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1 Spin decoherence in a perfectly aligned ring

Spin decoherence is an inherent weakness of the FS method, arising from the requirement that the polarization of the beam is turned into the horizontal plane.

1.1 Spin coherence time requirements

1.2 Origin of decoherence

The longitudinal dynamics of a charged particle on the reference orbit in a storage ring is described by the system of equations:

$$\begin{cases} \frac{\mathrm{d}\varphi}{\mathrm{d}t} & = -\omega_{RF}\eta\delta, \\ \frac{\mathrm{d}\delta}{\mathrm{d}t} & = \frac{qV_{RF}\omega_{RF}}{2\pi h\beta^2 E}\sin\varphi. \end{cases}$$

In the equations above: φ is the phase deviation from the reference $\varphi_0 = 0$; $\delta = \frac{\Delta p}{p_0}$ is the relative momentum deviation from the momentum p_0 of the reference particle; V_{RF}, ω_{RF} are the voltage and oscilation frequency of the RF field; $\eta = \alpha_0 - \gamma^{-2}$ is the slip factor, with α_0 being the compaction factor defined by ${}^{\Delta L}/{}_{L} = \alpha_0\delta$, and L being the orbit length; h is the harmonic number; E is the total energy of the accelerated particle. $\omega_{RF} = 2\pi h f_{rev}$, where $f_{rev} = T_{rev}^{-1}$ is the beam revolution frequency.

The solutions of this system form a family of ellipses in the (φ, δ) space, centered at $(0, 0)$. However, if we consider a particle involved in betatron oscillations, and use a higher-order Taylor expansion of the compaction factor $\alpha = \alpha_0 + \alpha_1\delta$, the first equation of the system transforms into: [1]

$$\frac{\mathrm{d}\varphi}{\mathrm{d}t} = -\omega_{RF}\left[\left(\frac{\Delta L}{L}\right)_\beta + \left(\alpha_0 + \gamma^{-2}\right)\delta + \left(\alpha_1 - \alpha_0\gamma^{-2} + \gamma^{-4}\right)\delta^2\right],$$

where $\left(\frac{\Delta L}{L}\right)_\beta = \frac{\pi}{2L}\left[\varepsilon_x Q_x + \varepsilon_y Q_y\right]$, is the betatron motion-related orbit lengthening; ε_x and ε_y are the horizontal and vertical beam emittances, and Q_x and Q_y are the horizontal nad vertical tunes. [1]

The solutions of the modified system are no longer centered at the same point. Orbit-lengthening and momentum deviation cause an equilibrium-level momentum momentum shift[1]

$$\delta\delta_{eq} = \frac{\gamma_0^2}{\gamma_0^2\alpha_0 - 1}\left[\frac{\delta_m^2}{2}\left(\alpha_1 - \alpha_0\gamma^{-2} + \gamma_0^{-4}\right) + \left(\frac{\Delta L}{L}\right)_\beta\right]$$

1.3 Sextupoles for the reduction of decoherence

Compaction factor effect. Orbit length effect. Decoherence type classification based on the source motion (horizontal betatron, vertical betatron, synchrotron). Optimal sextupole placement based on the classification.

1.3.1 Simulation

Description of the sextupole strength optimization procedure. Unoptimized vs optimized spin tune plots.

2 Fake signal simulation

Analytical estimates of the MDM precession frequency about the radial axis. Description of how element misalignments were introduced and why so (to preserve the closed orbit). Plots: precession frequency vs the mean tilt angle.

References

[1] Senichev Y, Zyuzin D. SPIN TUNE DECOHERENCE EFFECTS IN ELECTRO- AND MAGNETOSTATIC STRUCTURES. In: Beam Dynamics and Electromagnetic Fields. vol. 5. Shanghai, China: JACoW; 2013. p. 2579–2581. OCLC: 868251790. Available from: `https://accelconf.web.cern.ch/accelconf/IPAC2013/papers/wepea036.pdf`.