Emittance Reduction in Electron Storage Rings

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The natural emittance of the CG lattice is generally limited by a problem of dynamic aperture. In order to reduce the emittance under the achromatic condition, a horizontal betatron function is extremely lowered inside the bending magnets. This inevitably makes the peaks of the horizontal betatron function higher on both sides of the bending magnets. As a result, horizontal chromaticity is increased and sensitivity becomes high. On the other hand, the achromatic condition gives a strict constraint on the chromaticity correction with sextupoles. In the case where only two families of sextupoles are inside of the achromatic arc, their strength is automatically determined with the large value of a horizontal chromaticity. The dynamic stability of the CG lattice is just improved by canceling out harmful non-linearity due to these chromaticity correction sextupoles with other families of sextupoles installed in the dispersion free straight sections.

As one idea to break through this limit, we have investigated the possibility to reduce emittance effectively by breaking the dispersion-free condition in the straight sections for the IDs. In this case, we can't use the natural emittance to estimate how brilliant the photon beam is, because it doesn't include the effects of momentum spread on the phase space of electron beams. We therefore define a new parameter, which is called effective emittance, eeff. It represents the total spread of electron beams at the source points where the IDs are installed and expressed as

$$\varepsilon_{eff} = \left\{ \left[\beta_x \varepsilon_{x0} + (\eta_x \sigma_{\delta p/p})^2\right] \times \left[\gamma_x \varepsilon_{x0} + (\eta'_x \sigma_{\delta p/p})^2\right] - \left[-\alpha_x \varepsilon_{x0} + (\eta_x \sigma_{\delta p/p}) \times (\eta'_x \sigma_{\delta p/p})\right]^2 \right\}^{1/2}, \quad (1)$$

$$\alpha_x = -\frac{1}{2}\frac{d\beta_x}{ds}, \quad \gamma_x = \frac{1+\alpha_x^2}{\beta_x}, \quad \eta'_x = \frac{d\eta_x}{ds},$$

where, ε_{x0}, β_x, η_x, and $\sigma_{\delta p/p}$ are respectively the horizontal emittance, the horizontal betatron function, the horizontal dispersion function, and the rms. momentum spread. Under the achromatic condition, the ε_{eff} is completely equal to the natural emittance, ε_{x0}. When the IDs are installed, the ε_{x0} and the $\sigma_{\delta p/p}$ are no longer natural values for the ring without the IDs. Assuming all magnetic fields are isomagnetic and of separated function, they are expressed [1] in the form of Eqs. (2) and (3). The parameters, ρ, Γ, J_E, and J_x are respectively the radius of curvature of bendingmagnets, Lorentz factor, the horizontal and longitudinal damping partition numbers. The symbols, BM and ID at the integral show respectively the integration within all bending magnets and all IDs.

$$\varepsilon_{x0} = \frac{C_q \Gamma^2}{J_x} \cdot \frac{\oint_{BM} \frac{H(s)}{|\rho(s)|^3} ds + \oint_{ID} \frac{H(s)}{|\rho(s)|^3} ds}{\oint_{BM} \frac{1}{\rho(s)^2} ds + \oint_{ID} \frac{1}{\rho(s)^2} ds}, \quad (2)$$

$$(\sigma_{\delta p/p})^2 = \frac{C_q \Gamma^2}{J_E} \cdot \frac{\oint_{BM} \frac{1}{|\rho(s)|^3} ds + \oint_{ID} \frac{1}{|\rho(s)|^3} ds}{\oint_{BM} \frac{1}{\rho(s)^2} ds + \oint_{ID} \frac{1}{\rho(s)^2} ds}, \quad (3)$$

$$H(s) = \gamma_x \eta_x^2 + 2\alpha_x \eta_x \eta'_x + \beta_x \eta'^2_x .$$

The simulation results for the ESRF case were reported in Ref. 2. We found that the effective emittance in the ESRF storage ring can be reduced from 7 to less than 4 nm.rad keeping the dynamic stability [2]. The achievable emittance is shown in Fig. 1 for three kinds of the practical installation of the IDs. (See Ref. 2)

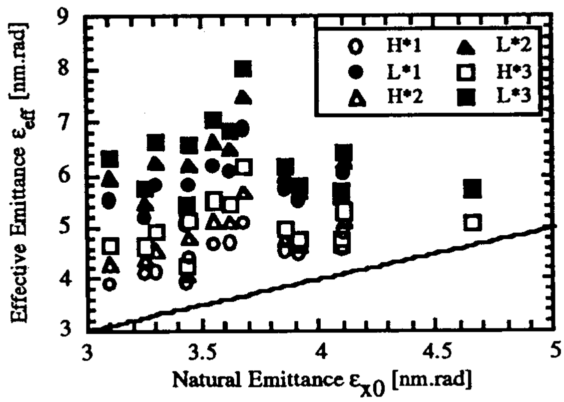

Fig. 1 Correlation of effective emittance obtained under the practical installation of IDs with natural emittance. The H and L represent respectively the emittance at a high and a low β straight sections. Each kind of the symbols show the different distribution of the IDs. The solid line shows the condition of no emittance growth, i.e. $\varepsilon_{eff}=\varepsilon_{x0}$.

References

[1] M. Sands: SLAC-121, 1970.

[2] J. L. Laclare et al.: ESRF/MACH-LAT-93-08, 1993.