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An injection scheme with non-disturbance to stored beam

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Overview

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- Our injection scheme
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Issue

Goal → Small natural emittance

Scheme → High gradient quadrupoles and strong chromaticity correction sextupole

Consequence → Restrict the physical and dynamic aperture of the storage ring

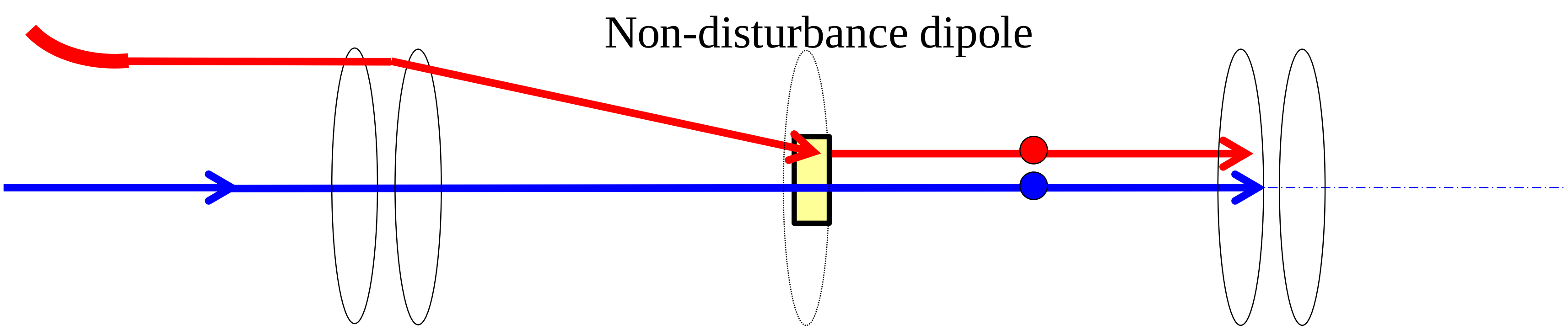
Problem → **Complex injection**

Top-up Injection Schemes

- On-axis injection
  - Swap-out injection
    - Smallest aperture
    - Another storage ring needed
  - Longitudinal injection
    - Non-disturbance to stored beam
    - Dipole kicker shorter than bunch space
- Off-axis injection
  - Bumped orbit injection
    - Dipolar oscillation
    - Require sufficient aperture
  - Pulse multipole kicker injection
    - Theoretical non-disturbance to stored beam
    - Simple injection system and required no high technical kicker
    - Time jitter for kickers

