

3 (c) Supermirror systems in VITESS: the `sm_ensemble` module

1 Introduction

Complex systems of supermirrors can be modelled with the `sm_ensemble` module, in which any user-defined coordinates and orientation of supermirror plates can be given. We are going to build a bi-spectral beam extraction system consisting of several, differently inclined mirrors surrounded by guide walls. Note that this is not an optimized extraction system, its sole purpose is to illustrate usage of the `sm_ensemble` module.

2 Bi-spectral extraction system

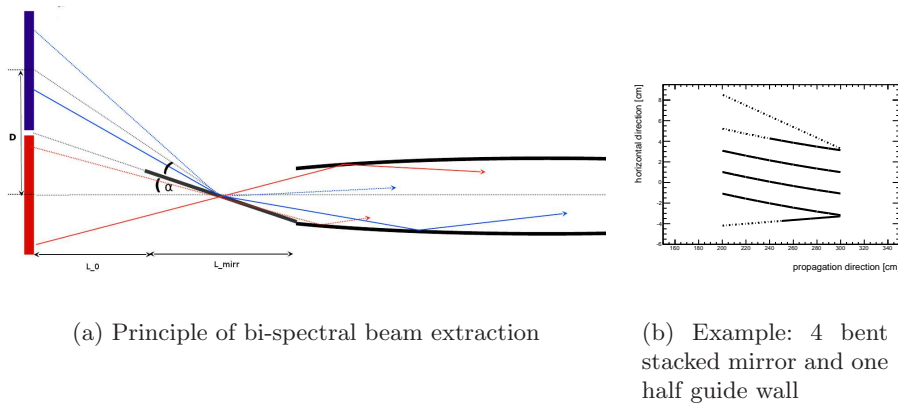


Figure 1: Bi-spectral beam extraction (top view)

2.1 Preparations

In this exercise, we will build bi-spectral beam extraction systems of different complexities. The idea is to put a semi-permeable supermirror plate in front of a thermal moderator inclined such that thermal neutrons can pass through the mirror and cold neutrons from a cold moderator next to the thermal one are reflected into a guide, see figure 1(a). So first we build a bi-spectral source: put the 2012 ESS source and create a moderator file with

- moderator 1: coupled, rectangular, width and height 12 cm, center at (0,0,0), temperature 325 K, colour 1 (leave everything else 0 or empty)
- modeator 2: used, coupled, rectangular, width and height 12 cm, center at (0,12,0), temperature 50 K, colour 2

This places the moderators directly next to each other. We give different “colour” so we can later distinguish from which moderator the neutrons have come from.

Next, we put 2 m space followed by a neutron guide; the extraction system can then be inserted in between in the next step. Take a 10 m long constant $10 \times 10 \text{ cm}^2$ guide for simplicity, with $m = 2$. Put two lambda monitors after the guide, select neutrons from the cold and thermal moderator by the colour.

2.2 Simple extraction system with one mirror

Now we can place a simple bi-spectral extraction mirror in front of the guide: it should be $L_{\text{mirr}} = 2.88 \text{ m}$ long, 10 cm wide and inclined by 1° with respect to the x axis. The position of its center is at $(x,y,z) = (L_{\text{mirr}}/2, 0, 0)$. Use a mirror coating of $m=5$ and a silicon substrate of 0.5 mm thickness.

1. insert a `sm_ensemble` before the guide module at 2 m distance from the source
2. the mirror properties have to be given in an input file in *geometry and reflect. data*, which we can create in two ways:
 - (a) the hard way: read explanation in help file and put it together
 - (b) the easy way: use tool `Generate Extraction System`

We are going for the easy option here: start the tool and give input parameters required¹. Look at help file (*Help* → *Tools* → *Generate Extraction System*) for a detailed explanation of the possibilities.

3. choose silicon as substrate material and set the spin quantization direction to the same as in the source (but leave degree of polarization at 0% in the source)
4. set the output frame to $(L_{\text{mirr}}, 0, 0)$
5. Before we can run the simulation, we have to choose an appropriate *virtual window* in the source to fully illuminate the mirror as well as the guide entry. Unfortunately, in VITESS we have to use the same virtual window for both moderators, and it has to be centralized around the x axis. Considering neutron trajectories from the edges of the moderators, we can calculate that we need to illuminate a 18 cm x 10 cm (WxH) window at 3.44 m
6. to check your mirror, choose *visualization: output in collision file* in the `sm_ensemble` module and run simulation with not too many trajectories (e.g. 10000). The collision points written into the collision file show you where your mirror is, for example in gnuplot use *plot “collision.dat” using 7:8* to see the inclination in the x-y plane (similarly, using 7:9 shows the x-z plane). Examples (of the next systems) are shown in figure 2.

