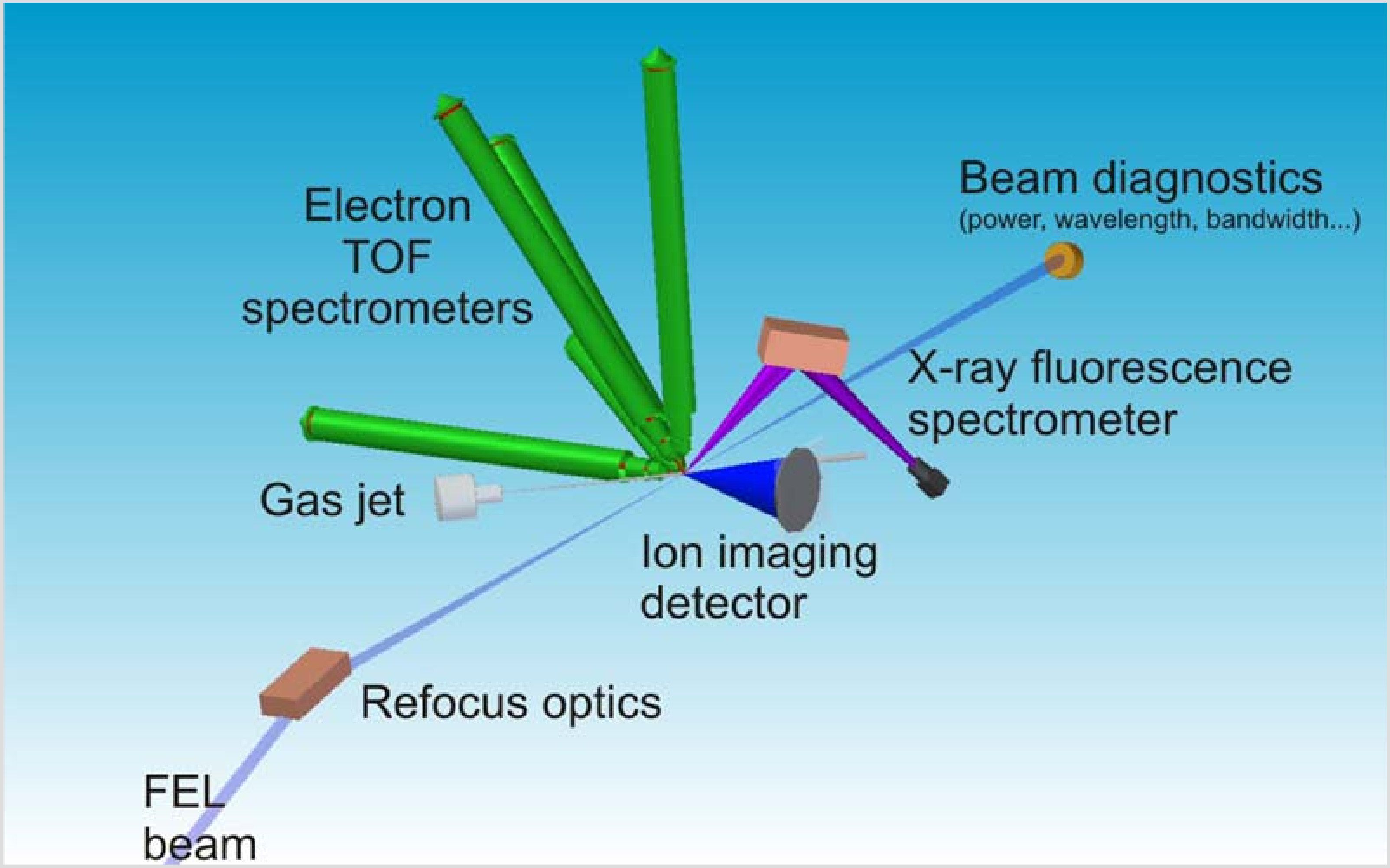
$N_{1,2} \equiv$ noise counts

$C \equiv$ average count rate

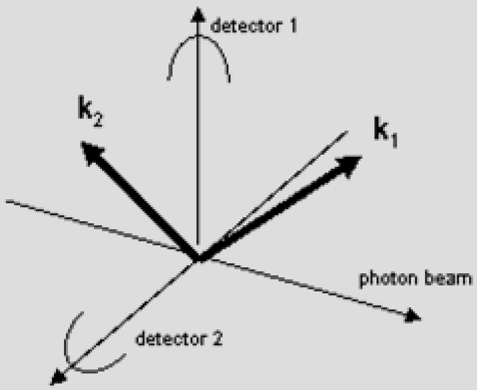
$f \equiv$ repetition rate

- the 120 Hz operation of the LCLS makes coincidence experiments high risk, thus the initial AMOS end-station will not have this capability.

AMOS end-station: single-shot measurements



coincidence measurement



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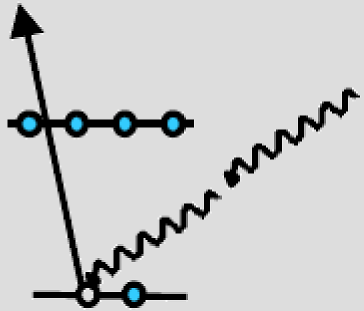
- the 120 Hz operation of the LCLS makes coincidence experiments high risk, thus the initial AMOS end-station will not have this capability.
