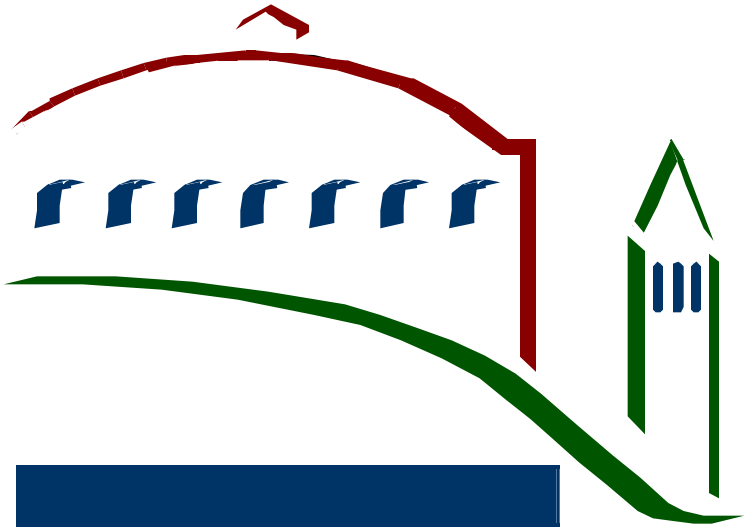
Alight A Beam and Beaming Light
—— A Theme with Variations



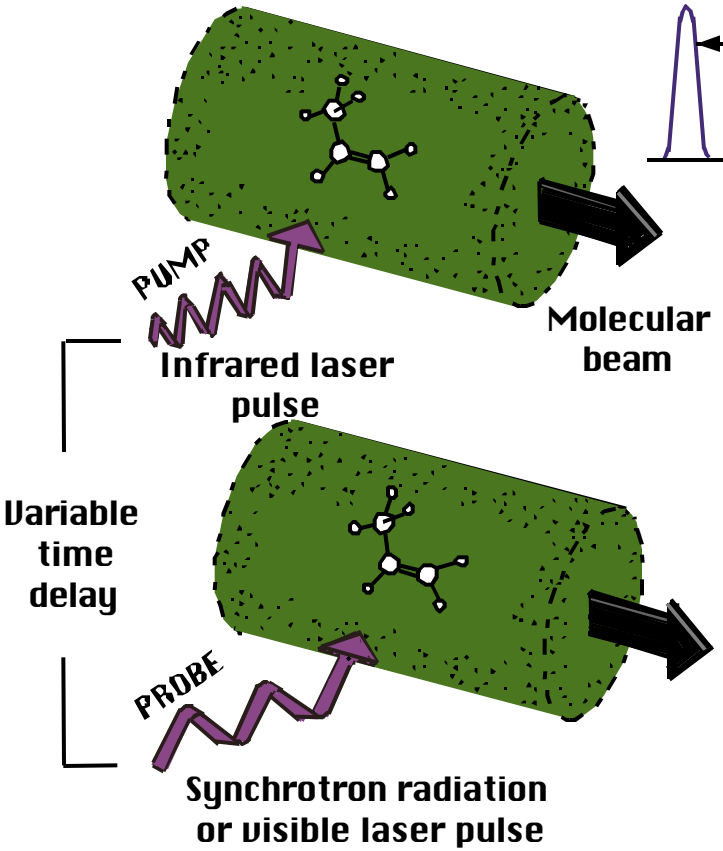
presented by

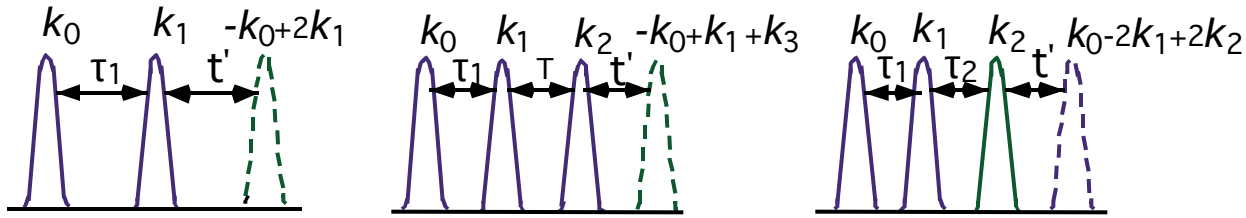
Dr. Swapan Chattopadhyay

APS/DPP Meeting
Pittsburg, PA
11/21/97

A Two-Color Experiment for Studying Chemical Reactions

Novel Multiple Pulse Photo - Electron Nonlinear Echo Schemes



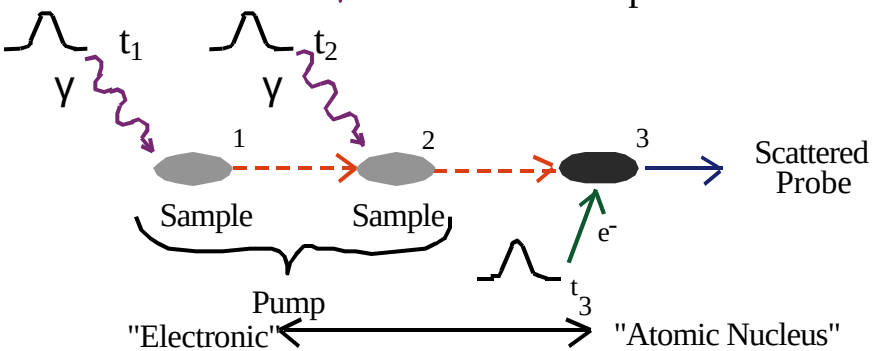


γγ → γ **"Photon"** Echo

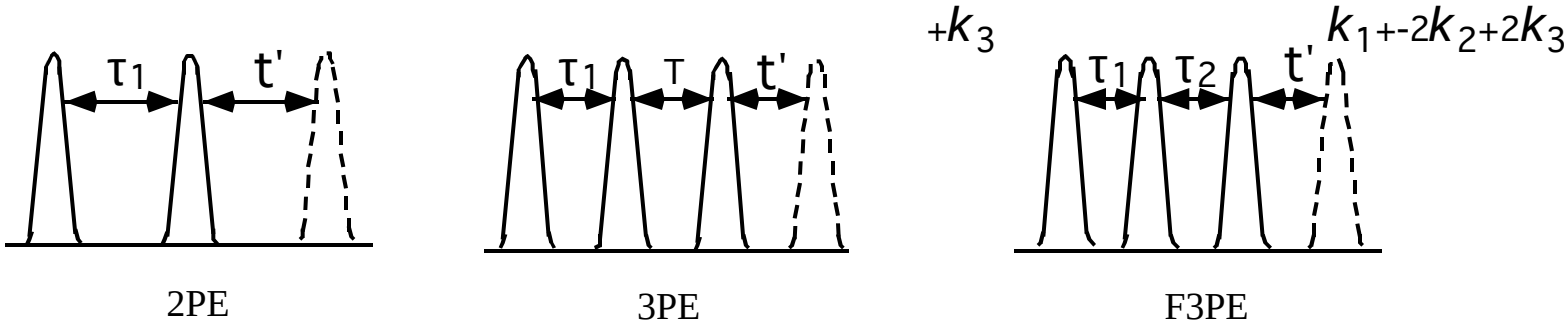
ee → **e** **"Electron"** Echo

γγ → **e** **Photon** Pump → **"Electron"** Echo

ee → γ Electron Pump → **"Photon"** Echo



Novel Multiple Pulse Photon - Electron Nonlinear Echos Schemes

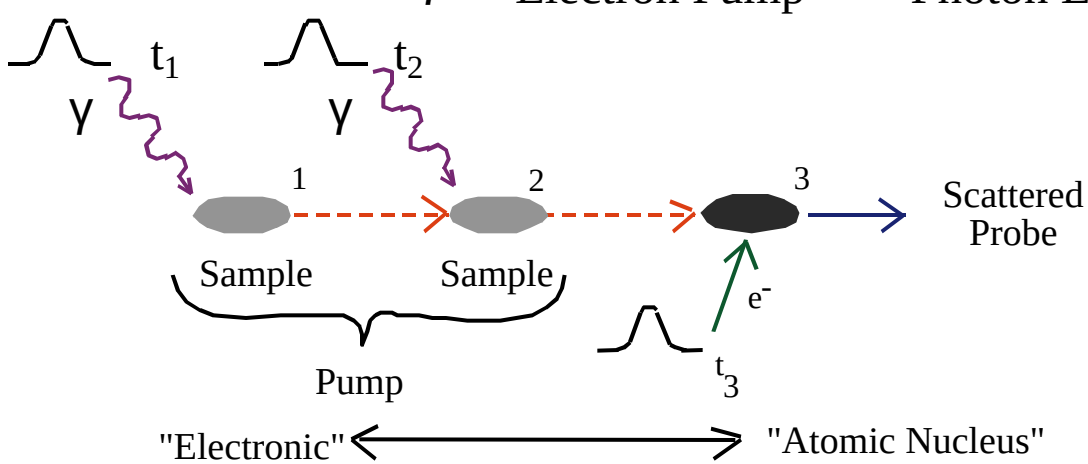


γγ → γ "Photon" Echo

ee → e "Electron" Echo

γγ → e Photon Pump → "Electron Echo"

ee → γ Electron Pump → "Photon Echo"