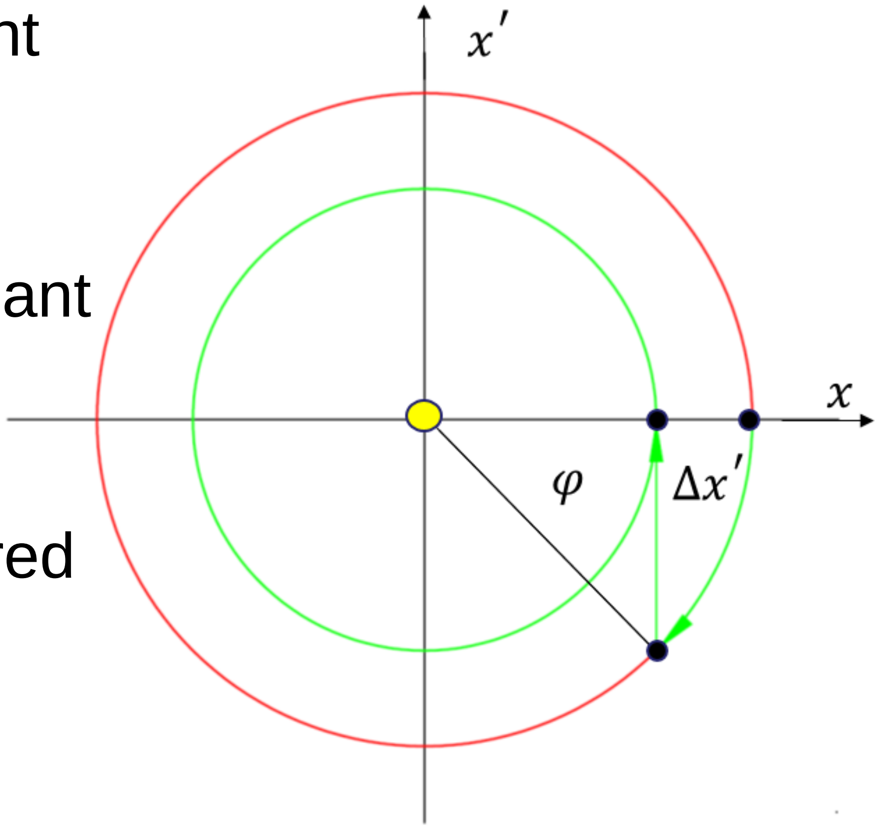
Non-disturbance injection scheme

- Off-axis
- Consisting
  - Septum dipole magnet
  - Pulse dipole kicker
    - Installed in the vacuum chamber
    - Stored beam face no magnetic field
- Injected beam transported into the acceptance of the storage ring
- Merge into stored beam after the damping effect



Principle of non-disturbance injection

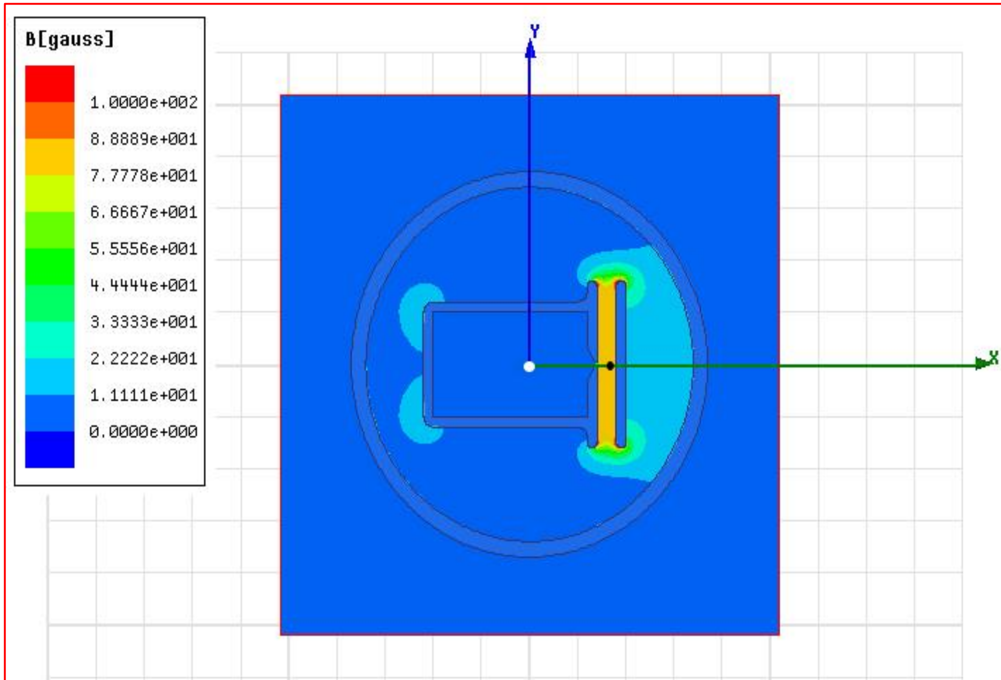
- Beam transportation and Courant-Snyder invariant
- Injected beam and stored beam
- Injection point and kicker point
- Certain phase advance and constant invariant
- A kick $\Delta x'$ and reduced invariant
- Smaller enough than the accelerator acceptance
- Injected beam may be captured



Two-dimensional distribution of flux density

- Installed in the vacuum chamber
- Dipole kicker with conductive plate
- Injected beam through the gap and receive a kick
- Enter the field-free chamber
- Stored beam transportation

