TRIUMF Beam Physics Note
TRI-BN-24-03
Feb., 2024

OLIS emittance scanner tests

R. Baartman

TRIUMF

Abstract: Emittance scan measurements were performed Feb. 9, 2024. These served the purpose of testing both the TRANSOPTR model from the OLIS slit to the scanner, and for verifying the operation of the scanner. It was discovered that the emittance scan is flipped. This could be either the position had left-right interchanged, or the scanner electric field had wrong sign.

4004 Wesbrook Mall, Vancouver, B.C. Canada V6T 2A3 Tel: 604 222-1047 Fax: 604 222-1074
www.triumf.ca

1 Introduction

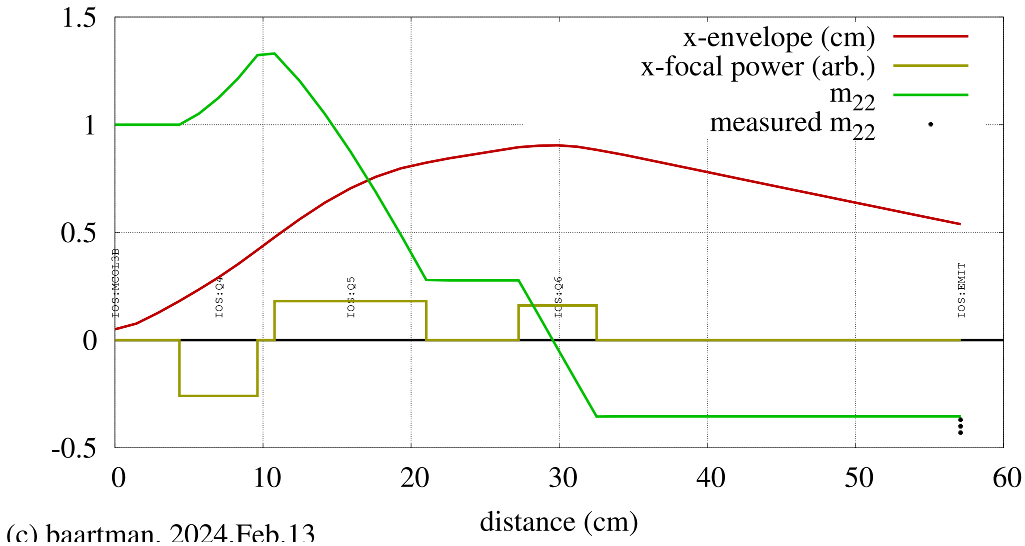
The situation is that we wish to use the OLIS emittance scanner to help construct a model of the optics of the OLIS separator. We know some details to some accuracy, but do not know very much to high accuracy. The most recently measured details are here, and here[1, 2].

2 TRANSOPTR model

According to this, we have the following code snippet for transport from the OLIS slit MCOL3B to the emittance scanner for TRANSOPTR's sy.f.

```
call DRIFT((1806.06-1736.16)/10.-5.268/2.,".")
call EQUAD(  Q4,2.5400,   5.2680,   1.0,"IOS:Q4")
call DRIFT((1895.16-1806.06)/10.-(5.2680+10.2464)/2.,".")
call EQUAD(  Q5,2.5400,  10.2464,   1.0,"IOS:Q5")
call DRIFT((2035.07-1895.16)/10.-(5.2680+10.2464)/2.,".")
call EQUAD(  Q6,2.5400,   5.2680,   1.0,"IOS:Q6")
call DRIFT((2307.35-2035.07)/10.-5.268/2.+dex,"IOS:EMIT")
```

On the date the emittance scans were made, beam energy = 8.16 keV, and the three quadrupoles set as follows: Q4 = 455 Volts, Q5 = 318 V, Q6 = 282 V. This yields the horizontal envelope shown in the figure. The starting condition is as prescribed by the 1 mm slit in place at MCOL3B. (The envelope is the half-size, 0.5 mm.)



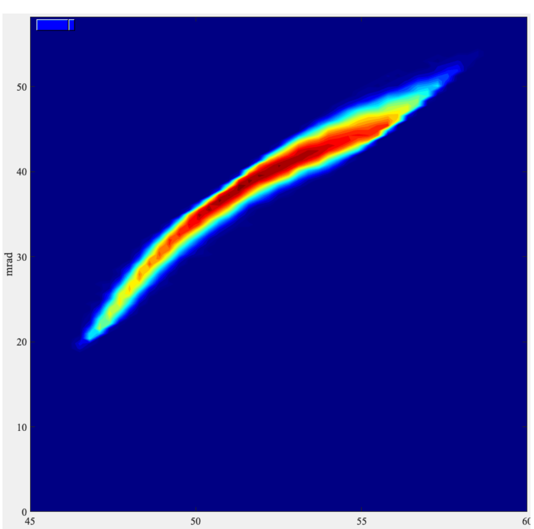
The calculated transfer matrix is

$$\mathbf{M} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} = \begin{pmatrix} -0.608 & 0.134\,\mathrm{m} \\ -5.84/\mathrm{m} & -0.354 \end{pmatrix}, \tag{1}$$