BEAMS :

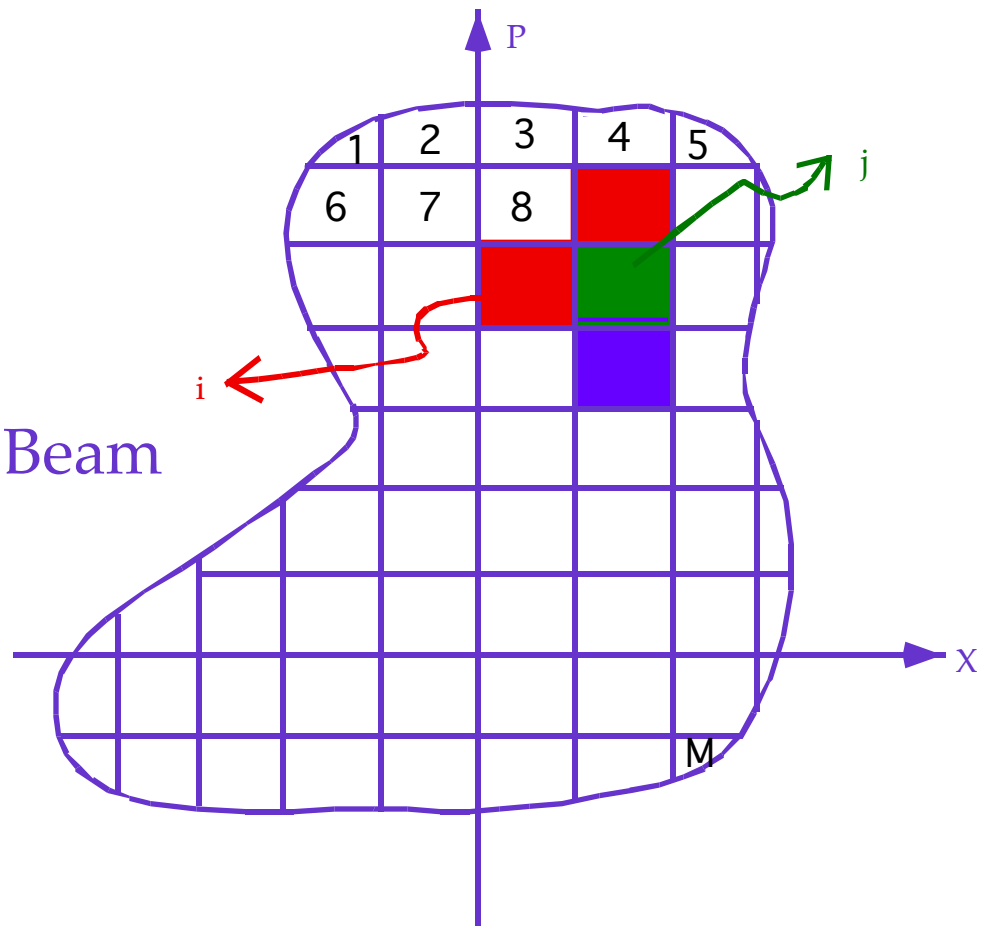
- Energy in a Beam

$$E_b \sim \sum_{i=1}^{N} [p_i^2 c^2 + m_i^2 c^4]^{1/2}$$

- Entropy & Information in a Beam

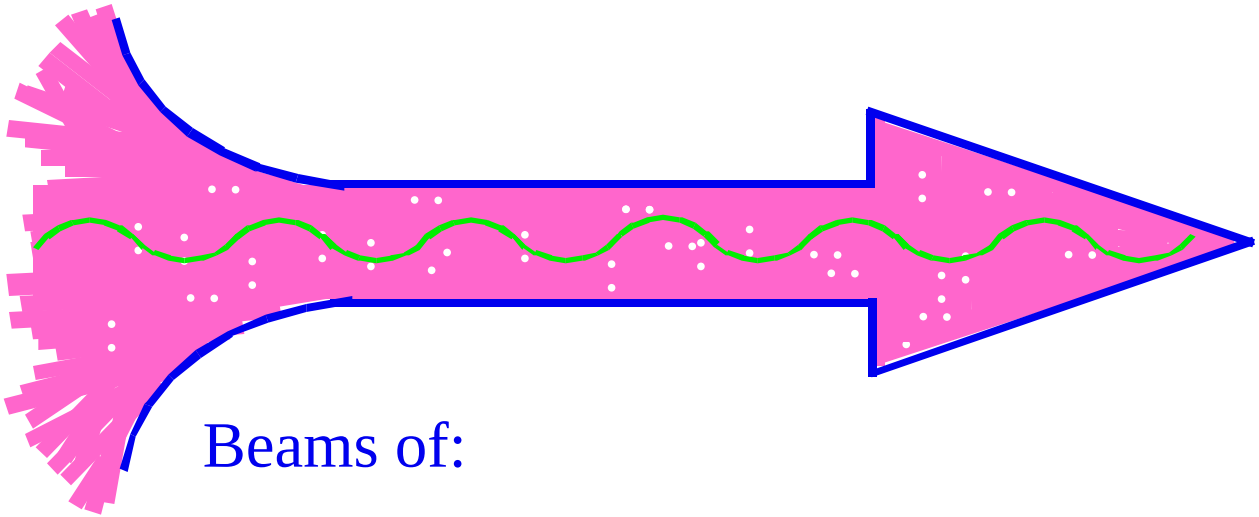
$$S_b \sim k\left[N \log N - \sum_{j=1}^{M} n_j \log n_j\right]$$

Phase Space in Rest Frame



BEAMS

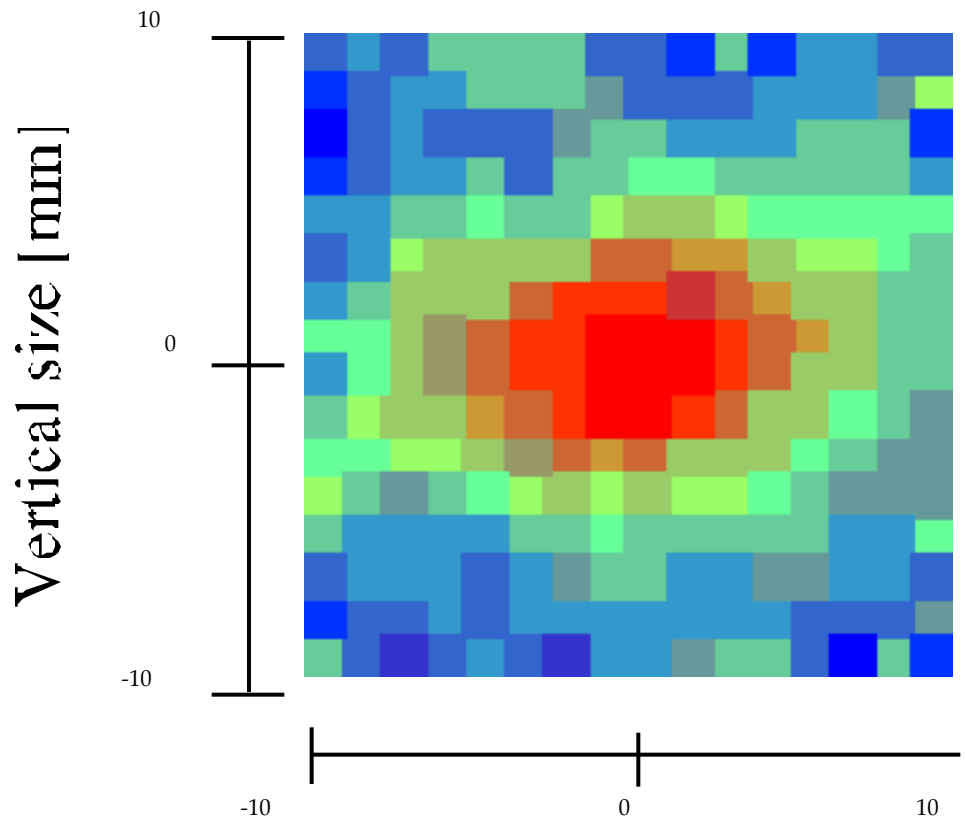
Directed and Focused Flow of Energy and Information



