Accelerator Physics Experiment for Physics 456/656

Introduction to Accelerator Physics and Technology (Hoffstaetter)

Experiment 1:
Measure the beta functions in x and y at the quadrupoles QW10 and QE11 and compare with the linear optics of CESR. For this you need to change the quadrupole strength by Δkl and observe the tune changes $\Delta\nu_x$ and $\Delta\nu_y$. The beta functions are then given by

$$\beta_x = 4\pi\frac{\Delta\nu_x}{\Delta kl} \ . \tag{1}$$

Measuring the tune:
(1) Find the display with the horizontal and vertical beam spectrum.
(2) Record the frequencies f_x and f_y at the peaks of the spectrum. The tunes are given by $\nu_x = f_x/f_0$ with the beam's revolution frequency $f_0 = 390.13$kHz. This spectrum displays the Fourier transform of the beam oscillation. In linear optics, the beam position after turn n at a place with beta function β is given by $x_n = \sqrt{2J_0\beta_x}\sin(n2\pi\nu_x + \phi_0)$. Since one turn takes a time $T = 1/f_0$, a beam oscillation with $x(t) = \sqrt{2J_0\beta_x}\sin(2\pi\frac{\nu_x}{T}t + \phi_0)$ is observed. The peak of the spectrum therefore has the frequency $f_x = \nu_x/T$.
(3) Compute the frequencies for which the horizontal or vertical tunes would be 1/2 or 1/3 and make sure the tunes are not close to these points.

Changing Δk:
(1) Find the computer with which accelerator elements are addressed.
(2) Chose the menu "RING MAGNETS" and push the black button below the selection dial besides the monitor.
(3) Chose "CSR QUAD CUR" and push the red button above one of the four dials below the monitor.
(4) Chose the quadrupole, e.g. "CSR QUAD 10 WEST", by flipping the back switch below the dial several times.
(5) Change the strength of the quadrupole by turning the corresponding dial until the tune has changed by an appreciable amount. Avoid a change of the tune below $f_x = 198$kHz, $f_y = 220$kHz and above $f_x = 203$kHz, $f_y = 230$kHz.
(6) Record the change of computer units that are displayed below the dial.
(7) For CESR's standard quadrupoles, computer units k_{CU} are converted to changes in the quadrupole strength by

$$\Delta k = k_{CU}\frac{1}{E}6.75\cdot 10^{-5}\frac{GeV}{m^2} \ . \tag{2}$$

The length of the quadrupole is $l = 0.6$m.
(8) Obtain the energy by finding the NMR field measurement in a main dipole

magnet (on the colorful screen) and determine for what energy this leads to the required bending radius of 88m.
(9) Compute the change in quadrupole strength Δkl.

Obtain CESR's beta functions:
(1) Type "cesrv" at a computer console.
(2) Type "base none" to eliminate unnecessary normalization factors.
(3) Type "plot beta" and watch the beta function display.
(4) Type "scale beta 50" for better viewing.
(5) Type "whatlat" at a computer console where cesrv is not running and record the name of the currently used optics.
(6) Type "pa.lat" and look for a file with the name "geno_"+ the name that you recorded. The columns 4 and 5 in this file describe β_y and β_x.

Experiment 2:
Measure the change of the closed orbit due to the corrector magnets "V17W" and "V33W" and compare with the change that is predicted by the linear optics of CESR. For this you create an orbit angle of $\Delta\theta$ by a corrector magnet at beta function β_k, which creates a close orbit change at monitor m of

$$\Delta x_m = \Delta\theta \frac{\sqrt{\beta_m \beta_k}}{2\sin(\pi\nu)} \cos(|\psi_m - \psi_k| - \pi\nu) \ . \tag{3}$$

Note that the corrector angles are produced by suitably putting current through some of the windings of the sextupoles "SEX_17W" and "SEX_33W".
Measuring the closed orbit
(1) Type "cesrv" at a computer console.
(2) Type "take o" and wait about 20 seconds while the orbit is measured.
(3) Type "plot o", watch the orbit display and record the orbit file name of the form "BUTNS.95"+number.
(4) At a console where cesrv is not running type "pa.orbit.but.95".
(5) Type "dir /sin" and find the file that contains your orbit measurement. Look at this file, it shows four button signals in computer units.
(6) Type "show orbit" to look at an orbit file that is calibrated in mm.
(7) Type "& show orbit" to write this file.