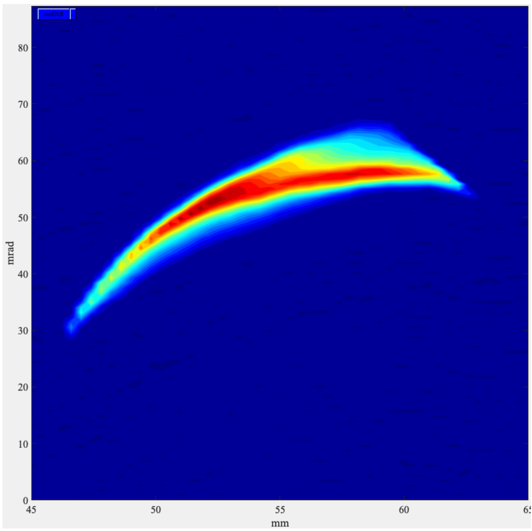
of which the 22 element is plotted.

3 Measurement

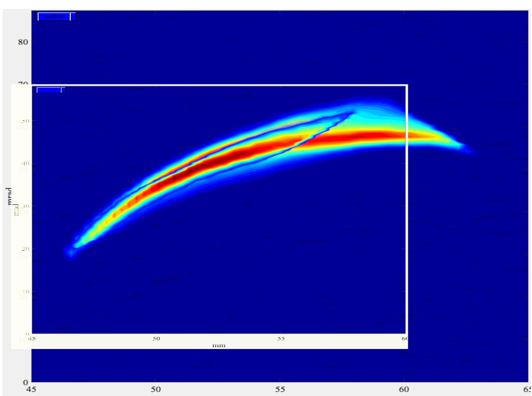
The emittance scan `240209_1127ILTEMIT.txt` with MCOL3B at 1 mm width is shown below.



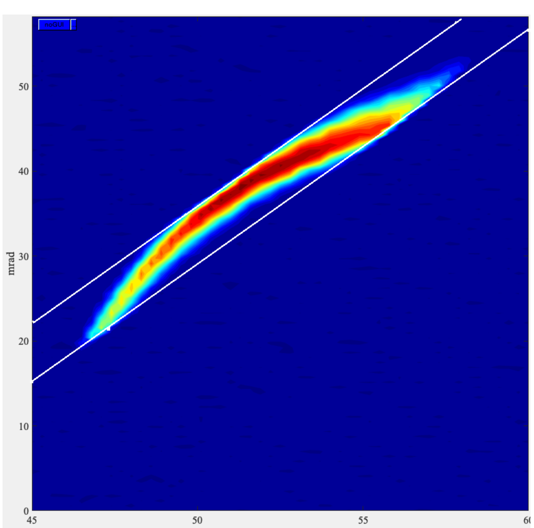
Here is the scan for wide open slit (`240209_1158ILTEMIT.txt`):



Placing the former scan over top of the latter, we have:



This shows how the slit has selected the 1 mm width. To emphasize the point, I've drawn white lines at the edges for the first scan:



For a fixed x', the slit edges are separated by $(2.5 \pm 0.2)\,\mathrm{mm}$.

Applying to the above matrix, we have:

$$\begin{pmatrix} x \\ x' \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \begin{pmatrix} \pm s/2 \\ x'_i \end{pmatrix}, \tag{2}$$

where s is the full slit width at MCOL3B. Inverting the matrix gives

$$m_{22}x - m_{12}x' = \pm s/2 \tag{3}$$

For fixed x', we thus find the white lines on the above figure should be separated by

$$|m_{22}|\Delta x = |m_{22}|(2.5 \pm 0.2)\,\mathrm{mm} = 1\,\mathrm{mm}. \tag{4}$$

