USPAS Fort Collins, June 2013
Design of Electron Storage and Damping Rings

Computer lab:

1. **Introduction to Matlab and SAMM**
   - **Using Matlab to generate a phase space plot**
   - **Using SAMM to generate a phase space plot**
2. Introduction to GUI programming in Matlab
   - Setting up a Graphical User Interface
   - Customising controls
3. Optimisation routines in Matlab

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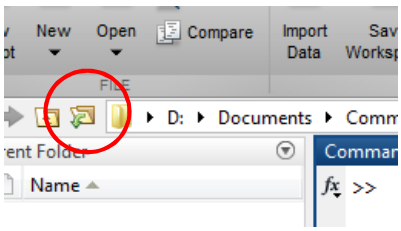
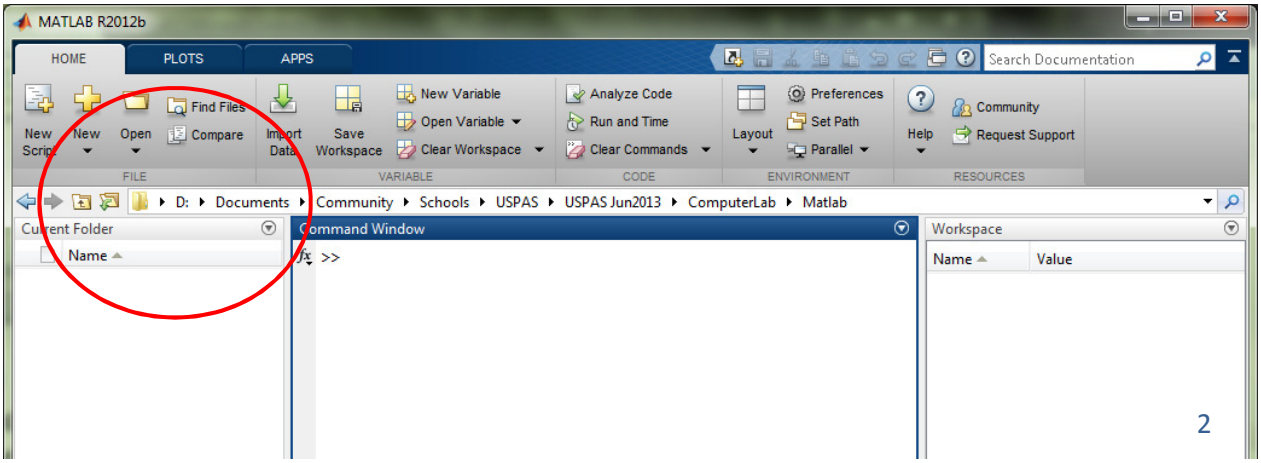
Computer Lab 1.1: Using Matlab to generate a phase space plot

Initial steps:

