ICFA
17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Generating Circular Polarization with Crossed-Planar Undulators in High-Gain FELs

K.-J. Kim, ANL

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ARGONNE NATIONAL LABORATORY, ARGONNE, IL U.S.A.

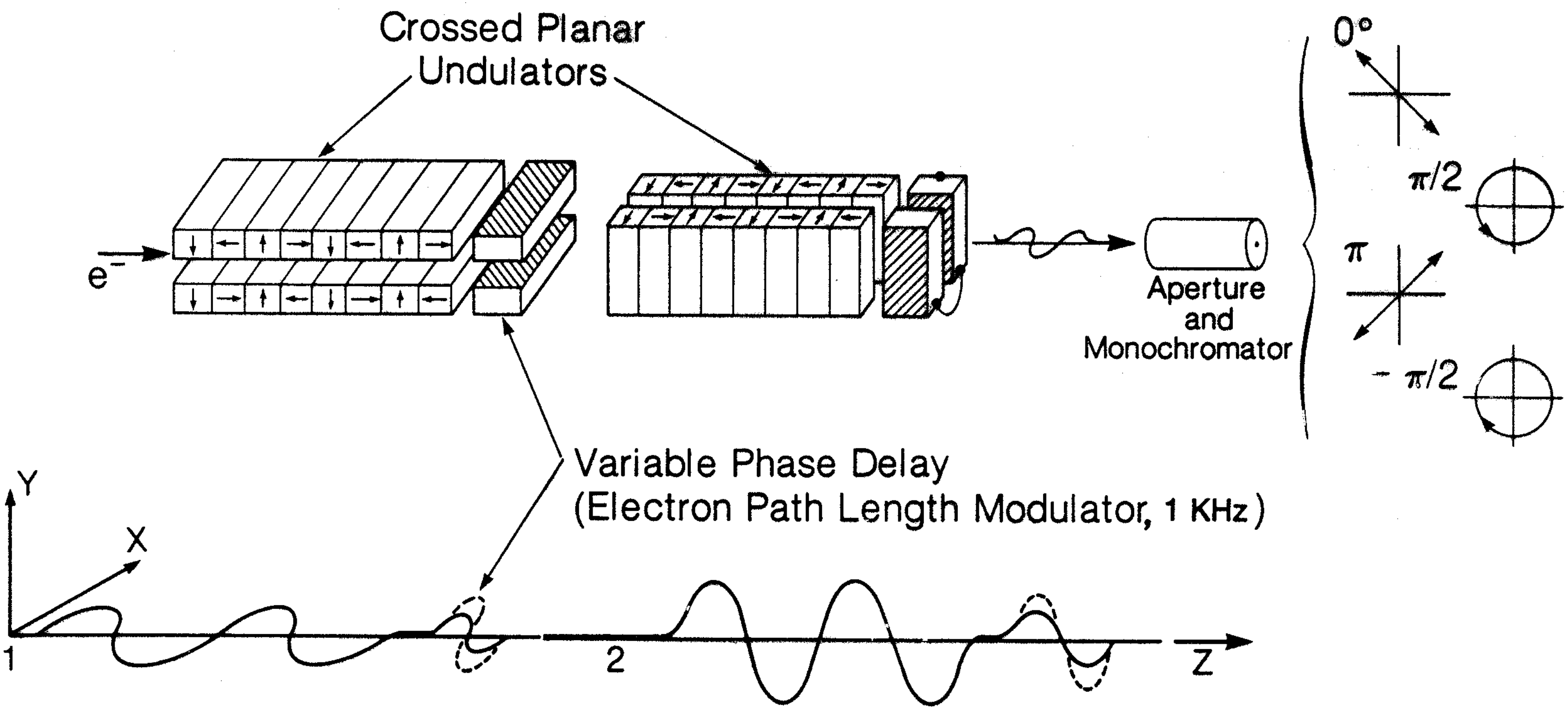
- Switchable, circular polarization may be useful for SASE light sources

- Long, helical undulator gives high gain & circular polarization, but switching may be difficult.

- We propose another scheme here:

$$\boxed{\begin{array}{l}\text{Long planar x-undulator} \\ \qquad\qquad + \text{ dispersive section} \\ \qquad\qquad + \text{ Short planar y-undulator}\end{array}}$$

Similar to crossed-undulator but with a different operating principle.