- the ERL does have the advantage of high duty cycle!
- does it have high enough intensity for exploring multiphoton processes?

maybe?



consider a 2-photon K-shell transition:

- estimate 2-photon cross-section, σ_2

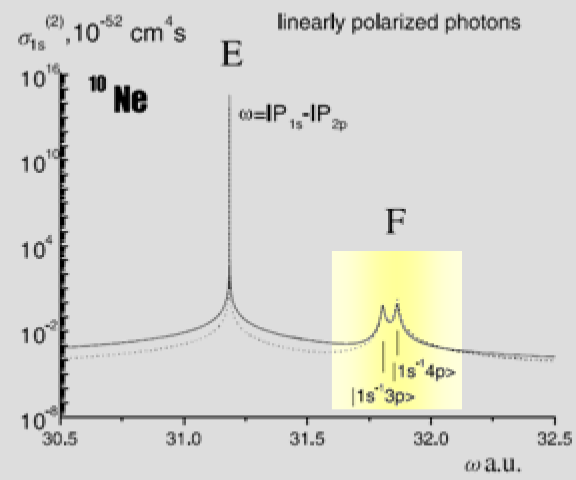
  perturbative scaling laws[1]: $\sigma_2 \approx 10^{-54}$ cm^4 s

  2^{nd}-order perturbation theory[2]: $\sigma_2 \approx 10^{-52}$ cm^4 s

ERL parameters:

10^6/shot, 100 fs, 1A

20 nm waist yields flux ~10^{30} cm^{-2} s^{-1} (10^{15} W/cm^2)