1. Launch Matlab.
2. Set the working directory to a convenient folder.



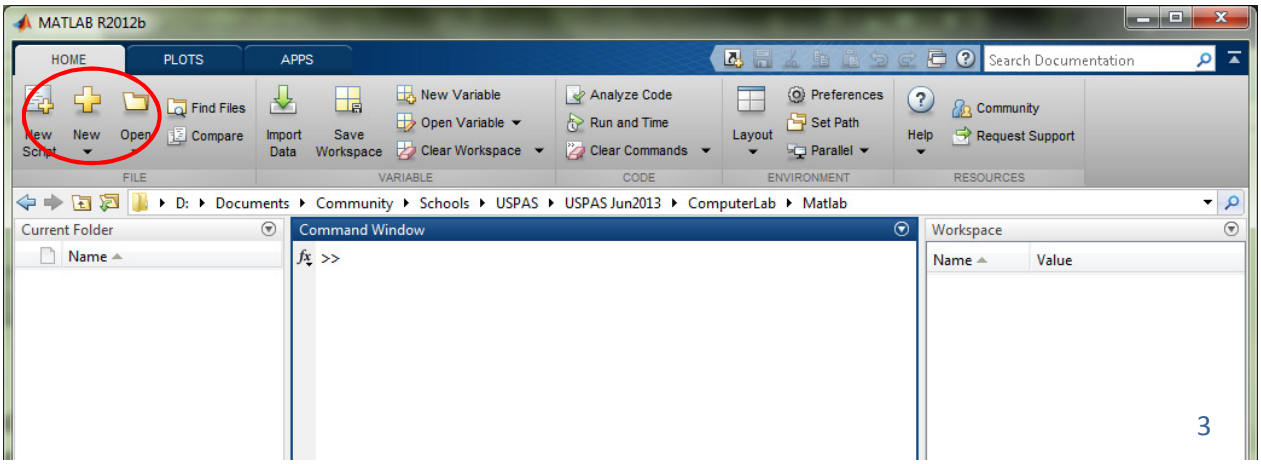


Computer Lab 1.1: Using Matlab to generate a phase space plot

Create a new script:

3. Click on “New”, and select “Script”.

This will open a new window in which you can edit your script.



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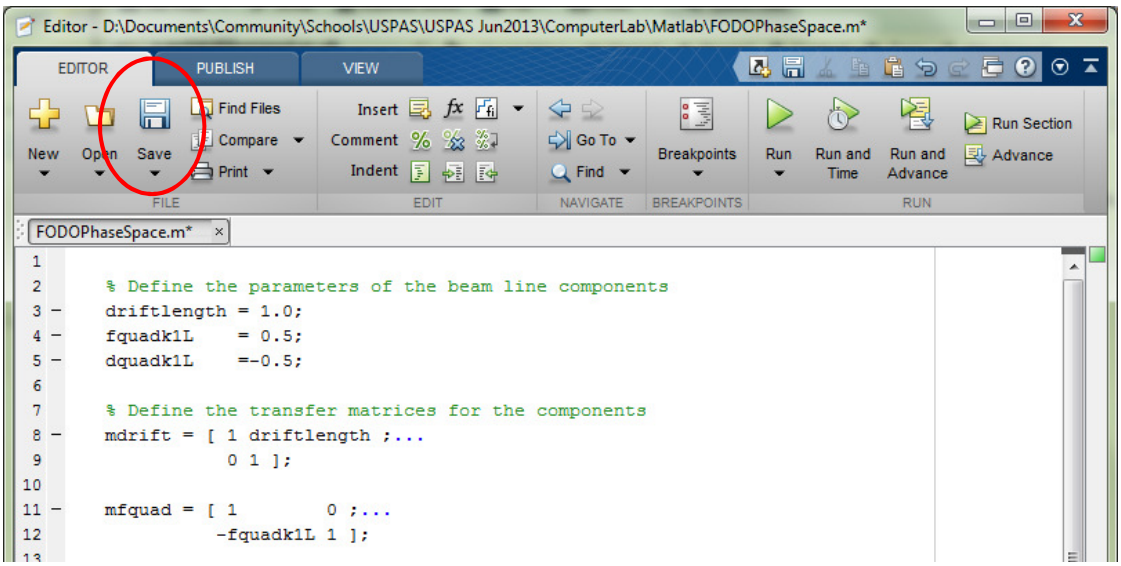
Edit the script:

4. Enter the required commands, and save the script.



Some notes about Matlab commands:

- End a line with a semicolon to suppress any output.
- Anything after a "%" symbol is ignored.
- Arrays and matrices can be defined using square brackets, e.g. m = [1 2; 3 4]. Separate elements within a row by a comma or a space; separate rows with a semicolon.
- Use a single quote to transpose an array or matrix, e.g. m' is the transpose of m.
- Specify an element of an array or matrix using parentheses, e.g. m(1,2) is the element in the first row and second column of m.
- Use a colon to refer to all the elements in a row or a column, e.g. m(:,2) is the second column of m.
- Matrix multiplication is performed using (for example) m = a * b.
- Use "…" to continue a command on the following line.