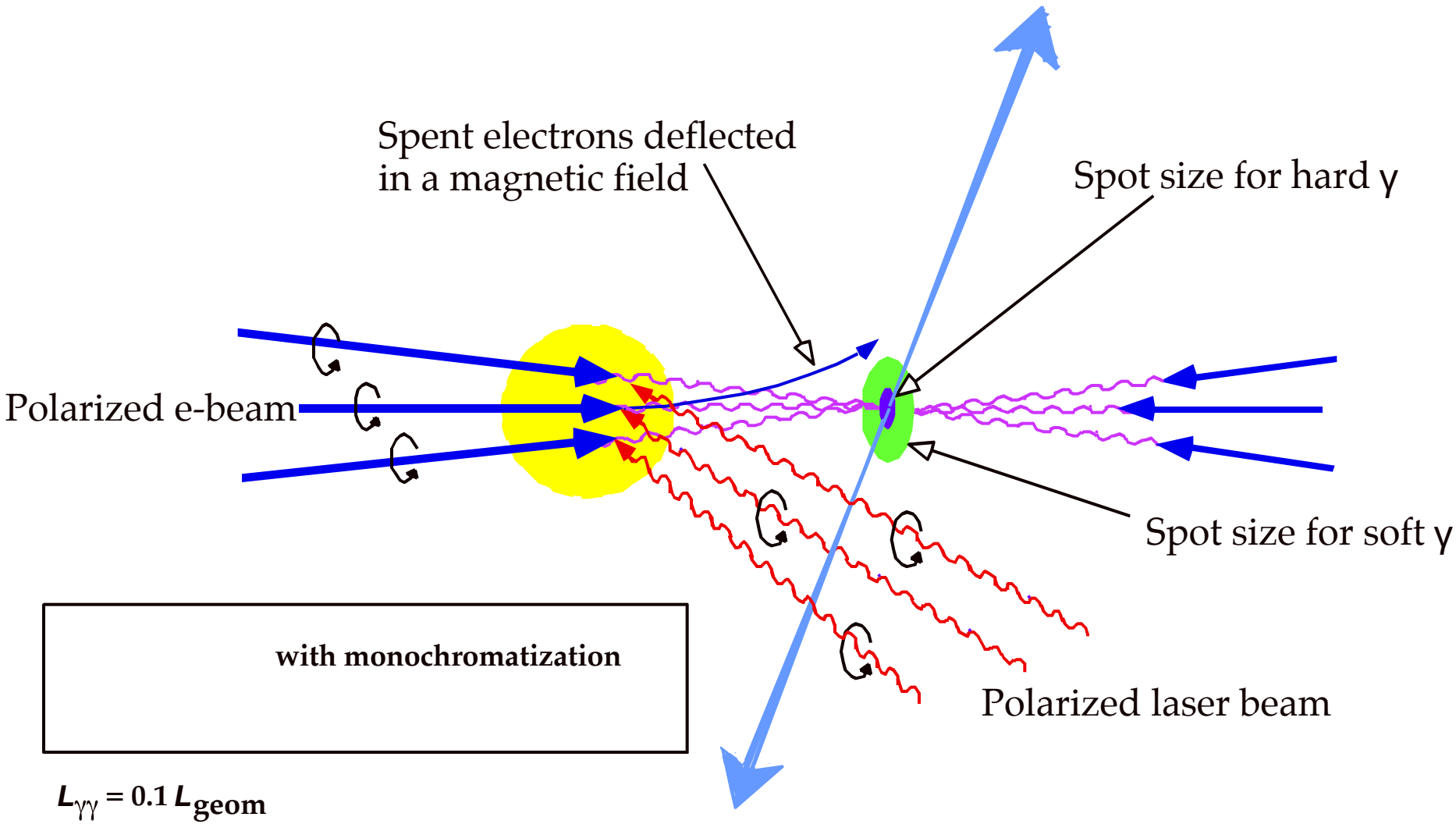
Beams of:

- Particles: electrons, protons, ions, ...
- Ultraviolet, Visible, Infrared, X-ray, Photons; Radio Waves; Lasers

False Color CCD Image of the spatial profile of a 30 keV x-ray pulse on the phosphor screen, which is located 80 cm from the IP.



Compton Conversion into Hard Gamma Rays

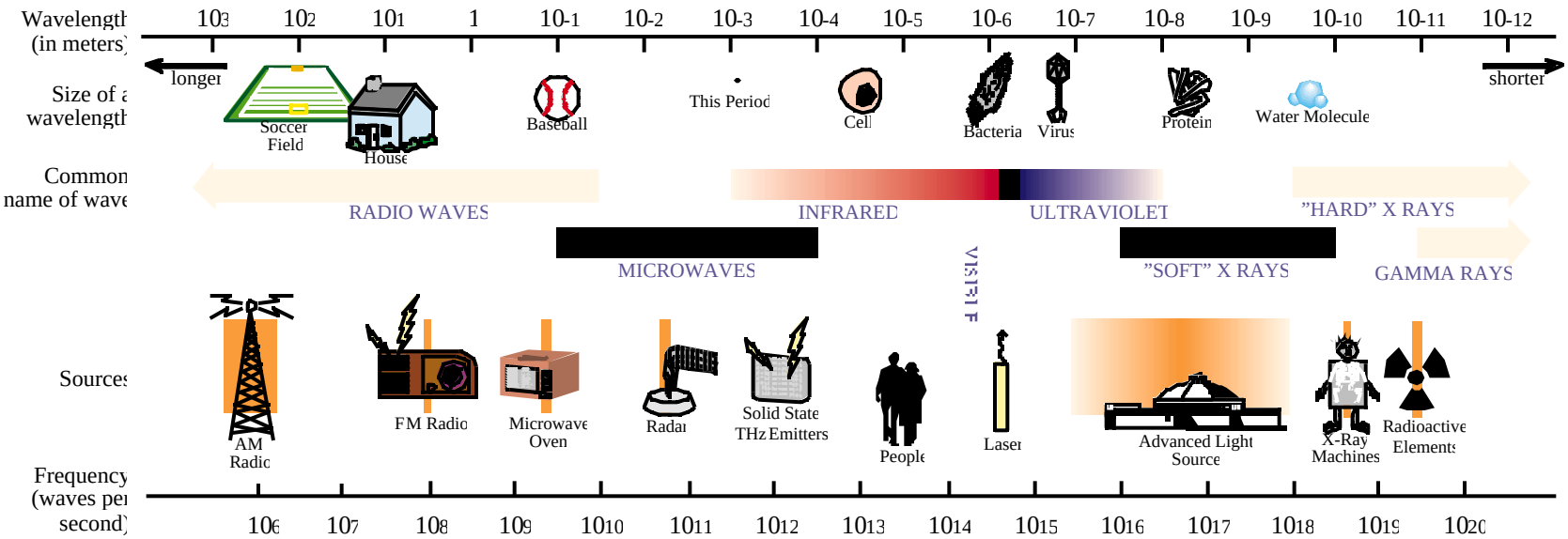


with monochromatization

$L_{\gamma\gamma} = 0.1\, L_{geom}$

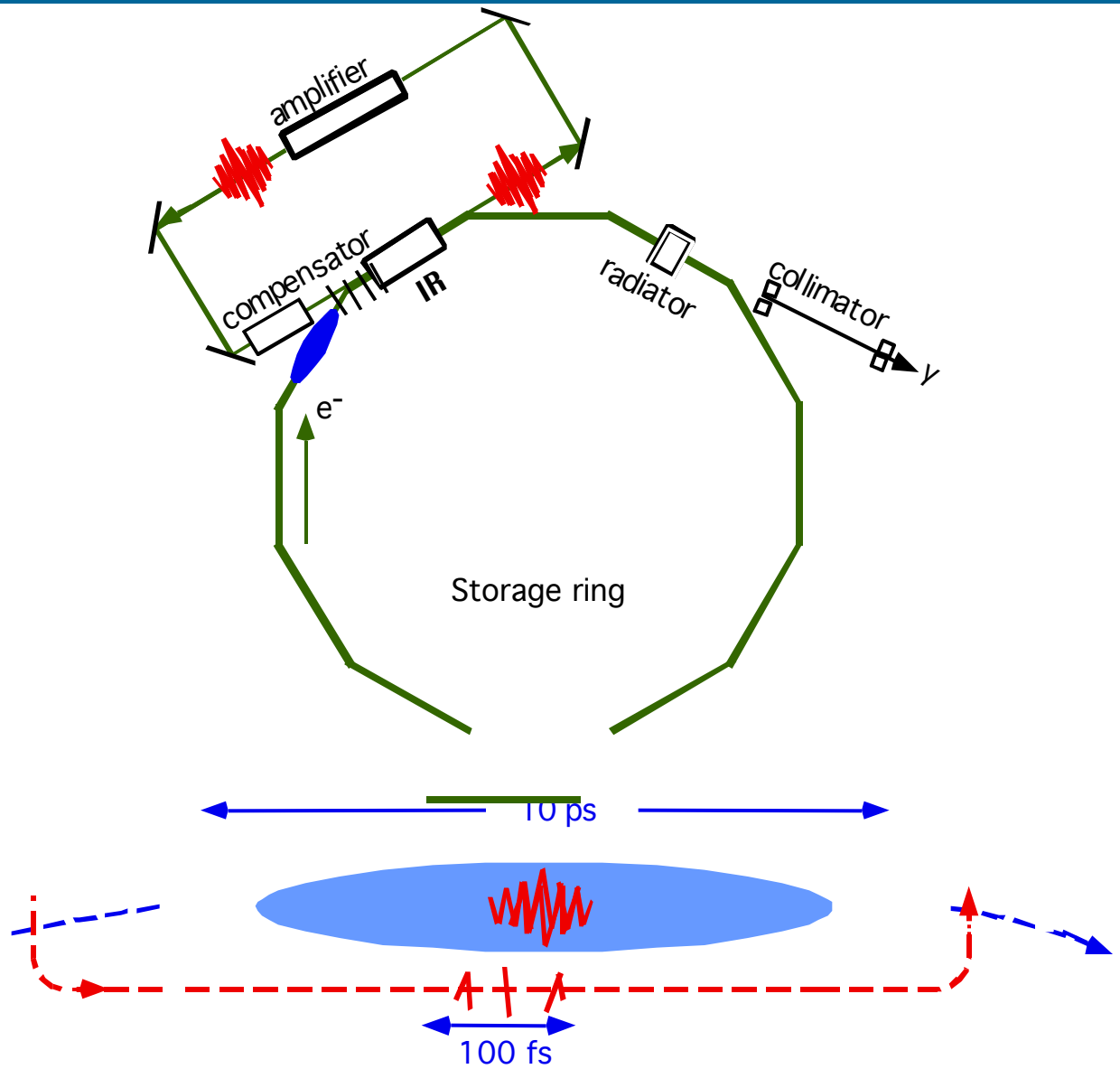
$L_{\gamma\gamma} \geq 0.3\, L_{geom}$ **without monochromatization**

