Tunes, Beta functions, Chromaticity Lab

Homework

Due Wednesday 30 June 2004

You will find it helpful to refer to my lecture from Tuesday, 22 June, in doing this homework.

Numerical answers must also include units, unless dimensionless. E.g.: What is the revolution frequency of the Aladdin storage ring? "3.372130" Wrong. "3.372130 MHz" Correct.

1. Tune determination (9 points)

During the lab, three spectrum analyzer screen dumps (plots) were made: One at nominal quadrupole settings, one with 2Q1A (H focusing quad) shunted, and one with 2Q1B (V focusing quad) shunted.

On the "nominal quad settings" plot, indicate (e.g., with labeled arrows) which peaks are harmonics of the ring revolution frequency. Label each peak with which harmonic number of the ring revolution frequency it is. The ring RF frequency is 50.581945 MHz, and the ring harmonic number (number of RF wavelengths in the ring circumference) h=15.

On the "2Q1A changed" plot, indicate (e.g., with labeled arrows) which peaks are horizontal betatron sidebands. (Indicate both the "real" and "aliased" betatron sidebands.) For the horizontal betatron sidebands between the two revolution harmonics, calculate the fractional horizontal tunes they represent, assuming they are sidebands of the *lower* revolution harmonic. Knowing that 2Q1A is horizontally focusing, and that increasing the shunting decreases the quad strength, indicate which peak is the "real" tune, as opposed to the aliased ($1-\nu_x$) sideband. Briefly explain your reasoning.

On the "2Q2B changed" plot, indicate (e.g., with labeled arrows) which peaks are vertical betatron sidebands. (Indicate both the "real" and "aliased" betatron sidebands.) For the vertical betatron sidebands between the two revolution harmonics, calculate the fractional vertical tunes they represent, assuming they are sidebands of the *lower* revolution harmonic. Knowing that 2Q2B is vertically focusing, and that increasing the shunting decreases the quad strength, indicate which peak is the "real" tune, as opposed to the aliased ($1-\nu_y$) sideband. Briefly explain your reasoning.

2. Beta function measurement by quadrupole perturbation (12 points)

How much did the horizontal tune change between your "nominal quad settings" plot, and your "2Q1A changed" plot?

How much did the 2Q1A quadrupole strength (k) change between the two plots? (Use the change in quadrupole current, and the appropriate equations from the lecture.)

Using the tune change and quadrupole strength change from the preceding two steps, what is the horizontal beta function at the location of quadrupole 2Q1A?

Repeat the above three calculations for the vertical plane and quadrupole 2Q1B.

3. Chromaticity measurements

3a. Energy change by changing the RF frequency (12 points)

During the lab, you recorded horizontal and vertical tune frequencies for different RF frequencies.

Convert the RF frequencies to fractional changes in the beam energy. You will need an equation from the lecture. For the Aladdin LF15 lattice, the momentum compaction = 0.0054.

Convert the x and y tune frequencies to fractional tunes.

Plot the measured x tune as a function of fractional change in beam energy. From these data, what is the horizontal chromaticity of the storage ring?

Repeat the above step for the vertical plane.

3b. Energy change by changing the ring dipole strengths (15 points)

During the lab, you recorded horizontal and vertical tune frequencies for different dipole strengths.

Convert the changes in dipole strengths to fractional changes in beam energy.

Convert the x and y tune frequencies to fractional tunes.

Plot the measured x tune as a function of fractional change in beam energy. From these data, what is the horizontal chromaticity of the storage ring?

Repeat the above step for the vertical plane.

Why are the x and y chromaticities measured in **3a** and **3b** different?

4. Beta function measurement by orbit perturbation (12 points)

During the lab, you recorded how much the beam moved in *x* in response to changes in an *x* steerer, and similarly for *y*.

Using the steerer calibration given in the lecture, calculate how much the *x* steerer deflects the beam at each of the steerer currents recorded

Convert each of the *x* BPM readings to millimeters (or meters). One BPMU (BPM unit) on Aladdin = 18.75 mm.

Plot the *x* beam position as a function of the deflection by the *x* steerer at 2Q1A. From these data (and using the equation from the lecture), what is beta-x at this location? Use ν_x =7.139 and ν_y=7.234.

Repeat the above three steps for the vertical plane at location 2Q1B.

5. Comparison with theory (6 points)

How do the beta functions you measured using the quadrupole perturbation technique compare to the design values given in the MAD output file at http://www.src.wisc.edu/USPAS/GeneralInformation/LF15-Twiss.txt ?
Quadrupole 2Q1A is located at s=12.910 m. Quadrupole 2Q2B is located at s=19.680 m.

Briefly list three possible reasons for any differences between the measured and design values. (Examples of being brief: “phase of the moon” or “color of accelerator operator’s hair”).

How do the beta functions measured using orbit perturbation compare to the design values? List three possible reasons for any differences.