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```
% Define the parameters of the beam line components
driftlength = 1.0;
fquadk1L    = 0.5;
dquadk1L    =-0.5;

% Define the transfer matrices for the components
mdrift = [ 1 driftlength ;...
           0 1 ];

mfquad = [ 1         0 ;...
          -fquadk1L 1 ];

mdquad = [ 1         0 ;...
          -dquadk1L 1 ];

% Calculate the transfer matrix for a full cell
mfodo  = mdrift * mdquad * mdrift * mfquad;
```

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```
% Set up a data structure to record the tracking data
psx      = zeros(2,100);

% Define the starting point in phase space
psx(:,1) = [0.01 0]';

% Track multiple times through the cell
for n = 2:100

    psx(:,n) = mfodo * psx(:,n-1);

end
```


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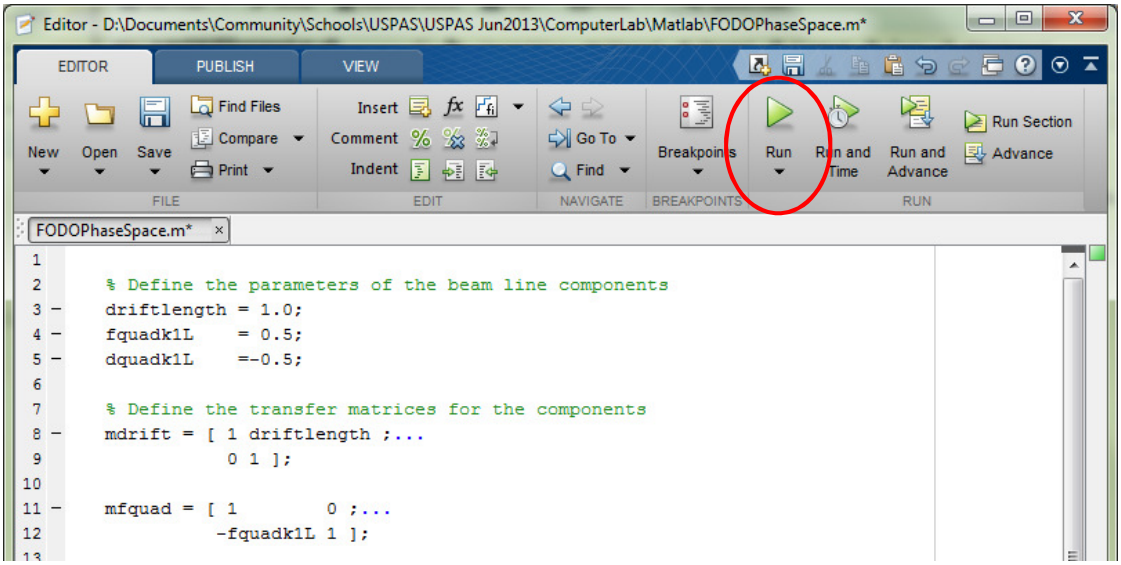
```
% Create a new figure
figure;

% Plot the tracking results
plot(psx(1,:),psx(2,:),'.k');

% Label the axes
xlabel('x')
ylabel('p_x')
```

5. Execute the script by clicking on "Run".

   It is possible to execute part of a script by selecting a section of the script, and hitting F9.