The Electromagnetic Spectrum

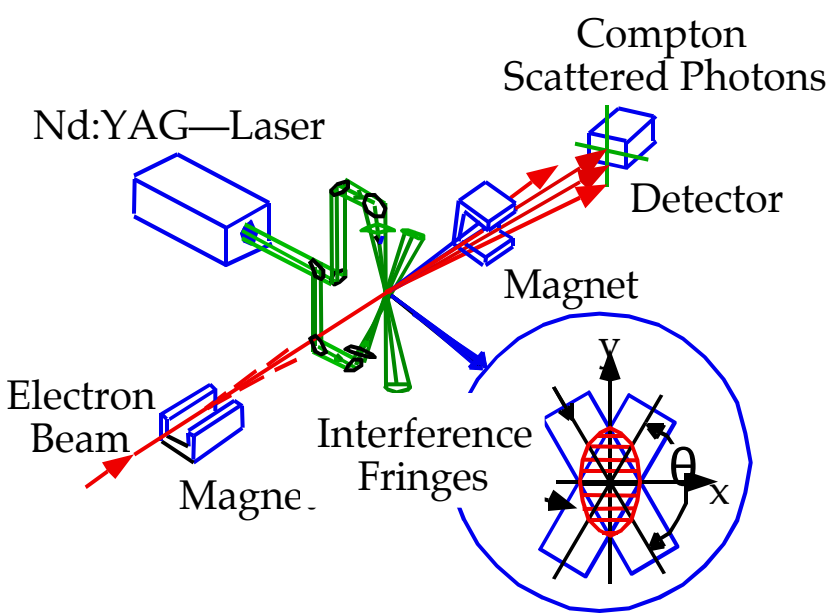


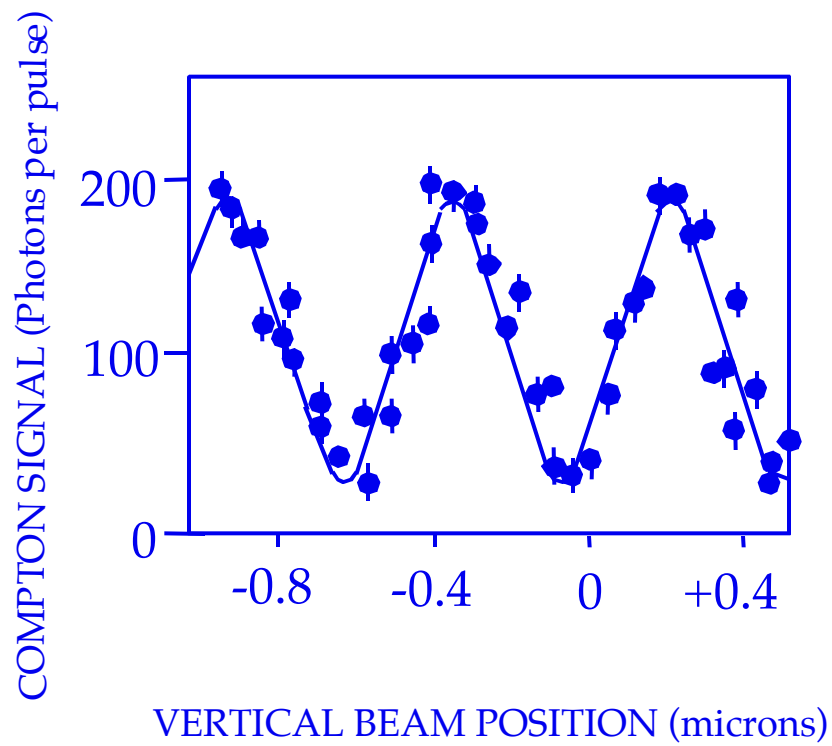
Femtosecond Slicing in a Storage Ring

Implementation in the ALS

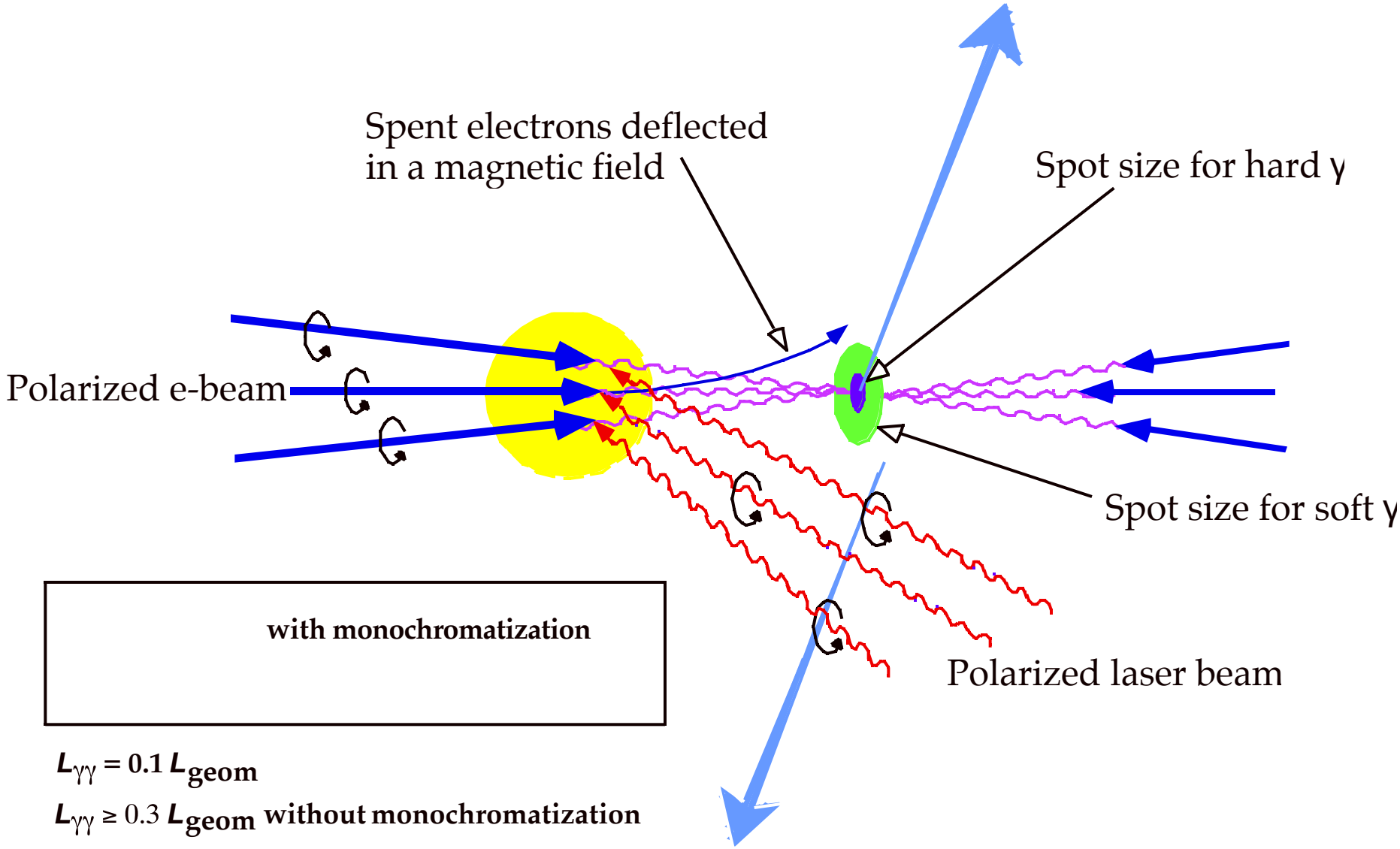


Final Spot Size measurement at the SLC via Comton Scattering across laser interference fringes.