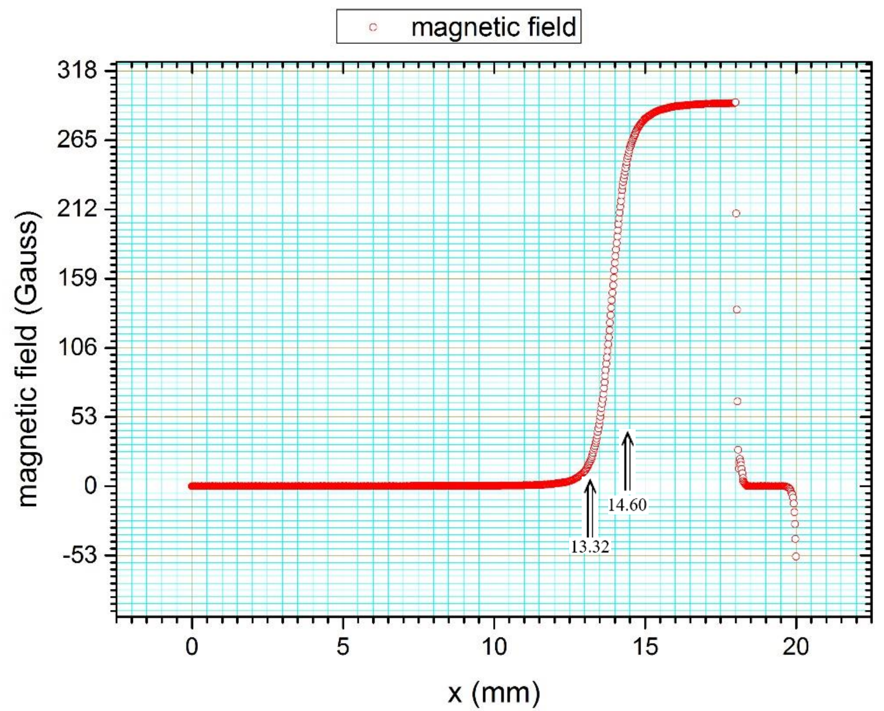
- Aperture : 1 mm



Radial distribution of dipole kicker magnetic field

- Radial size is 20 mm ,installed Inside the vacuum chamber
- 0-13.32 mm, magnetic field is zero
- 14.6-16.6 mm, magnetic field is about 300 Gauss. On-going work, 400 Gauss now.

- Radial size is 20 mm in this figure, 6 mm now,
- 3 mm is planning to do.



Derivation of particle transportation

- Transfer matrix between any two points
- Injection point and kicker point $\alpha = 0$

$$\mathrm{M}(s_2/s_1) = \begin{bmatrix} \sqrt{\dfrac{\beta_2}{\beta_1}}\left(\cos\Delta\varphi_{1,2} + \alpha_1 \sin\Delta\varphi_{1,2}\right) & \sqrt{\beta_1\beta_2}\sin\Delta\varphi_{1,2} \\ -\dfrac{(1+\alpha_1\alpha_2)\sin\Delta\varphi_{1,2} + (\alpha_2 - \alpha_1)\cos\Delta\varphi_{1,2}}{\sqrt{\beta_1\beta_2}} & \sqrt{\dfrac{\beta_1}{\beta_2}}\left(\cos\Delta\varphi_{1,2} - \alpha_2 \sin\Delta\varphi_{1,2}\right) \end{bmatrix}$$

The relationships

- i : injection point, k: kicker point
- φ_{i-k}:phase advance from injection to kicker
- From equation, Injection needs big β_i function
- With proper β_k and φ_{i-k}

$$x_k = x_i\sqrt{\frac{\beta_k}{\beta_i}}\cos\varphi_{i-k}$$

$$x'_k = -\frac{x_i}{\sqrt{\beta_i\beta_k}}\sin\varphi_{i-k}$$

Example

- $x_i = 10\ mm,$
- $\beta_i = 20\ mm\ , \beta_k = 5\ mm$
- $\varphi_{i-k} = 60\ °$
- Then
- $x_k = 0.010 \times \sqrt{\frac{5}{20}} \times \cos 60\ ° = 0.0025\ m$
- $x'_k = -\frac{0.010}{\sqrt{5 \times 20}} \times \sin 60\ ° rad = 0.000866\ rad$

Summary

- Without complex injection system and possible used
  - Septum dipole and dipole kicker
- Non-disturbance to stored beam
  - Field-free chamber
- No time jitter
  - Single kicker

Outlook

- Track of injection
- Three-dimensional magnetic field calculation based on the overall design
- Dipole kicker with bigger angle
- Simulation with energy dispersion
- Prototype design and development
- The lifetime of oxygen-free copper dipole kicker in vacuum chamber

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Thank you for your attention!