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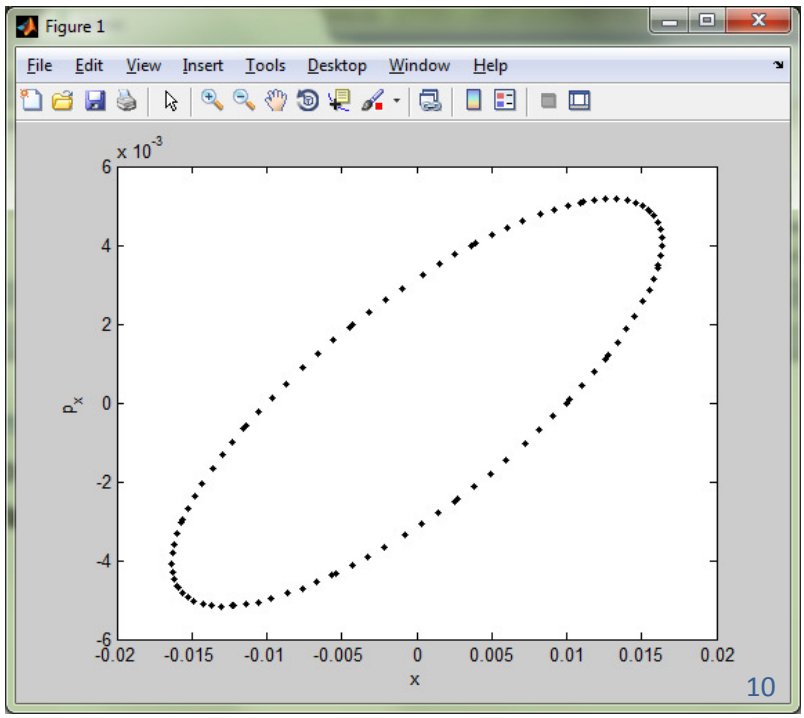
The result:



Note:

*Type "close" in the command window to close **all** open Figures;*

Type "close(1)" to close just Figure 1.

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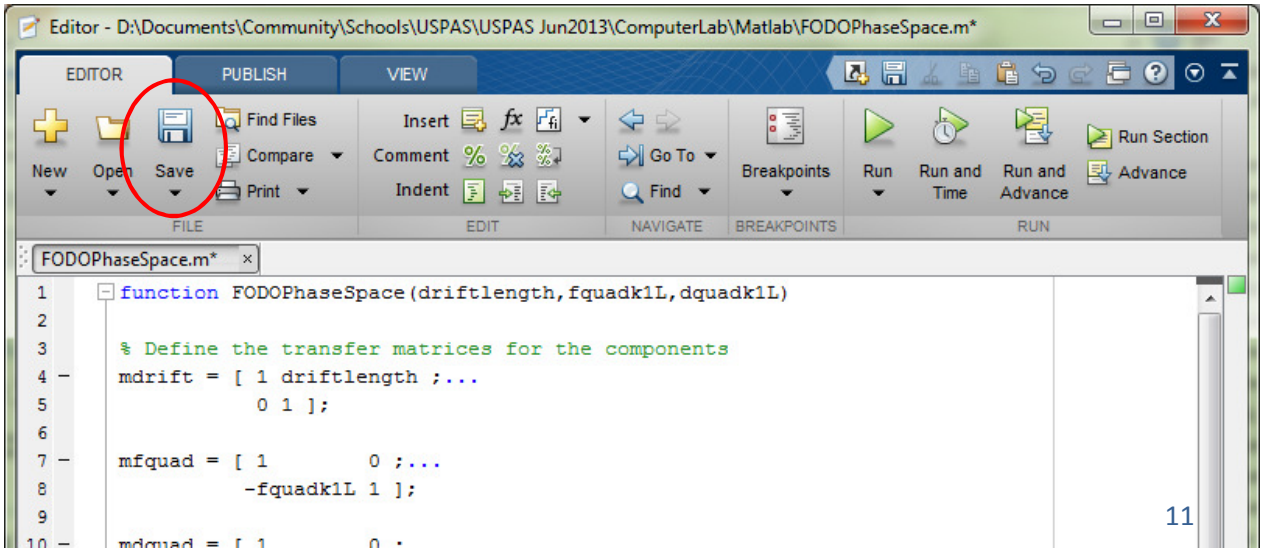
Turn your script into a function:

6. Edit the first part of the script as shown below, and click "Save".
   Note: you should save the file with same name as the function, i.e. in this case the filename should be "FODOPhaseSpace.m".