Compton Conversion into Hard Gamma Rays

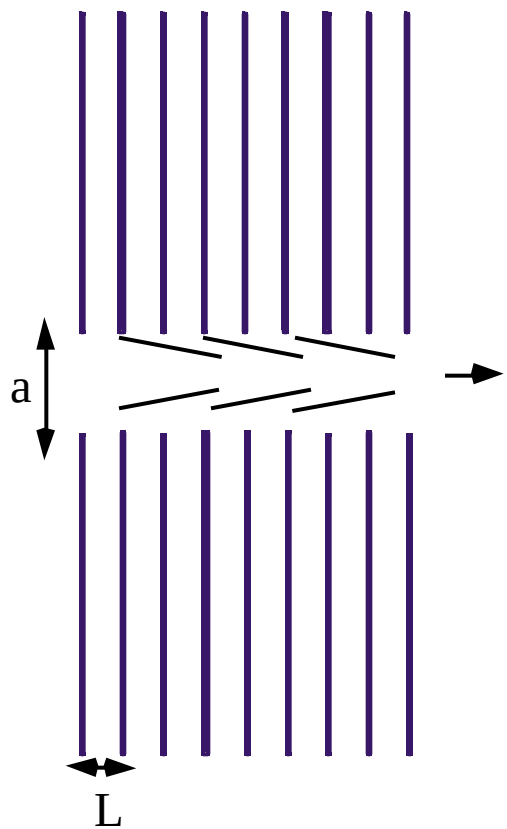


with monochromatization

$L_{\gamma\gamma} = 0.1\, L_{geom}$

$L_{\gamma\gamma} \geq 0.3\, L_{geom}$ **without monochromatization**

IRIS Loaded Structure in "Diffractive" Mode

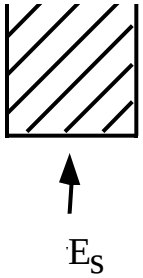


a, L ~ 1 mm

λ ~ 1 µm

E_{ac} ~ 1 GV/m

E_s ~ 10 GV/m

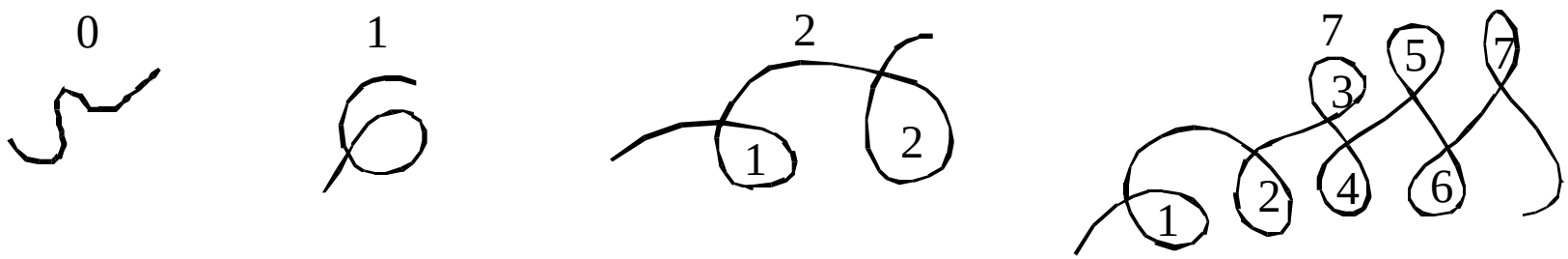


a, L >> λ

Heme - Protein Folding

τ_{rebx} ~1 μs

$\tau_{electronic}$ ~1 ns

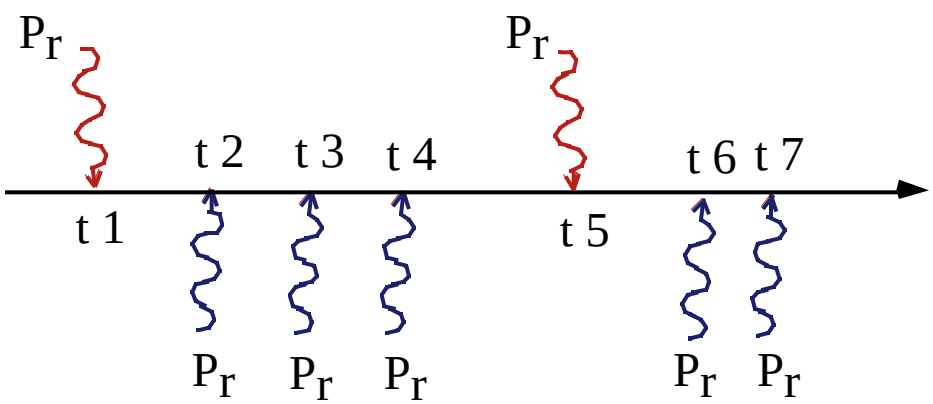


Pump ~ 10 μm

C - C - 0_2 (bond excitation)

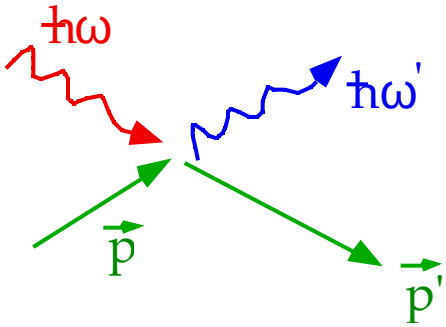
Probe ~ 5 Å

~ 1 - 5 KeV



t1, t2, t3, t4, - - -

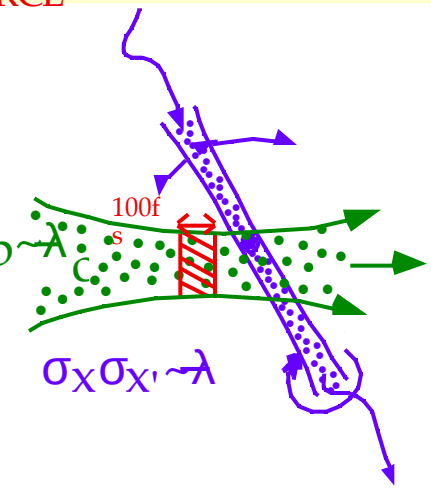
Laser-Beam Interactions : Promising Directions

- 

Energy ⇒ Mapping

'SCATTERING ' : → high energy photons
→ manipulate temporal & spectral profile

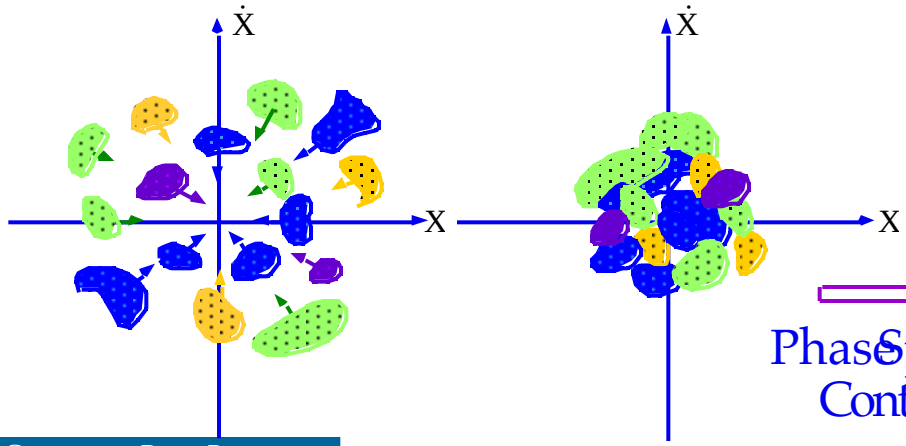
γ, X-RAYS SOURCE



- 'PROBING' : → monitoring 'phase-space'
→ manipulate 'phase-space'