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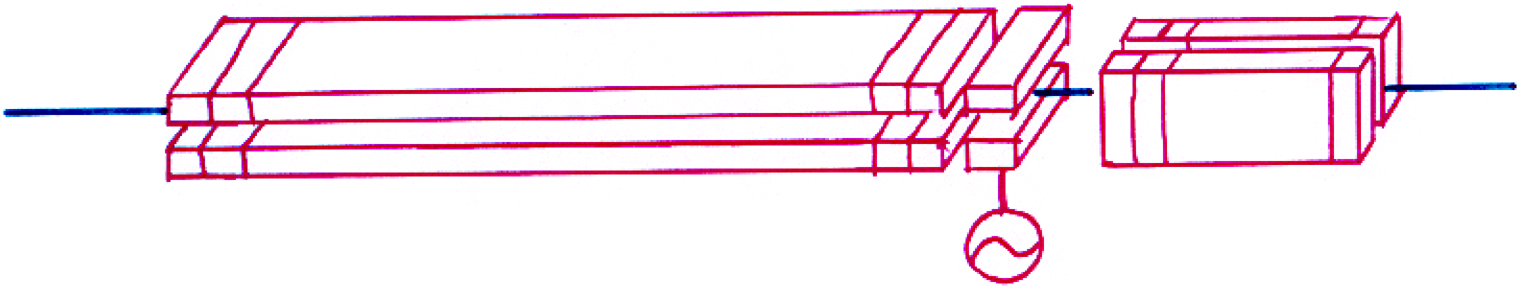
$\mathcal{U}_x$ $\mathcal{D}$ $\mathcal{U}_y$



$\mathcal{U}_x$: start-up & saturation of A_x & bunching.

$\mathcal{D}$: phase adjustment

$\mathcal{U}_y$: Growth of A_y from prebunched beam

High-Gain Regime

$$\begin{cases} \text{EM Amplitude} & A_x, A_y \\ \text{Electron bunching} & F \end{cases}$$

In the exponential gain regime (with x-undulator)

$$\left[\begin{array}{l} A_x(z_2) = e^{-2ik_u \rho \lambda (z_2 - z_1)} \dfrac{\left[A_x(z_1) - \dfrac{1}{\varkappa} \displaystyle\int \dfrac{d\delta\, F(\delta, z_1)}{(\lambda + \delta)} \right]}{1 - \displaystyle\int d\delta \dfrac{v'(\delta)}{(\lambda+\delta)^2}} \\ \\ F(\delta, z_2) = \dfrac{\varkappa\, A(z_2)\, v'(\delta)}{(\lambda + \delta)} \end{array}\right.$$

(I) After U_x:

initial noise in e-beam

$$A_x(L) = \frac{1}{\varkappa} e^{-2ik_u\rho\lambda L} \frac{\int \frac{d\delta\, F(\delta,0)}{(\lambda+\delta)}}{1 - \int d\delta \frac{v'(\delta)}{(\lambda+\delta)^2}}$$

$$A_y = 0$$

$$F(\delta,L) = \frac{\varkappa A_x(L)\, v'(\delta)}{\lambda+\delta}$$

(II) $\mathcal{D}$:

$$A_x = A_x(L)\, e^{i\Delta\nu k_u d}, \quad A_y = 0$$

$$F = F(\delta,L)\, e^{i(\Delta\theta_0 + D\delta)}$$

$$\Delta\theta_0 = -(k_u d)\left[\frac{1+K_D^2/2}{1+K^2/2} - 1\right]$$

$$D = 2\rho k_u d\,(1+K_D^2/2)/(1+K^2/2)$$

$$K_D^2 = \frac{2}{d}\left(\frac{e}{mc}\right)^2 \int_0^d \left[\int_0^z B(z')\,dz'\right]^2 dz$$

III After U_y

$$A_x = A_x(L)\, e^{i(\Delta\nu)(k_u)(d+\ell)}$$

$$A_y = \frac{-\,e^{-2ik_u\rho\lambda\ell}\left[\int \frac{d\delta\ \nu'(\delta)}{(\lambda+\delta)^2}\, e^{iD\delta}\right]}{1 - \int d\delta\, \frac{\nu'(\delta)}{(\lambda+\delta)^2}}\, e^{i\Delta\theta_0}\, e^{i\Delta\nu k_u(\ell t)_2}$$

$$\times A_x(L)$$

Choose ℓ & $\Delta\theta_0$ so that

$$|A_x| = |A_y|$$

$$\text{phase}(A_y) = \frac{\pi}{2} + \text{phase of } A_x$$

$\rightarrow$ Circular polarization.