Change a corrector magnet:
(1) Find the computer with which accelerator elements are addressed.
(2) Chose the menu "RING MAGNETS" and push the black button below the selection dial besides the monitor.
(3) Chose "CSR VERT CUR" and push the red button above one of the four dials below the monitor.
(4) Chose the corrector, e.g. "CSR VERT 17 WEST", by flipping the back switch below the dial several times.

(5) Change the strength of the corrector magnet so that a maximum orbit excursion of 0.5cm is produced. For this you should measure the orbit after a small change and extrapolate the effect to larger corrector changes.
(6) Record the change of computer units θ_{CU} that are displayed below the dial.
(7) Compute the change in corrector angle by using

$$\theta = \theta_{CU}\frac{1}{E}1.85\text{GeV}\ \mu\text{rad}\ . \tag{4}$$

Experiment 3:
Measure the dispersion of CESR at the beam position monitors (BPMs) and compare with the design values. For this you produce a relative energy change of δ and measure the change Δx in the closed orbit. The dispersion is then $\eta = \Delta x/\delta$. To reduce the measurement error, it is good to perform this measurement for different δ and then, for each BPM, fit a line through the data points of Δx versus δ. The energy change is created by changing the RF frequency by Δf_{RF}. Since the RF oscillates a fixed number of times during one revolution, the change in revolution frequency is given by $\Delta f_0 = \Delta f_{RF}\frac{f_0}{f_{RF}}$. This in turn changes the length of the orbit around the ring by $\Delta L = -\Delta f_0\frac{L_0}{f_0}$. The beam can only take a longer orbit by changing its energy and traveling along $\Delta x(s) = \delta\eta(s)$.
The orbit length that corresponds to an advance ds on the design orbit is given by $|d\vec{r}| = (1+\frac{x}{\rho})ds$. The length of the orbit $\eta\delta$ is therefore $L_0 + \Delta L = \int_0^{L_0}(1+\frac{\eta}{\rho}\delta)ds$. And with $\alpha_p = \frac{1}{L_0}\int_0^{L_0}\frac{\eta}{\rho}ds$ we obtain $\Delta L = \alpha_p L\delta$.
The dispersion η at a monitor is thus obtained as $\eta = -\frac{\Delta x}{\Delta f_{RF}}f_{RF}\alpha_p$.

Change CESR's RF frequency:
(1) Find the computer with which accelerator elements are addressed.
(2) Chose the menu "CESR RF" and push the black button below the selection dial besides the monitor.
(3) Chose "CSR FREQ CON" and push the red button above one of the four dials below the monitor.
(4) Chose "CSR FM ON ENABLE", by flipping the back switch below the dial several times.
(5) Change the displayed integer to 1.
(6) Chose "CSR FM ADJUST", by flipping the back switch below the dial several times.
(7) You can change the frequency by up to ± 2000 computer units f_{CU}.
(8) Obtain the change in RF frequency by reading the read display that starts with 499.

Obtain α_p:
(1) Type "whatlat" at a computer console where cesrv is not running and

record the name of the currently used optics.
(2) Type “pa.lat” and look for a file with the name “geno_”+ the name that you recorded. At the top of the file there are some global parameters, including α_p.

Obtain CESR’s dispersion:
(1) Type “cesrv” at a computer console.
(2) Type “base none” to eliminate unnecessary normalization factors.
(3) Type “plot disp” and watch the dispersion display.
(4) Type “scale beta 2” for better viewing.
(5) Type “whatlat” at a computer console where cesrv is not running and record the name of the currently used optics.
(6) Type “pa.lat” and look for a file with the name “geno_”+ the name that you recorded. The column 9 η_x.