SUB-PS TIME-RESOLVED DIAGNOSTIC, OPTICAL COOLING

PhaseSpace ⇐ Mapping

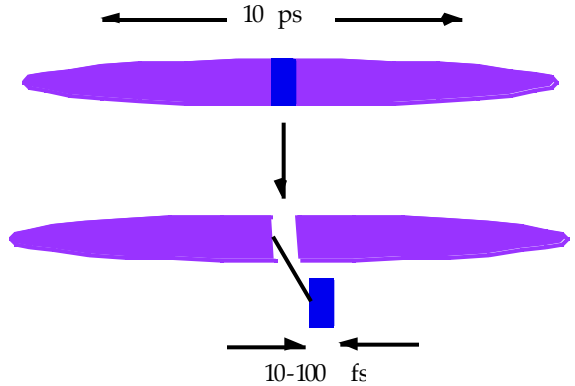


⇒ PhaseSpace Control

Phase Space Cooling at Optical Wavelengths

Laser-Beam Interactions : Promising Directions

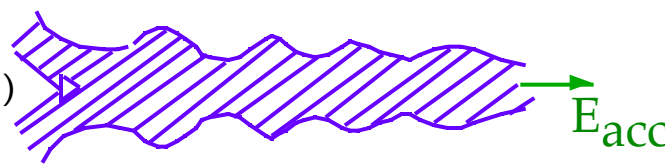
(d)



Phase Space ⇒ Control

Beam & Radiation Slicing

(e)

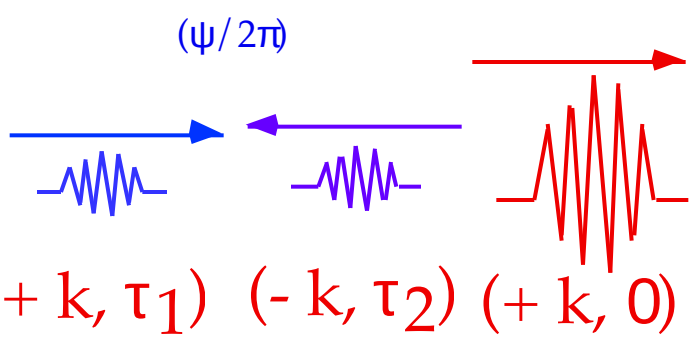


Energy ⇒ Focussing

Laser 'CHANNELING' & guiding

→ PARTICLE ACCELERATION

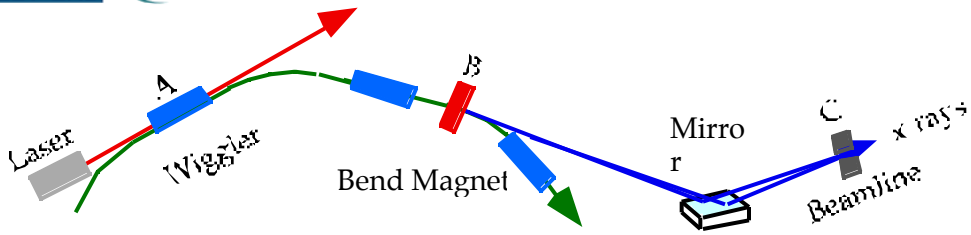
(f)

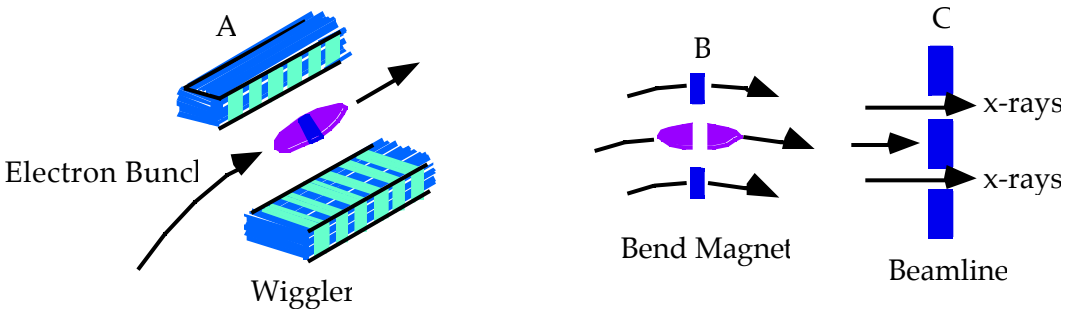


Phase lockin and capture of particle and radiation ⇒

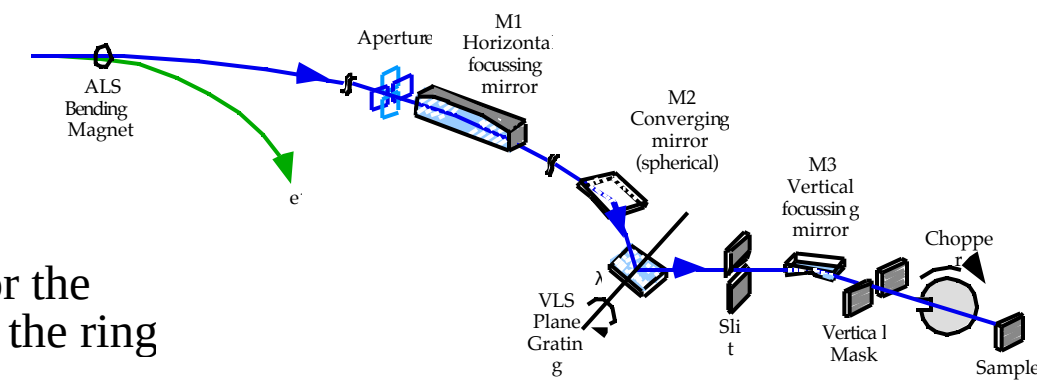
'SYNCHRONIZED 'ejection' & 'injection' of particles

→ INJECTORS, COLLIMATORS, ETC.



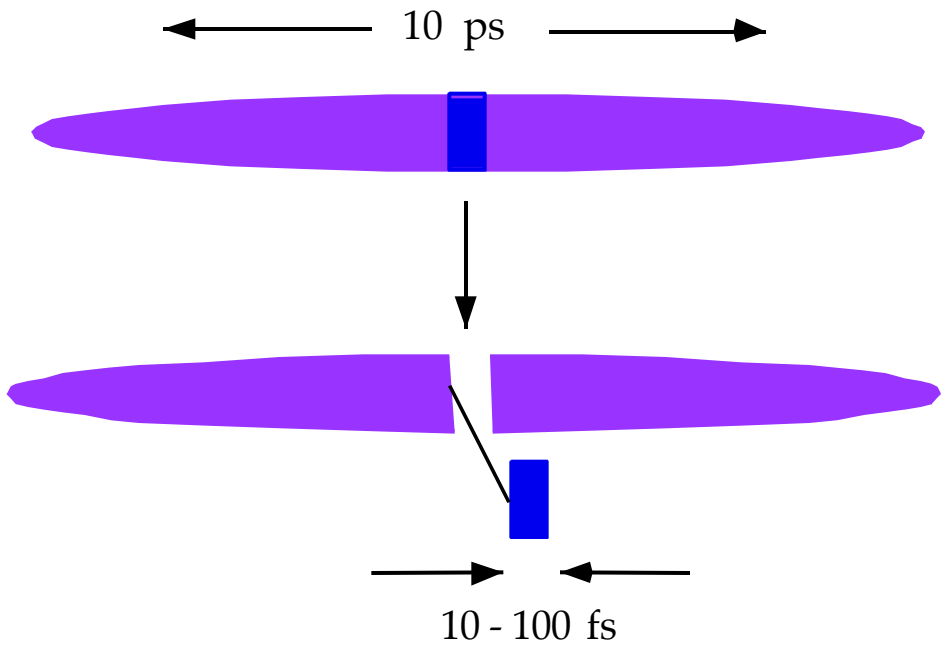


Magnetic discrimination of the energy modulated femtosecond longitudinal slice in the transverse plane