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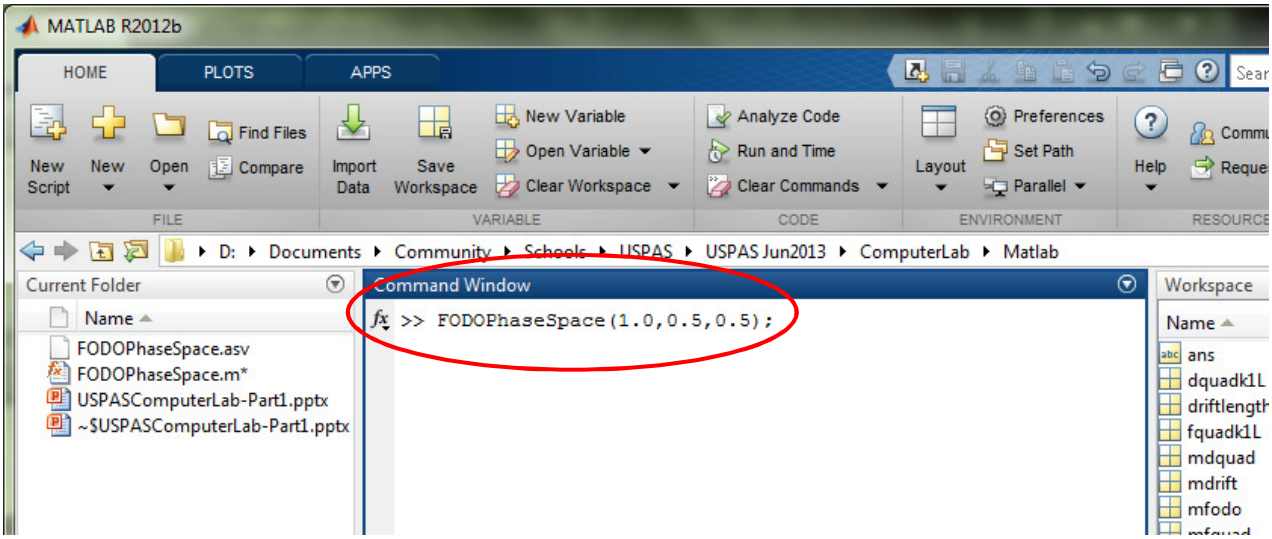
Turn your script into a function:

