IP Coupling/Dispersion Knob by using Sextupole Bumps on LHC optics

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Introduction

- Motivation
  - Zimmermann and Rogelio suggest me to make a IP coupling/dispersion tuning knobs.
  - I try to make a test code of IP knob for fine tuning after optics correction.
- Parameters of coupling/dispersion knob(lowest order)
  - XY-coupling parameter: R_1, R_2, R_3, R_4
  - Vertical dispersion: η_y, $\eta_{y'}$
  - Horizontal dispersion: η_x, $\eta_{x'}$
- How to make coupling/dispersion
  - XY-coupling: by skew quadrupole
  - Vertical dispersion: convert horizontal dispersion via local coupling
  - Horizontal dispersion: generate by local beta function distortion around bending magnets

How to make coupling/dispersion(cont.)

- Required degree of freedom to make individual knobs
  - Vertical: 8(IP1/2/3/4/5/6/7/8) × 6
  - Horizontal: 8(IP1/2/3/4/5/6/7/8) × (2 + 6(for $\beta / \alpha / \phi$))
- Coupling/Dispersion generators
  - Coupling Correcter in LHC lattice
    - 4 Skew Quadrupoles per Arc(MQS)
    - Number of MQS is less than number of required parameters.
  - Sextupole Bumps
    - 18/18(H/V) closed bumps per Arc(around MS)
- Code for proof of principle(POP Code)
  - Implemented by using sextupole bumps on SAD
  - Lattice is converted from V6.501/V6.5.seq and V6.5.coll.str
  - Sextupole bumps are calculated by using SVD of response matrix between bump height and coupling/dispersion parameter

Tuning Range per 1mm Bump Height

	IP1	IP2	IP3	IP4	
R_1	1.149×10^{-2}	1.210×10^{-2}	4.893×10^{-3}	1.577×10^{-2}	[rad]
R_2	5.703×10^{-3}	1.737×10^{-1}	1.839×10^{-1}	1.281×10^{0}	[m]
R_3	1.884×10^{-2}	1.548×10^{-3}	5.065×10^{-5}	6.247×10^{-5}	[m^{-1}]
R_4	1.238×10^{-2}	6.120×10^{-3}	3.012×10^{-3}	3.955×10^{-3}	[rad]
η_y	3.680×10^{-4}	2.084×10^{-3}	3.728×10^{-3}	8.453×10^{-3}	[m]
$\eta_{y'}$	1.033×10^{-3}	9.070×10^{-5}	4.539×10^{-5}	2.081×10^{-5}	[rad]
η_x	7.022×10^{-4}	6.018×10^{-3}	1.276×10^{-3}	5.868×10^{-3}	[m]
$\eta_{x'}$	5.829×10^{-4}	1.271×10^{-4}	4.070×10^{-5}	2.020×10^{-5}	[rad]

	IP5	IP6	IP7	IP8	
R_1	7.395×10^{-3}	1.018×10^{-2}	5.371×10^{-3}	1.456×10^{-2}	[rad]
R_2	3.165×10^{-3}	1.808×10^{0}	5.637×10^{-1}	1.044×10^{-1}	[m]
R_3	1.865×10^{-2}	5.894×10^{-5}	4.784×10^{-5}	1.155×10^{-3}	[m^{-1}]
R_4	1.253×10^{-2}	9.344×10^{-3}	5.524×10^{-3}	1.494×10^{-2}	[rad]
η_y	2.105×10^{-4}	7.078×10^{-3}	4.465×10^{-3}	1.980×10^{-3}	[m]
$\eta_{y'}$	1.057×10^{-3}	5.979×10^{-5}	4.615×10^{-5}	1.507×10^{-4}	[rad]
η_x	7.111×10^{-4}	2.437×10^{-2}	1.933×10^{-2}	9.831×10^{-4}	[m]
$\eta_{x'}$	5.843×10^{-4}	3.750×10^{-5}	4.538×10^{-5}	2.004×10^{-4}	[rad]

Bump Height vs. Tuning Range

- Bump height
  - Limited by machine aperture.
  - Depends on optics and sextupole strength.

- Tuning range required
  - for help of global optics correction
    - Measured coupling/dispersion error
  - for fine tuning after global optics correction
    - Resolution of coupling/dispersion measurement
    - Residual coupling/dispersion after global correction

Coupling/Dispersion Error Estimation

- Rough estimation of maximum coupling/dispersion error at IP1 from gaussian error distribution
  - Source: Sextupole vertical misalignment($\sigma = 5 \times 10^{-4}$ m)
  - Number of samples: 300

	Maximum error at IP1	Bump height for corr.[m]
R_1	4.25×10^{-1} [rad]	3.70×10^{-2}
R_2	2.64×10^{-1} [m]	3.58×10^{-2}
R_3	6.88×10^{-1} [m^{-1}]	3.65×10^{-2}
R_4	4.39×10^{-1} [rad]	3.55×10^{-2}
η_y	6.81×10^{-3} [m]	1.85×10^{-2}
$\eta_{y'}$	1.18×10^{-2} [rad]	1.14×10^{-2}

  - Coupling/dispersion error from sextupole vertical misalignment MUST be corrected by other global corrector(MQS skew quadrupoles?)
  - Global coupling/dispersion correction is not implemented on SAD model yet.