EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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CAS 2003

Exercises in the optics course at the CAS 2003 in Zeuthen.

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15th September 2003

1 Exercise 1

1.1 Problem:

Design a machine for protons at a momentum of 20 GeV/c with the following basic parameters:

- Circumference = 1000 m,
- Quadrupole length L_{quad} = 3.0 m,
- 8 FODO cells.
- Dipole length is 5 m, maximum field is 3 T

Apply the knowledge from previous lectures at this school and find the optics (strength of dipoles and quadrupoles) so that $\beta_{max} \equiv \hat{\beta}$ is around 300m. Implement it into MAD format using thin lenses for all elements and verify the calculations.

2 Exercise 2

2.1 Problem:

Start with the lattice from exercise 1 and modify it so the maximum betatron function $\hat{\beta}$ is around 100 m. The circumference must not be changed.

3 Exercise 3

3.1 Problem:

Start with the lattice from exercise 2 and modify it so you can correct the chromaticity for both planes to zero. Try first to calculate approximately the required strengths. Implement your correction scheme in your previous MAD files and verify your calculation. Use MAD to compute the exact strengths required by matching the global parameters Q'_x and Q'_y (in MAD names: DQ1 and DQ2). Compare the results with your calculations.

4 Exercise 4

4.1 Problem:

Start with the lattice from the previous exercise and assume random misalignments of the quadrupoles of r.m.s. 0.1 mm in the horizontal and 0.2 mm in the vertical plane. Calculate the expected r.m.s. orbit and verify with MAD.

5 Exercise 5

5.1 Problem:

Start with the lattice from the previous exercise and add the necessary equipment to be able to correct the closed orbit in both planes, (using MAD). Estimate first the maximum necessary strength of the orbit correctors assuming a maximum quadrupole displacement of 1 mm.

6 Exercise 6

6.1 Problem:

Start with the lattice from the previous exercise and first double the circumference to 2000 m and the number of cells to 40. Change the phase advance to $\phi = 60^o$ per cell. Insert a straight section: i.e. 2 cells without bending magnets but keep the same focusing. Modify now the lattice to keep the horizontal dispersion function small ($<$ 1-2 m) along this straight section. At this stage do not change the focusing properties in any of the cells. Such straight sections with very small dispersion are very useful for the installation of RF equipment, wigglers, undulators, beam instrumentation, collimation systems etc., or to house an experiment.

7 Exercise 7

7.1 Problem:

Start from the previous lattice and design a symmetric insertion with a low-β section in a dispersion free region. The β should be smallest and should have a waist at an ”interaction point”. Try to follow these steps:

- Insert an insertion into the previous lattice, using the optics with the half field dispersion suppressor. For that, replace the ”straight section” of the previous exercise.
- Leave 8.5 m on each side of the interaction point empty for possible equipment.
- Design a fully symmetric insertion with 4 independent quadrupoles on each side. The corresponding quadrupoles on the left and the right side should have the same strengths.
- Calculate the initial settings for these quadrupoles for reasonable values of β_x and β_y and a waist at the interaction point. Correct a possible β-beating.
- Compute the settings for your low-β insertion to get a small ratio of β_x/β_y or β_y/β_x. The ratio is limited by the maximum β-function in the quadrupoles. Which is the smallest ratio when $\hat{\beta}$ in the quadrupoles is limited to 1000 m ?

8 Exercise 8

8.1 Problem:

Use the lattice from exercise 7 and try to answer the following questions.

- Can you make the ratio of β_x/β_y or β_y/β_x to become 1 (e.g. $\beta_x = \beta_y$ = 50 m) ? What is the best you can do ?
- Replace the innermost quadrupole by a quadrupole doublet and re-assess the last question.
- For discussion only: what steps do you propose to get something like $\beta_x = \beta_y$ = 10 m (or smaller) ?

9 Exercise 9

9.1 Problem:

For the operation the optics usually needs some ”knobs” for fine tuning, such as tune or dispersion.

- The dispersion can become slightly mismatched. Insert individually powered quadrupoles into the dispersion suppressor to control the dispersion beating.