7. Call the function from the command window.



Computer Lab 1.1: Using Matlab to generate a phase space plot

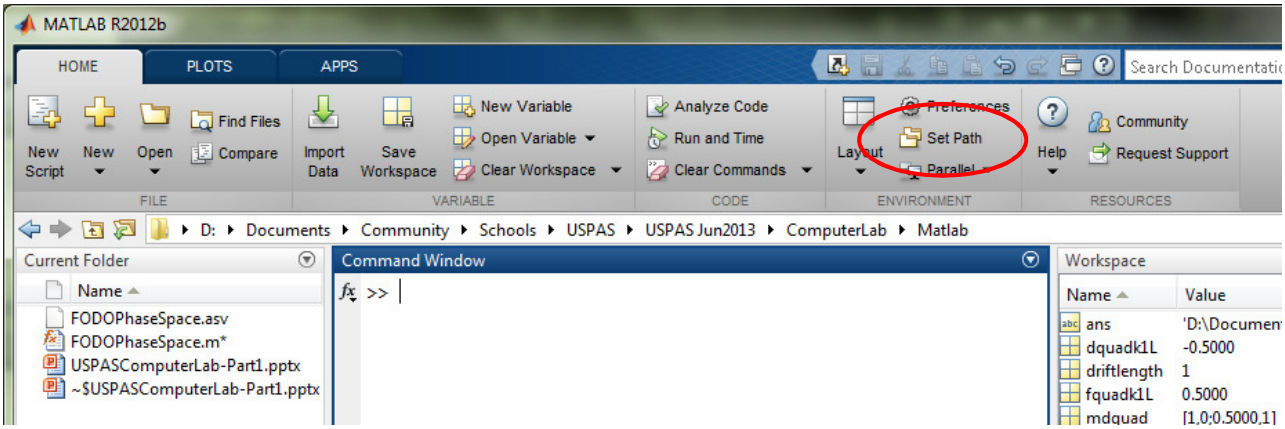
Scripts and functions…

- A "script" is simply a sequence of commands stored in a file. When the script is executed, each command is processed exactly as if it was entered at the command prompt in the main Matlab window.
- A "function" is block of code designed to perform a particular calculation. Usually, a function requires one or more input parameters, and returns one or more output parameters.
- By default, variables defined within a function have "local scope": that is, they exist only within the function, and cannot be accessed by any code executing outside the function. This can be helpful for avoiding duplication of variable names, but needs to be borne in mind when debugging.

Computer Lab 1.2: Using SAMM to generate a phase space plot

SAMM (Simple Accelerator Modelling in Matlab) is a set of Matlab functions and classes for modelling accelerators.

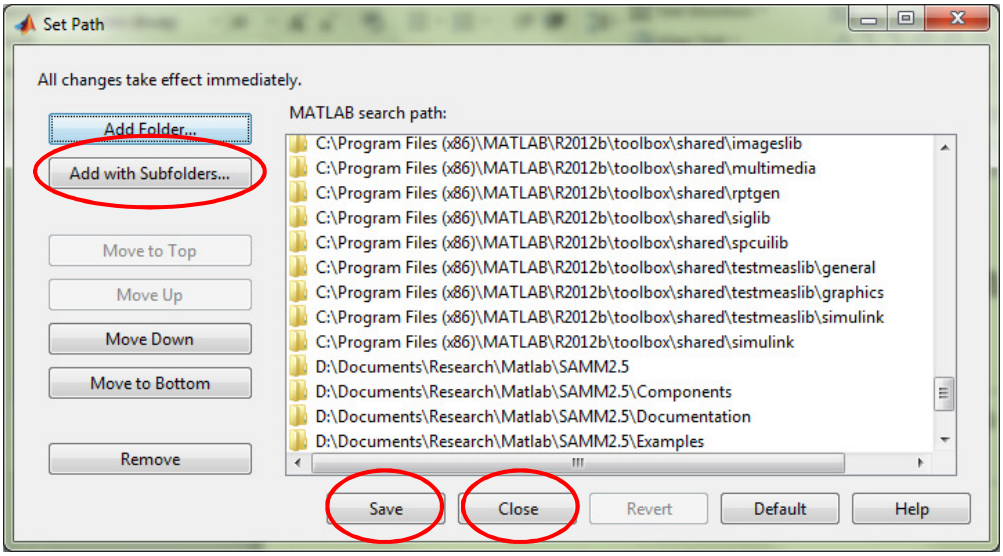
To install SAMM, simply copy the files onto your computer, then add the folders to the Matlab path (so Matlab knows where to find the code when you call a SAMM function).



Computer Lab 1.2: Using SAMM to generate a phase space plot

In the "Set Path" dialogue:

- *Click on "Add with Subfolders…"*
- *Browse to the top level SAMM folder, and click "Select Folder"*
- *Click on "Save", and then "Close".*



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8. Set the working directory in Matlab to the folder with the following files:

- DBA.save.xsif
  This is a file containing a lattice definition in "extended standard input format" (used, for example, by MAD).

- ParseMAD.m
  This is a Matlab function for reading an xsif file, and generating a data structure representing the lattice in Matlab (for use in SAMM).