¹hint: we want one rectangular mirror in the x-z plane

7. if you installed an X3D viewer, you can visualize the whole instrument by clicking on *Trajectories*. Use only about 10 trajectories to see the mirror!
8. Reset visualization to *no output* and run with more statistics. Look at the spectrum at the end of the guide and at the different contribution from the cold and thermal moderator.
9. Now that we have a working supermirror ensemble input file, look at it and go through the parameter file list explanation in the *sm_ensemble* help file. Now you can easily modify your mirror length, inclination or coating by changing the respective parameters. Of course, you can also use the tool each time to create a new file. Note that you can give different reflectivity and attenuation parameter values for different polarizations (not used in this exercise).

2.3 Mirror inserted in guide

In order to extend the guide around the mirror, we have to add the guide walls in the *sm_ensemble* input file. The only difference to the supermirror plate above is that no transmission is allowed. This is done by setting the attenuation parameters $\mu \cdot d$ and $\mu_{inc} \cdot d$ to a very high value.

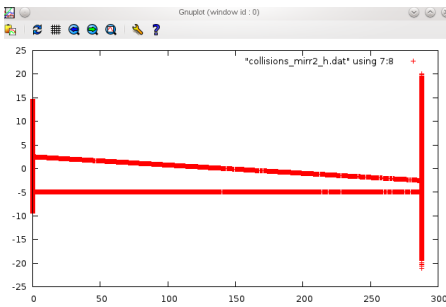
1. In the same way as for the mirror before, use the tool to create three 2.88 m long guide walls extending the 10x10 cm² guide. Leave the side towards the cold moderator open to avoid blocking neutrons from the mirror. Add those walls to the mirror. Compare the values!
2. We included one error in the input file that you just created: do you see it? - It's actually a bug in version 3.1 that will be corrected in 3.2.: *horizontal guide* walls get the sign of z_2 and z_3 inverted, so exchange the minus sign such that all z and y columns have the same sign. Figure 2(a) shows how your input file should look like.
3. check either with the visualization or with the collision file that your mirror system looks as intended (to easier see e.g. the structure in the horizontal dimension by the collisions, you can switch off horizontal plates). Figure 2 shows an example what you should see with the collision file.
4. add a fourth guide wall inclined such that it points towards the edge of the cold moderator, i.e. inclined by 1.5° and centered at (144,8.84,0) cm: copy either the lower guide wall or the mirror and change the appropriate values in the input file. Adjust the bottom and top part of the guide by extending the plate on one side to 12.67 cm (i.e. it covers [-5,12.67]). Figure 3 shows how this should look like.
5. Now remove the first half of the wall added in the last step by reducing the wall length to 144 cm and setting the centre position to (216 cm,7 cm,0 cm).

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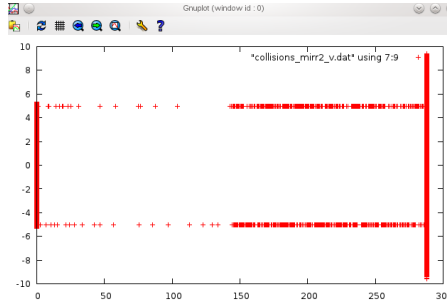
Input file for sn_ensemble, generated with Tool 'Generate Extraction System':
on y1 z1 y2 z2 y3 z3 y4 z4 X Y Z H/* V/* h/* v/* Up: th_c th_csm R_csm μ*d μ_inc*d Down: th_c th_csm R_csm μ*d μ_inc*d Name
0 144.022 5.000 -144.022 5.000 -144.022 -5.000 144.022 -5.000 144.000 0.000 0.000 89.00 0.00 0.00 0.00 0.00173 0.00865 0.69 0.00024 0.00150 0.00173 0.00865 0.69 0.00024 0.00150 -- mirr1 --
0 144.000 5.000 -144.000 5.000 -144.000 -5.000 144.000 -5.000 144.000 0.000 0.000 90.00 0.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- low --
1 5.000 144.000 -5.000 -144.000 -5.000 144.000 5.000 -144.000 144.000 0.000 -5.000 0.00 90.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- left --
1 5.000 144.000 -5.000 -144.000 -5.000 144.000 5.000 -144.000 144.000 0.000 5.000 0.00 90.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- right --

```

(a) Example input file



(b) Mirror + guide system, top view (xy plane)



(c) Mirror + guide system, side view (xz plane)

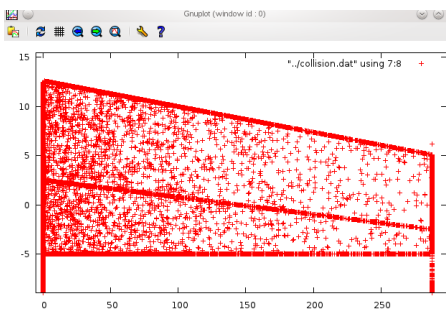
Figure 2: Input file with xz-plates switched off to see xy plane and visualization of collision points with gnuplot.

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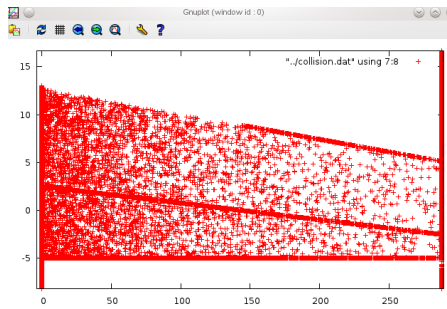
Input file for sn_ensemble, generated with Tool 'Generate Extraction System':
on y1 z1 y2 z2 y3 z3 y4 z4 X Y Z H/* V/* h/* v/* Up: th_c th_csm R_csm μ*d μ_inc*d Down: th_c th_csm R_csm μ*d μ_inc*d Name
1 144.022 5.000 -144.022 5.000 -144.022 -5.000 144.022 -5.000 144.000 0.000 0.000 89.00 0.00 0.00 0.00 0.00173 0.00865 0.69 0.00024 0.00150 0.00173 0.00865 0.69 0.00024 0.00150 -- mirr1 --
1 144.000 5.000 -144.000 5.000 -144.000 -5.000 144.000 -5.000 144.000 -5.840 0.000 88.50 0.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- low --
1 12.67 144.000 -5.000 144.000 -5.000 -144.000 5.000 -144.000 144.000 0.000 -5.000 0.00 90.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- left2 --
1 12.67 144.000 -5.000 144.000 -5.000 -144.000 5.000 -144.000 144.000 0.000 5.000 0.00 90.00 0.00 0.00 0.00173 0.00346 0.93 100.000 100.000 0.00173 0.00346 0.93 100.000 100.000 -- right2 --