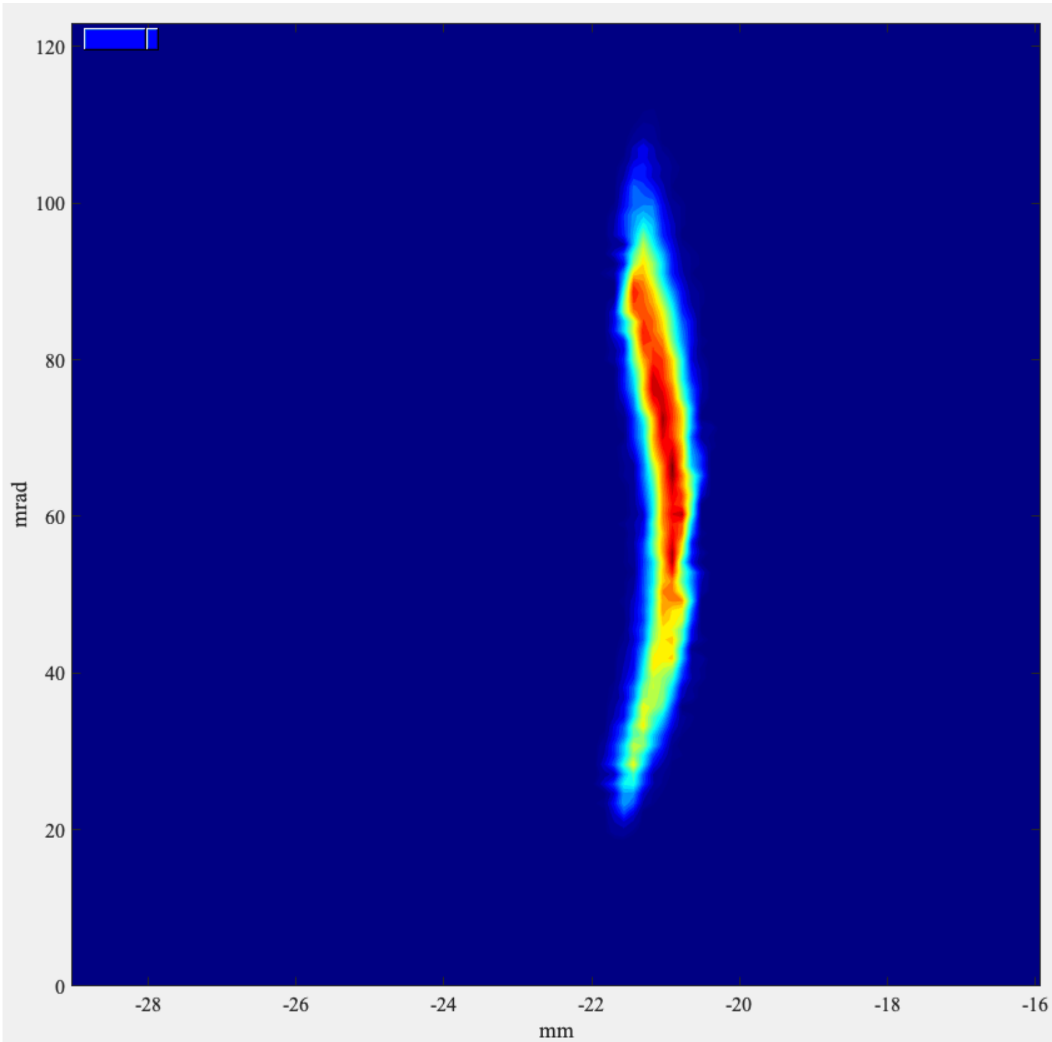
(The sign is indeterminate since we do not know which edge corresponds to which white line.) This finds

$$|m_{22}| = 0.40 \pm 0.03 \tag{5}$$

It disagrees with the `TRANSOPTR` result of 0.35, but this can be adjusted by changing slightly the drift from MCOL3B to Q4, which in any case is uncertain to a level of about 1 cm.

A more direct comparison of model with the emittance scan can be achieved by simply inverting the calculated transfer matrix (1) to transport the emittance scan back to the location of the slit.

But first we must resolve a contradiction between envelope and matrix: The emittance scans show a strongly diverging beam (particles at largest x have largest x'), while the calculated envelope is clearly converging. So the sign of x or x' in the emittance scans must be incorrect. This could happen in any number of ways; for example, the left and right emittance scanner plates could be wired interchanged, or the power supply incorrectly connected, or position has wrong sign due to interchanged left and right. When matrix $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$ is applied first and then inverted matrix $\begin{pmatrix} m_{22} & -m_{12} \\ -m_{21} & m_{11} \end{pmatrix}$ applied, we get:



which quite convincingly shows the transmitted beam fitting within the 1 mm slit.

References

[1] O. Shelbaya, Report On OLIS Quadrupoles 5 and 7 , Tech. Rep. TRI-BN-22-12, TRIUMF (2022).

[2] O. Shelbaya, OLIS to RFQ Beam Transport and Acceleration in TRANSOPTR, Tech. Rep. TRI-BN-20-13, TRIUMF (2020).