9. Create a new script called "DefineLattice.m" with these commands:

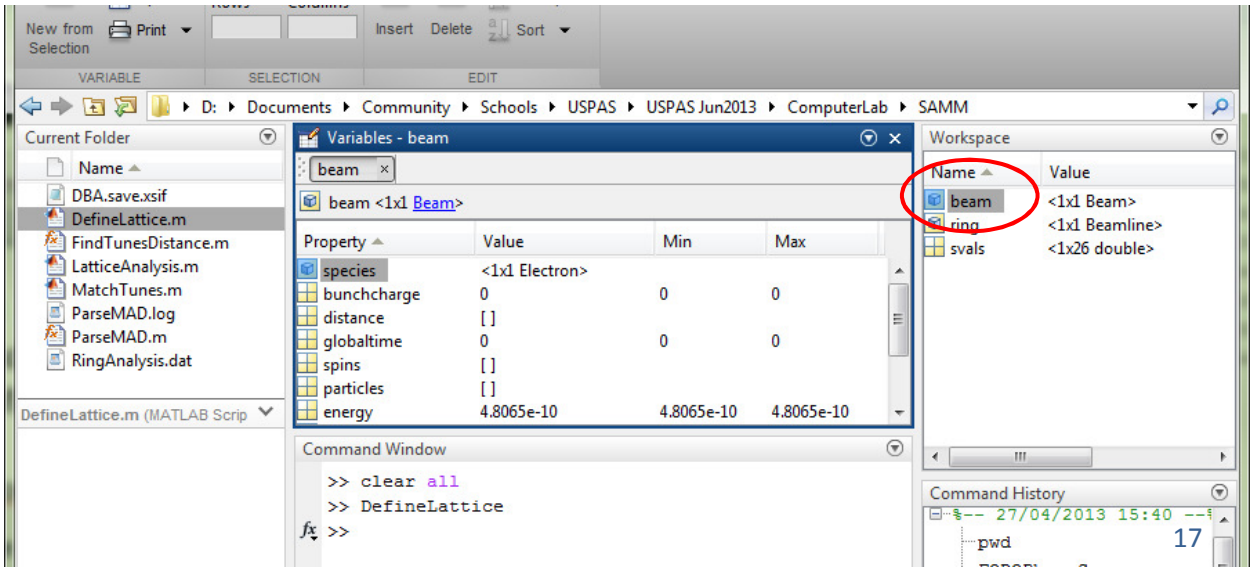
```
beam = Beam(Electron);
beam.energy = 3.0 * PhysicalUnits.GeV;

ring = Beamline;

ring.componentlist = ParseMAD('DBA.save.xsif','DBACELLRFX',beam);
```

Computer Lab 1.2: Using SAMM to generate a phase space plot

10. Execute the script "DefineLattice.m".
11. In the "Workspace" pane in the main Matlab window, double click on "beam" to inspect its properties:



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A few words about "classes" in Matlab (and other object-oriented programming languages):

- A "class" is a specification for a set of data and functions.
- An "object" is a particular instance of a class.

SAMM defines a class called "Beam" in Matlab. The "Beam" class contains a number of variables, including:

- species (of particle);
- bunch charge;
- (reference) energy;
- phase space co-ordinates of particles within the beam;
- etc.

Computer Lab 1.2: Using SAMM to generate a phase space plot

12. Add the following code to your script, to track a particle through 100 turns of the "ring" beam line:

```
closedorbit         = ComputeClosedOrbit(ring,beam);
beam.particles      = closedorbit(:,end) + [1e-6 0 0 0 0 0]';

trackingdata        = zeros(6,100);
trackingdata(:,1)   = beam.particles;

for n = 2:100

    beam = ring.Track([1 numel(ring.componentlist)], beam);
    trackingdata(:,n) = beam.particles;

end
```

Note: the Matlab function "numel" returns the number of elements in an array.