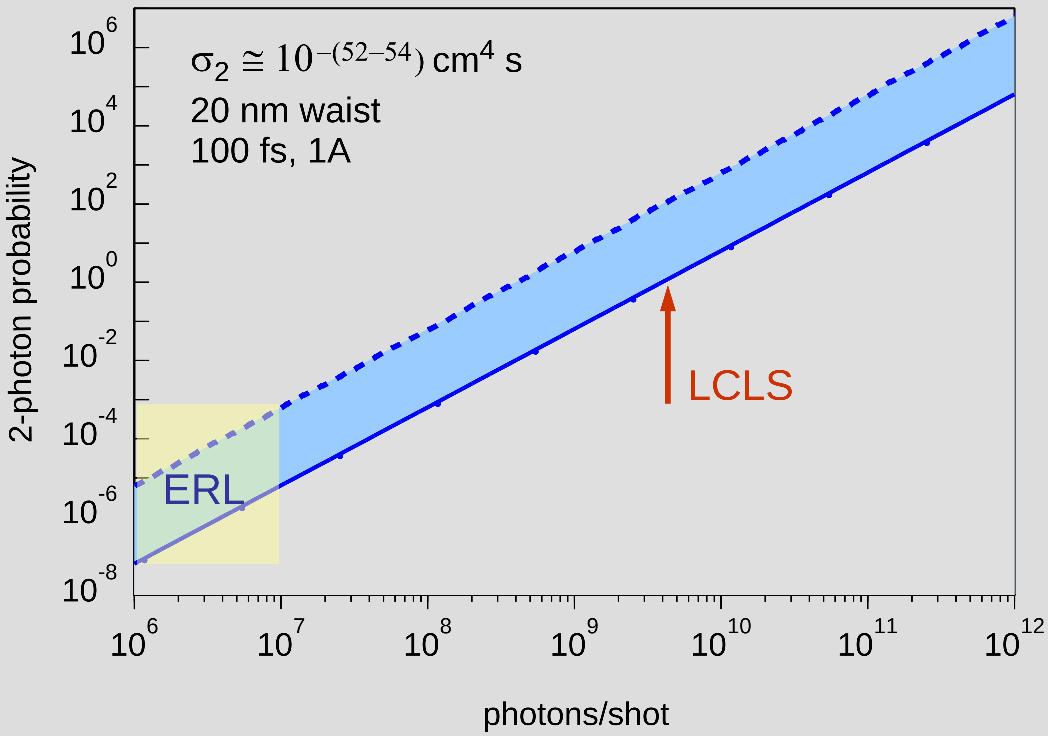
transition probability:

$P_2 \approx 10^{-(5-7)}$

[1]P. Lambropoulos and X. Tang, J. Opt. Soc. Am. B **4**, 821 (1987)

[2]S. A. Novikov and A. N. Hopersky, JPB **33**, 2287 (2000)

two-photon ionization



- use near resonant enhancement of σ_2
- increase number of photons/shot over average power

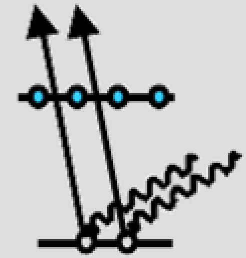
open the possibility of temporal metrology!

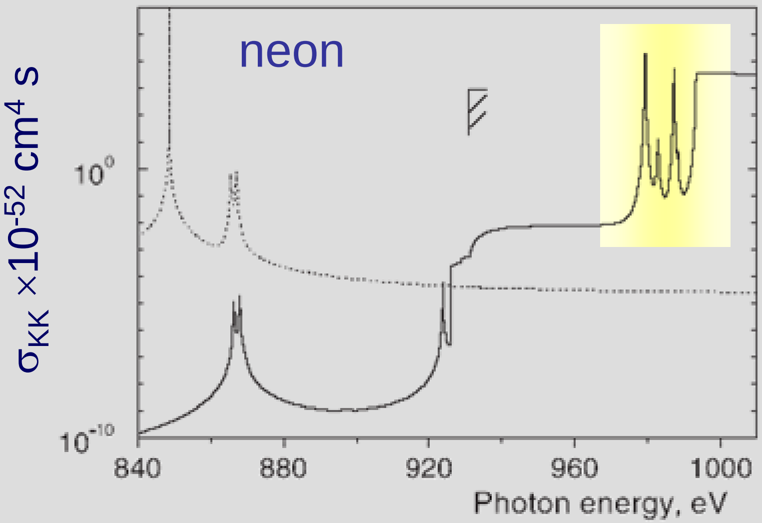
2-photon, 2-electron ionization

consider a 2-photon KK-shell transition:

$\sigma_{KK} \approx 10^{-48}$ cm^4 s

$P_{KK} \approx 0.1$





coincidence investigations:

- atomic
- aligned molecules
- cluster dynamics

S.A. Novikov & A. N. Hopersky, JPB **35**, L339 (2002)

x-ray-laser metrology

Observation of Laser-Assisted Auger Decay in Argon

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