```

(a) Example input file of 2.3.4



(b) Mirror + guide system of 2.3.4



(c) Mirror + guide system of 2.3.5

Figure 3: Input file to 2.3 (4) and visualization of xy plane (with virt. window at 2 m).

2.4 Stack of mirrors

In some beamlines, a stack of shorter mirrors performs better or is otherwise preferable. This can now be easily be simulated in the same way we did before:

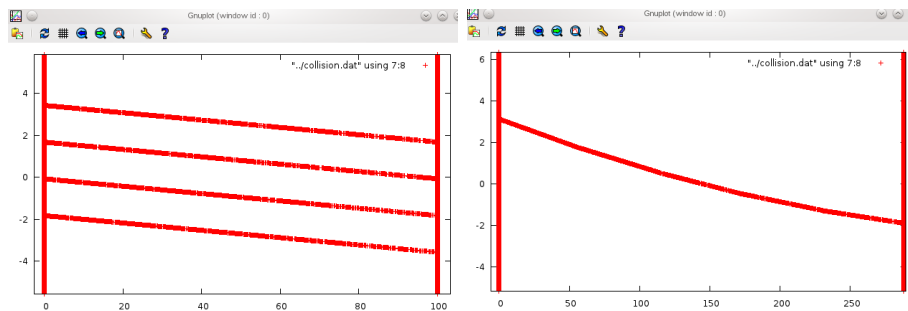
1. Exchange the 2.88 m long mirror from Ex. 2.3 by four stacked 1 m long mirrors with the same inclination (1°), such that thermal neutrons with zero divergence have to pass trough exactly one mirror. This can be realized e.g. by putting the mirrors 1.75 cm apart. Use $m=4$ for a change. If you use the tool, you only have to give common parameters once when creating a stack.
Don't forget to change the output frame in the supermirror ensemble and adjust the virtual window in the source.

2.5 Bent mirror

We cannot simulate a truly curved mirror with the `sm_ensemble` module, so similar to a curved neutron guide which is simulated as straight parts inclined with respect to each other, we have to build a bent mirror out of several pieces:

1. Use the setup from Ex. 2.3 and divide the mirror in 5 pieces with different inclinations. To design the `sm_ensemble` input file, you need to calculate the mirror center positions. (You can use the following example values: 1.4° , 1.2° , 1.0° , 0.8° , 0.6° , center in x: 28.8 cm, 86.4 cm, 144 cm, 201.6 cm, 259.2 cm, center in y: 2.41 cm, 1.11 cm, 0 cm, -0.9 cm, -1.61 cm.)

Now we have all building blocks to build e.g. something like shown in figure 1(b)!



(a) Mirrors of 2.4.1

(b) Bent mirror of 2.5.1

Figure 4: Visualization of 2.4.1 and 2.5.1.