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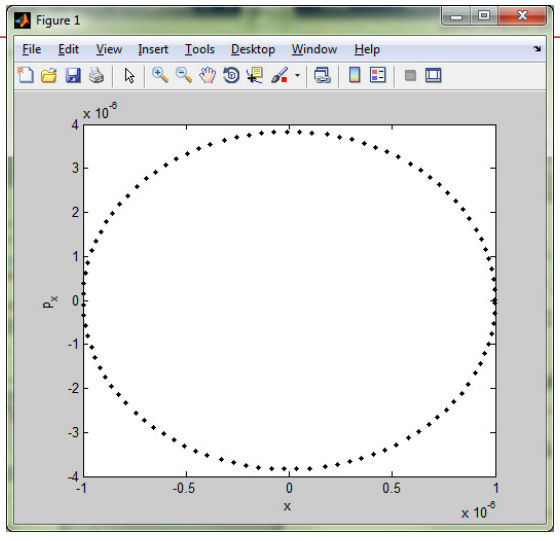
13. Add the following lines to generate a phase space plot:

```
figure;
plot(trackingdata(1,:),trackingdata(2,:),'.k');
xlabel('x');
ylabel('p_x');
```

14. Finally, execute your script…

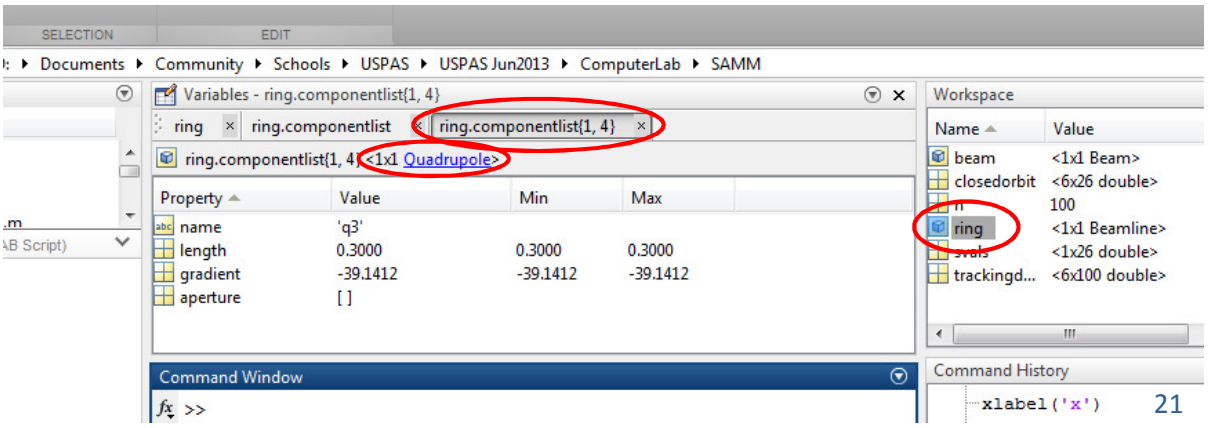


Computer Lab 1.2: Using SAMM to generate a phase space plot

It is possible to inspect (and change) the parameters of beam line elements by opening the appropriate beam line object from the Workspace pane.

Note that "ring.componentlist" is a "cell array" in Matlab: in a "cell array", each element of the array can be an object of a different class.

In "ring.componentlist", the fourth element of the array is an object of the class "Quadrupole":



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Some exercises for the student:

A. Generate vertical and longitudinal phase space plots for the "ring" beam line.

B. Calculate the tunes of the lattice.
Hint: You can use `[closedorbit,m] = ComputeClosedOrbit(ring,beam);` *to find the transfer matrix m around the beam line, and the "eig" function in Matlab to find the eigenvalues of a matrix.*

C. Investigate the effect of changing the quadrupole strengths in the lattice. (Do this in Matlab, not by editing the xsif file!)

D. Generate a plot of the lattice functions.
Hint: Look at the script "DemoStorageRingAnalysis.m" in the Examples folder in SAMM. This exercise can be continued in Part 2 of the Computer Lab.