Energy Spread by Laser/Undulator Interaction

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Energy Modulation Mechanism

Resonance condition

2 \pi \text{ phase slip per undulator period}

\[ \Delta [\hat{A}] = \frac{13.056 [\text{cm}]}{E^2 [\text{GeV}]} (1 + K^2 / 2) \]

At 135 MeV and 890 nm invert to find K

K = 0.890 \quad \text{\(\Rightarrow\)} \quad B = 1050 \text{ Gauss for 8.5 cm period}

(note APS undulator has B = 5050 Gauss at 32 mm gap)
Laser Power

\[ P(t) = eE(t)\Delta(t)c \]

\[ \sum U = \sum Pdt = e\hat{E}\hat{\Delta} \frac{L}{c}c \]

\[ \hat{\Delta} = \frac{K}{\Delta} \]

\[ \langle S(x,y) \rangle = \langle E \Delta H \rangle = S(0,0)e^{\frac{x^2}{2\sigma^2}}e^{\frac{y^2}{2\sigma^2}} \]

\[ \sum U \frac{kV}{L} = \frac{K}{2} \sum \frac{5480}{[mm]} \sqrt{P_{\text{laser}}[MW]} \]
Energy Spread

- At 4.54 GeV, $\Delta = 3 \times 10^{-5}$ suppresses the CSR instability
- Choose $\Delta = 5 \times 10^{-5}$ for overhead, then at 135 MeV, before BC1

$$\Delta_{135} = \frac{4540 \cdot 0.19}{135 \cdot 0.83} \cdot 5 \Delta 10^{-5} = 3.85 \Delta 10^{-4} \text{ (rms)}$$

$$\Delta_{135} = 52 \text{ keV}$$

$$\frac{\Delta U}{L} = \sqrt{2} \cdot \Delta_{135} = 73.5 \text{ keV, 0 to peak}$$

For $L = 0.5 \text{ m}$, $\Delta \frac{\Delta U}{L} = 147 \text{ kV/m, and } \Delta = 1.5 \text{ mm}$

$P_{\text{laser}} = 143 \text{ MW}$
Optimizing Laser Power

- Bigger K (and therefore smaller $\Delta u$) would reduce required laser power.
- Example, $\Delta u = 5$ cm gives a resonant K of 1.94 and for $\Delta = 1.5$ mm, $L = 0.5$ m

$$\frac{\Delta U}{L} \left[ \frac{kV}{m} \right] = 26.8 \sqrt{P[MW]}$$

and the maximum required laser power for
3X10^{-5} energy spread is

$$P_{laser} = \frac{147}{26.8} = 30.1 \text{ MW}$$
Possible Layout

- laser
- undulator
Laser Source

- IR beam from drive laser
- 10 ps ~ 5 mj -> 500 MW @850 nm
- Makes reliability issue moot
- Light path could follow E/O path
- Don’t have to develop (another) new laser