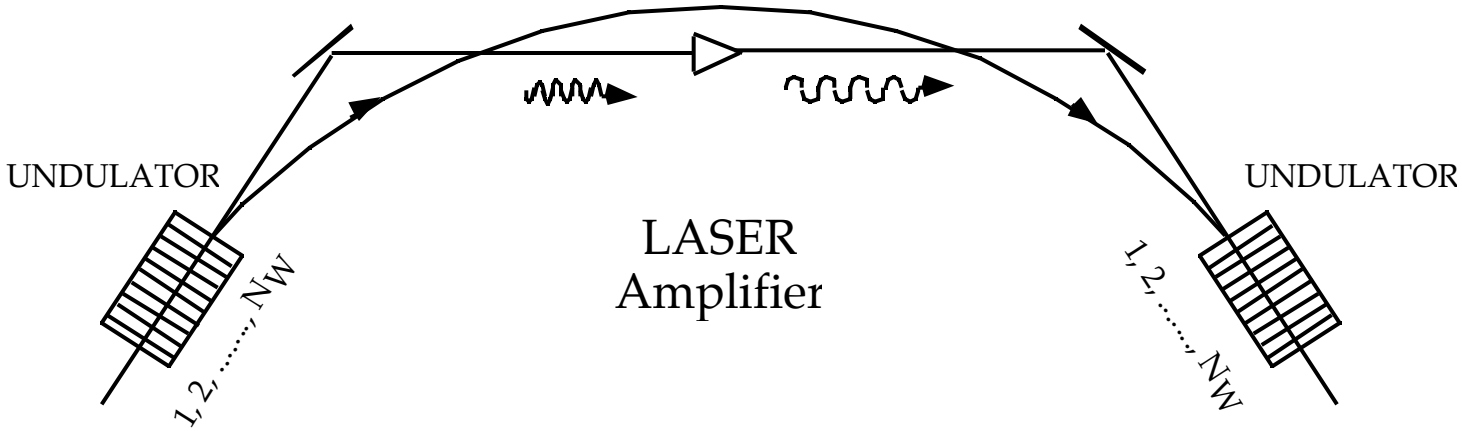


A special beamline for the femtosecond x-rays from the ring

Femtosecond 'Tickle' and Slicing of Picosecond Electron Beams



Optical Stochastic Cooling



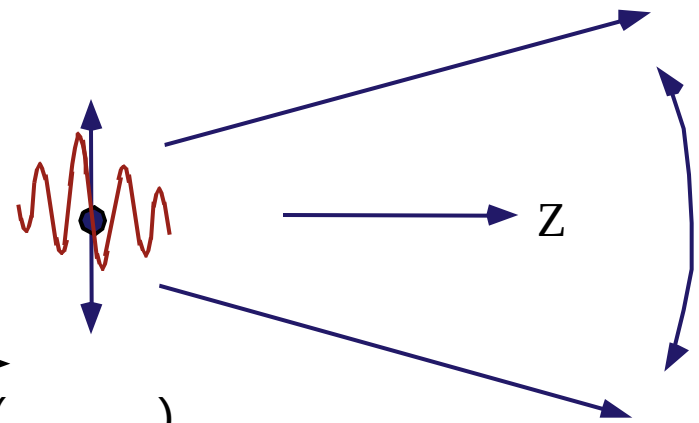
Bandwidth: $W = 3 \times 10^{14}$ Hz

Resolution: Δl 1μm

Gain: g 10^7

Phase Space of Radiation from a Single Oscillating Electron

$$\Delta a_R \sim \frac{1}{2}\left(\frac{\lambda L}{\pi}\right)^{1/2}$$



$$\Delta\theta_R \sim \left(\frac{\pi\lambda}{L}\right)^{1/2}$$

$$Z_R \sim (L/2\pi)$$

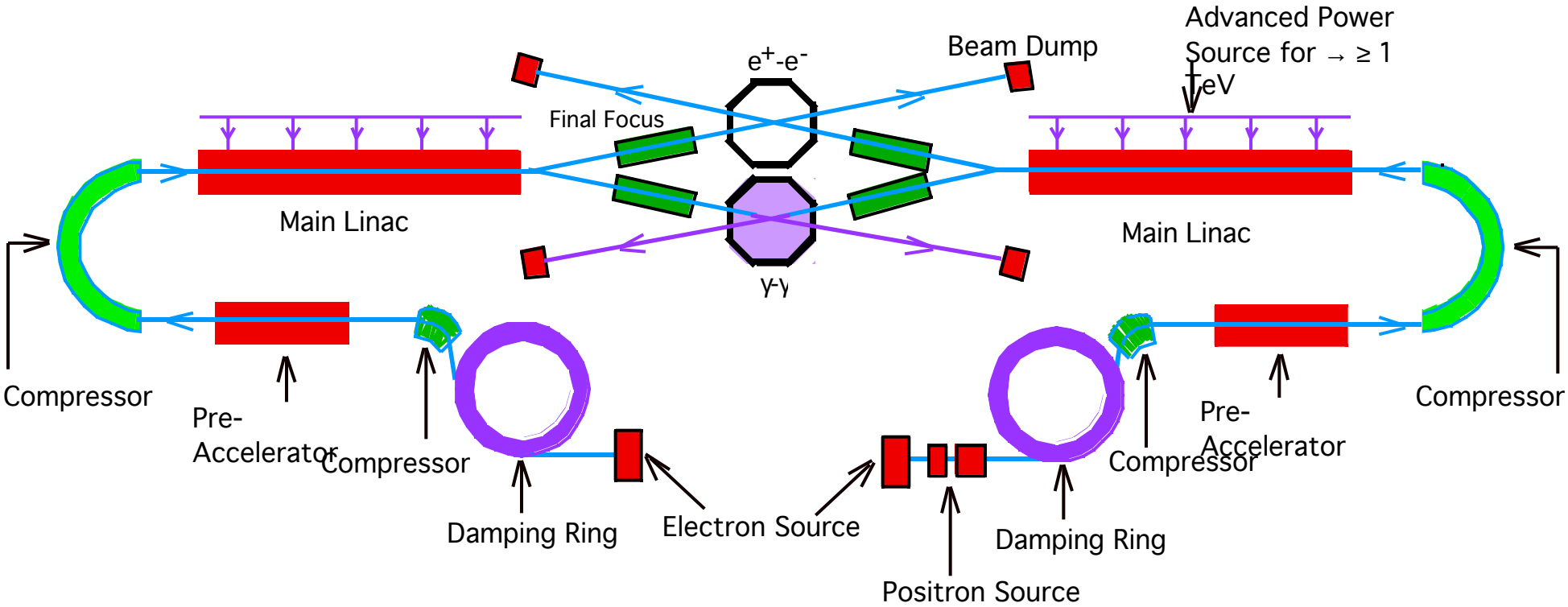
$$\lambda = \frac{\lambda_0}{2\gamma^2} f(\theta)$$

$$\Delta a_R \, \Delta\theta_R = \lambda/2$$

Radiated Energy $= \dfrac{2\pi e^2}{\lambda}$

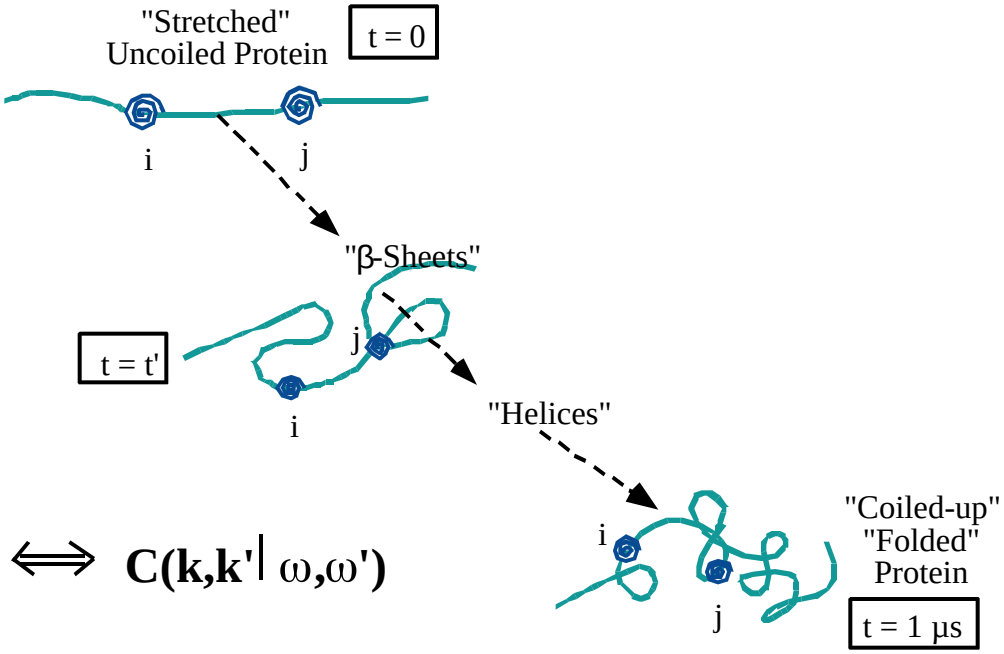
Band Width $\left(\dfrac{\Delta\omega}{\omega}\right)_R \sim \dfrac{L}{\lambda_0} \sim \dfrac{1}{N_0}$

A Schematic of a TeV-Scale Gamma-Gamma Collision



Structural and Temporal Correlation in a Protein Molecule between "Stretched" and "Folded" Patterns

