Companion software for "Volker Ziemann, *Hands-on Accelerator physics using MATLAB, CRCPress, 2019*" (https://www.crcpress.com/9781138589940)

Chromaticity of a FODO lattice (Section 3.4.1)

Volker Ziemann, 211124,

In this example we calculate the horizontal chromaticity of a somewhat contrived (no dipoles) ring made of 20 FODO cells.

We use the 2D software and define a FODO cell as in previous examples

```
clear
addpath ./2D
F=2.2   % Slider for the focal length of the quadrupoles
```

```
F = 2.2000
```

```
fodo=[ 1,  5,  0.2,  0;
         2,  1,  0.0, -F;
         1, 10,  0.2,  0;
         2,  1,  0.0,  F;
       1,  5,  0.2,  0];
beamline=fodo;
```

First we can calculate the transfer matrices with `calcmat()`, define the matrix Rturn, whch is the transfer matrix fromstart to end of the cell, and determine the phase advance of the cell Q in units of 2π and the periodic Twiss parameters α_0, β_0, and γ_0. And from those we cosntruct the beam matrix σ_0 which we later use to propagate the Twiss parameters through the ring.

```
[Racc,spos,nmat,nlines]=calcmat(beamline);
Rturn=Racc(:,:,end);
[Q,alpha0,beta0,gamma0]=R2beta(Rturn);
sigma0=[beta0, -alpha0; -alpha0,gamma0];
```

Next, we construct the beamline made of 20 FODO cells and calculate all transfer matrices with `calcmat()`.

```
beamline=repmat(fodo,20,1);  % 20 FODO cells
[Racc,spos,nmat,nlines]=calcmat(beamline);
```

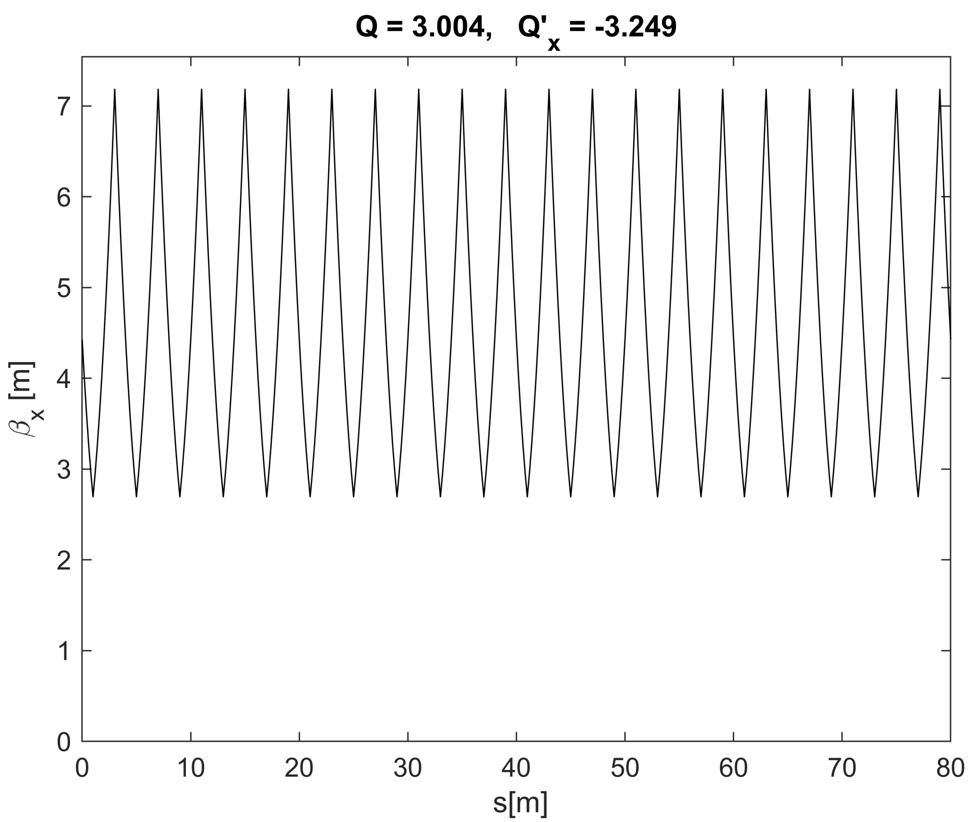
Having prepared the beam matrix σ_0 with the Twiss parameters and all transfer matrices, we use Equation 3.43 to propagate the Twiss parameters through the ring. At each position, labeled by the loop index k, we store the value of the beta function in the previously allocated array `beta`. Once the loop completes, we plot the beta function and annotate the axes.

```
beta=zeros(nmat,1);  % allocate space to store beta functions
for k=1:nmat
   sigma=Racc(:,:,k)*sigma0*Racc(:,:,k)';  % eq. 3.43
   beta(k)=sigma(1,1);
end
plot(spos,beta,'k');
```

```
xlabel(' s[m]'); ylabel('\beta_x [m]')
axis([0,spos(end),0,1.05*max(beta)])
```

Finally we calculate the chromaticity Q'_x from Equation 3.87. To do so we need to loop over all segments in the beamline and add $-\beta/4\pi f$ in each quadrupole. Once the loop completes, we report the tune of the ring, which is 20 times the tune of a cell, and the chromaticity in the title bar of the plot.

```
Chomaticity=0;     % initialize to zero
ic=1;
for line=1:nlines
  for seg=1:beamline(line,2)
    ic=ic+1;
    if beamline(line,1)==2    % quadrupole found
      Chomaticity=Chomaticity-beta(ic)/(4*pi*beamline(line,4));  % eq. 3.87
    end
  end
end
title(['Q = ',num2str(20*Q,'%6.3f'),',   Q''_x = ' num2str(Chomaticity,4)])
```



And now you can play with the slider to change the focal length F of the quadrupoles so see how stronger focussing quadrupoles increase both the tune and the chromaticity.