INVERSE COMPTON SCATTERING

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Inverse Compton Scattering

- Compton Scattering between pulsed laser and electron bunches
- Incoherent X-ray source of wave number:

\[ k' = \frac{k(1 - \beta \cos \theta_1)}{1 - \beta \cos \theta_2 + \frac{k}{E_0} (1 + \cos \theta_1 \cos \theta_2)} \]

\[ k' \approx \frac{k(1 - \beta \cos \theta_1)}{1 - \beta \cos \theta_2} \]
Advantages

- Peak photon energy is tunable
  - Energy of electron bunch
  - Angle of intersection
- Select bandwidth by adjusting acceptance angle
- Low energy, high brightness
- Maximum energy from $180^\circ$ scattering:

$$\lambda'_{\text{max}} = \lambda \frac{1 - \beta}{1 + \beta} = \lambda \frac{1 - \beta^2}{1 + 2\beta + \beta^2} \approx \frac{\lambda}{4\gamma^2}$$
Undulator Model

- Field of laser replaces field from undulator magnets
- Model predicts same initial emission produced by an undulator with period: $\lambda_{\text{und}} = \lambda_{\text{laser}}/2$
- For conventional undulator, $K \sim 3.5$ (LCLS)
- For the laser, $K$ is several orders of magnitude smaller
  - $K \propto \lambda_{\text{laser}} B/r$ (B = field amplitude, r = spot radius)

$$\lambda' = \lambda_{\text{und}} \frac{1 + 0.5K^2 + \gamma^2 \theta^2}{2\gamma^2}$$
Goal: Coherence

- **Step 1:** Initial X-ray radiation from ICS
- **Step 2:** X-rays interact with electron bunch to produce microbunching
- **Challenge:** Sustain microbunching to produce coherent X-rays
Obstacles and Options

- Short undulator period requires low energy electron beam to produce same x-ray frequency
  \[ \lambda' \approx \frac{\lambda_{Laser}}{4\gamma^2} \]
- Corresponding emittance of electron bunch is too large
  - Need \( \gamma\varepsilon < \gamma\lambda/4\pi \)
  - Electron bunches smear
- Improve emittance
- Beam Conditioning
- Longer laser wavelength (THz)
- Pre-bunching (emittance exchange)
Current Capabilities

- More easily attainable goal: increase # of photons/sec
- Increase repetition rate and/or increase brightness of electron pulses
- Beamline design:
  - Storage ring
  - Superconducting RF linac
ICS Storage Ring

- Small storage ring recirculates the electron bunch
- MHz repetition
- Beam emittance and energy spread gradually grow due to intrabeam scattering

Layout of the THomX concept
Linac Set-Up

- High brightness, short pulse duration
  - good for study of dynamical systems of matter
- Superconducting linacs need low temperature
  - Expensive cryogenic system
  - Poor Stability
References

- T. Raubenheimer, S³EPB Lecture Series