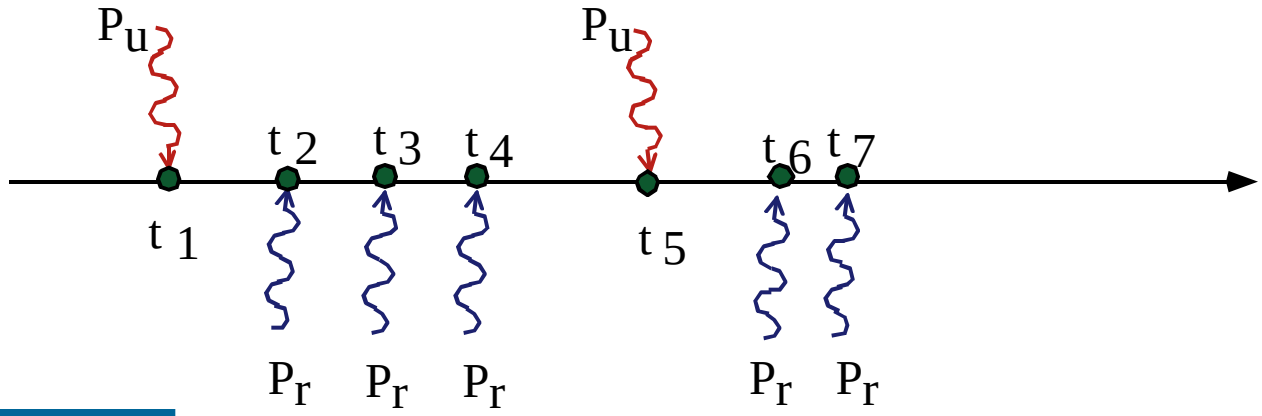
(a)



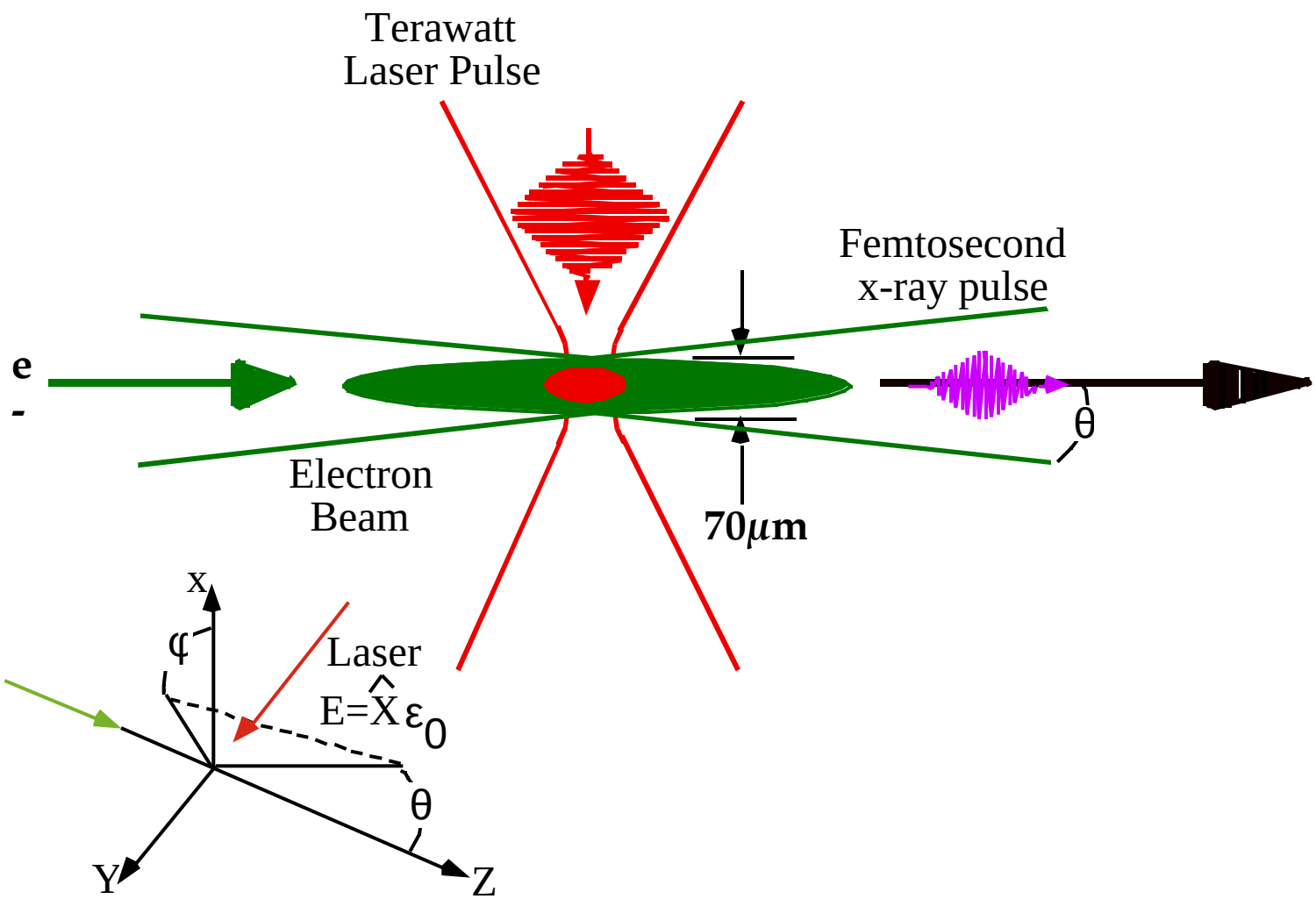
$$R(i,j|\,t,t') \Longleftrightarrow C(k,k'|\,\omega,\omega')$$

Pulse Sequence Schematic to study Correlation

(b)

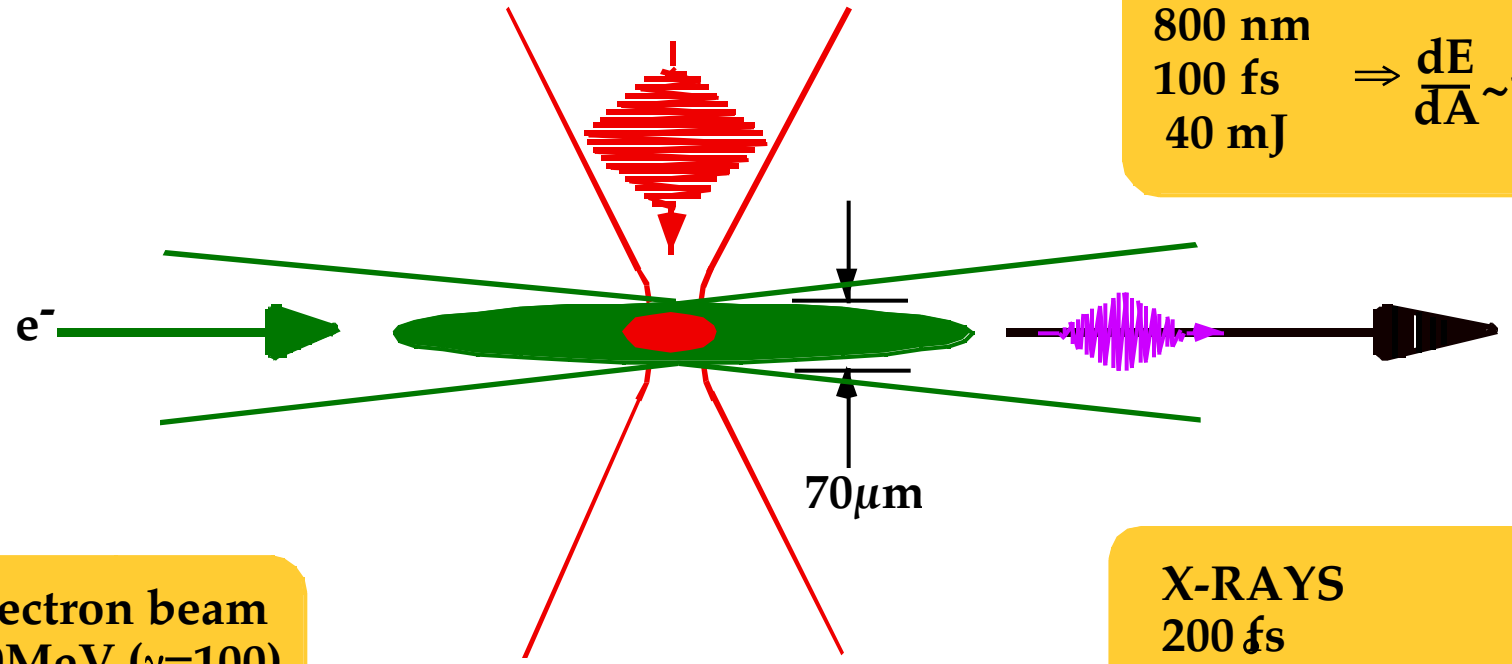


Orthogonal Thomson Scattering Configuration for producing Femtosecond X-Rays



90° Thomson Scattering

laser pulse
800 nm
100 fs
40 mJ
$\Rightarrow \frac{dE}{dA} \sim 10^{15} W/cm^2$



electron beam
50MeV (γ=100)
1.5 nC/pulse
15 ps

$$\lambda_x = \frac{\lambda_L}{2\gamma^2}$$

X-RAYS
200 fs
0.4 A (30keV)
10^5 photons/sec
θ~10 mrad (10% BW)