Simulation of the MAX IV 3 GeV ring using Winagile

An accelerator is built around a number of components. To get a picture of the operation of the accelerator one builds a model of the machine and uses this model to study different phenomena. Different accelerators have different aims, and thus the models, the way of doing models and the studies vary.

The machine in this case is the MAX IV 3 GeV storage ring. It is 528 m in circumference and can accelerate electrons to 3.0 GeV.

These machines are most important when operating steadily over long periods and the acceleration process is of less interest. In a first assumption one can thus study these machines without acceleration. In this way the machine is defined by the magnets steering the particles (in this case electrons) down the accelerator. To build a model of this machine we first need a description of the magnets and then a layout of where to place the magnets (lattice). To manage analyzing the machine during 2 hours an almost complete lattice file is available describing the MAX IV 3 GeV ring.

WINAGILE is an accelerator code developed for the CERN Accelerator Schools by Phil Bryant.

Calculations over particle transport in accelerators follows in a first approximation a rather “simple” matrix model, which has been discussed in the beam dynamics. Despite the relative simplicity the calculations includes many calculations which rapidly grow difficult to do by hand. Different program codes exist for the purpose and the most of them manage to calculate additional phenomena for the accelerators, beyond the most immediate matrix results. WinAGILE is not the only code available. OPA is another code with a user friendly interface, while more detailed studies of the dynamic aperture and lifetime limitations are carried out with computer codes with terminal based input and output, for example ZAP, TRACY and MAD.

What to do

You should during the Simulation session run WinAGILE, extract answers to a number of questions and discuss the results. You can work together in pairs. Start by reading section 1-2.1 in Tavares et al., “The MAX IV storage ring project”, to learn about the purpose and the linear optics of the MAX IV 3 GeV storage ring.

Questions and duties

The lattice file for the MAX IV 3 GeV ring is “incomplete”. The file describes 1/20 of the complete ring (one achromat) and one series of dipoles need additional data. A table of the achromat is found in the Appendix.

1) There are two sets of dipoles. For the entrance and exit dipoles the bending angles are given, but for the center dipoles (see the appendix) you have to calculate the value. All have the same bending angle. Input these in the lattice file (observe that you need to use “a large number” of decimals).

To change the input file:
file->edit
Double click the value you want to change. Input the value. Click ok.
Check_Data->Check_with_decompression->Yes

2) Looking at the input file, can you see any symmetry points?

3) Ask Winagile to find the solution for a ring with this lattice.

Calculations->Ring or matched section->(Check that you have electrons)
Continue->Ok

Plot the layout. Can you distinguish the different parts of the achromat?
Graphs->2d Geometry

4) Extract the transfer matrix for the entrance dipole.

In the window "Rings and matched sectons" double click the line for the element. (double clicking the last line named "end" gives the matrix for the complete machine)

What is the focusing of this magnet? Compare with the value given in the appendix.

5) Look at the transfer matrix for one of the quadrupoles. How can you see from the matrix if it is focusing or de-focusing? Is it similar to a thin lens (why/why not?)

6) Look at the output at the end. What are the tunes of the machine? Are these the tunes for the complete machine? If not what are the correct tunes?

Plot the tune diagram. Discuss if it is a good working point. Compare to the working point of the real machine.

To plot the tune diagram you have to run the complete machine which is 20 times the input file you have.
Options->Back to main window
File->Edit
Mark all elements in the lattice.
Structures->Repeat 'n' times: input 20 times -> Ok
Check_Data->Check_with_decompression->Yes
Calculations->Ring or matched sections
Graphs->Tune diagram

7) Plot the twiss parameters and the dispersion. This is easier to see if you change the range to only show one achromat.

Graphs->Twiss transverse parameters
The range can be changed in the bottom of the graph

Where is the beam big/small? Can you with this information say what the beam size is?

What does the dispersion mean? Does it exist in both transverse planes? If not, why?

8) Track a single particle (example: x=0, x'=0.0001, y=y'=0) one turn in the machine. Look at the orbit. Does it tell you something? Compare to tracking a particle in the vertical plane.

Calculations I->Tracking single particles (enter data) -> Continue
Graphs->Trajectories, transverse

9) Track a particle with x=x'=y=y'=0, but a deviation in energy (example 0.001). Look at the orbit. Do you recognize it from something else?

10) Track a beam of particles (emittance= 10, at least 10 beamlets).

Calculations I->Tracking transverse distributions->Continue
Beams->(enter values, examples: emittance=10, beamlets=10)->Ok->Ok
press "Step" multiple times.
Press "Phase space" if desired. Press "Real sp" to switch back.

For the start point, how does the beam look in real space? An in phase space? Compare with the twiss parameter plots above and see if the two pictures agree.

Go to element 9. How does the beam look in real space? An in phase space? Compare with the twiss parameters.

Step onwards from element 9. How does the beam look in real space? An in phase space? Compare with the twiss parameters. Sometimes you need to step through the drift after a magnet to see the effect.

11) Increase the emittance. Compare with the previous cases. What does this imply for the performance of the machine?

Appendix

One (simplified) achromat of the MAX IV 3 GeV storage ring

	Element	Length [m]		Bend [°]	k []
1	ll	2.5			
2	l1	0.175			
3	qfend	0.25			3.533676
4	l2	0.225			
5	qdend	0.25			-2.23958
6	l3	0.006			
7	dm	0.75432		1.5	-0.54525
8	l4	0.46268			
9	ls	1.302			
10	qfm	0.55			2.061576
11	l5	0.51311			
12	d0	1.22387		Calculate	-0.70480
13	l5	0.51311			
14	qf	0.55			2.202441
15	l5	0.51311			
16	d0	1.22378		Calculate	-0.70408
17	l5	0.51311			
18	qf	0.55			2.202441
19	l5	0.51311			
20	d0	1.22378		Calculate	-0.70408
21	l5	0.51311			
22	qf	0.55			2.202441
23	l5	0.51311			
24	d0	1.22378		Calculate	-0.70408
25	l5	0.51311			
26	qf	0.55			2.202441
27	l5	0.51311			
28	d0	1.22378		Calculate	-0.70408
29	l5	0.51311			
30	qfm	0.55			2.061576
31	ls	1.302			
32	l4	0.46268			
33	dm	0.75432		1.5	-0.54525
34	l3	0.006			
35	qdend	0.25			-2.23958
36	l2	0.225			
37	qfend	0.25			3.533676
38	l1	0.175			
39	ll	2.5			