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Introduction to Particle Accelerator Physics

Exercise 5

Discussion: 11.1.2005 Hand in: 18.1.2005

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1. Apertures, Dispersion, and Acceptance
Assume a simple ideal light source lattice, composed of identical arcs and identical dispersion free straight sections. The maximum beta functions occur somewhere in the arcs: $\beta_{x,\max} = \beta_{y,\max} = 25$ m/rad. The ideal machine will be flat, i.e. it has no vertical bending magnet fields and thus dispersion will be purely horizontal. The maximum horizontal dispersion is $D_{\max} = 0.5$ m and occurs at the same location as $\beta_{x,\max}$. In the center of all straights, there is a horizontal and vertical focus with $\beta_{x,0} = 9$ m/rad and $\beta_{y,0} = 1$ m/rad. The vacuum chamber has a constant cross section around the machine with an inner full width $w = 60$ mm and full height $h = 30$ mm. In one of the straight sections a (short) septum will be installed for injection, but we will place it 15 mm away from the beam axis in order to not introduce an additional aperture limitation.
a) What is the vertical acceptance A_y of the ring?
b) It is planned to install undulators centered in the straight sections. The undulators have a length $L = 4$ m and a full gap (vacuum chamber inner height) $g_u = 6$ mm. What is the vertical acceptance after the installation of the undulators?
c) What are the horizontal and vertical betatron phase advances ϕ_x and ϕ_y along the undulator?
d) We would of course like to have maximum vertical acceptance in order to minimize beam losses. What would the optimum choice of $\beta_{y,0}$ be?
e) The bending magnets in the arcs are equipped with gradients in order to achieve vertical focussing. Due to the thickness of the vacuum chamber (2×4 mm) the resulting magnetic gap will be $g_m = 38$ mm. Since after the installation of the undulators the vertical acceptance is restricted anyway, we may ask if the large magnetic gap leads to a waste of electric power. Assume the optimum $\beta_{y,0}$ from above and calculate the minimum magnetic gap height required in order not to further restrict the vertical acceptance.
f) How much power can be saved this way?

2. Solenoid Focussing
a) Recall from the lecture the definition of the solenoid transfer matrix and the statement "solenoids are used to capture divergent beams". Show how a solenoid magnet can be tuned to focus a divergent beam, i.e. calculate the solenoid transfer matrix for different values of the parameter φ.
b) In the scope of the Low Emittance Gun Project at PSI (`http://leg.web.psi.ch`) a 100 keV DC electron gun test stand will soon be commissioned. In order to focus a possibly divergent beam a solenoid magnet will be placed right after the anode iris; the effective solenoid length is 20 mm. What magnetic field on axis is required to focus such a beam?

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