Neutron guides with adiabatic shape transformation

Horizontal reflectometer:

– one of the key instruments for surface and nanoscience

– needs beam with small height and small vertical divergence

Neutron guides:

– have large height and small width close to the source

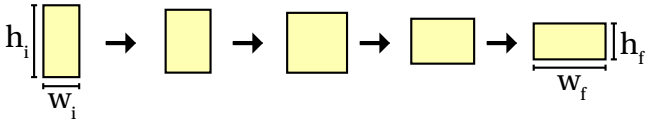
→ cross-section needs to be transformed to small height for horizontal reflectometer

An efficient transformation is a major problem!

Neutron guides with adiabatic shape transformation

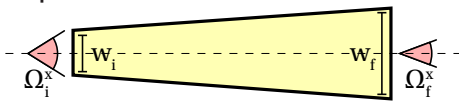
Existing standard »trumpet-shaped« rectangular guides

Change of cross-section:

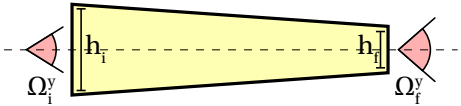


Linear transformation
→ no exchange between horizontal and vertical divergence as the reflecting surfaces are orthogonal to each other.

Top view:

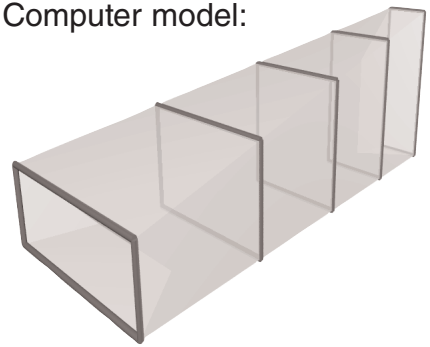


Side view:



$$h_i \cdot \Omega_i{}^y = h_f \cdot \Omega_f{}^y = \text{const} \quad \leftarrow \text{Liouville's theorem!} \rightarrow \quad w_i \cdot \Omega_i{}^x = w_f \cdot \Omega_f{}^x = \text{const}$$

Computer model:



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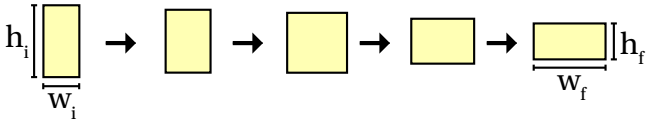

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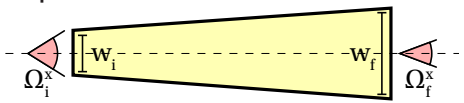

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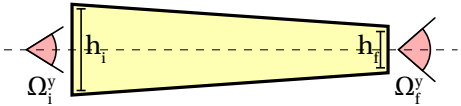

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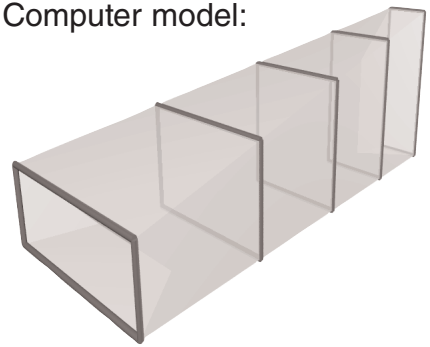
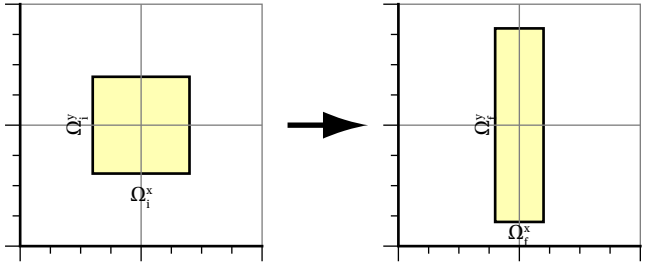


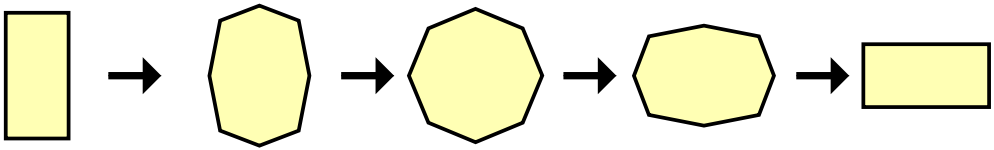
Resulting divergence distribution:



Very unfavourable for a horizontal reflectometer!

Guides with adiabatic shape transformation

Basic idea: **inclined surfaces** make **exchange** between horizontal and vertical beam divergences possible (if the guide is long enough).



This continuous exchange leads to an isotropic divergence distribution perpendicular to the optical axis.

How will it look like?

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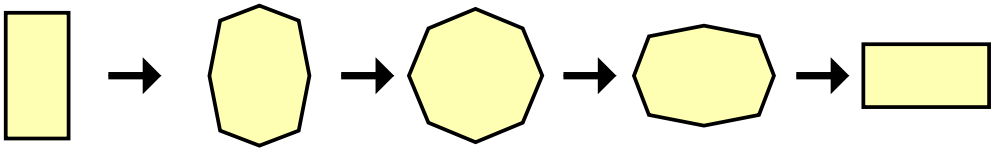

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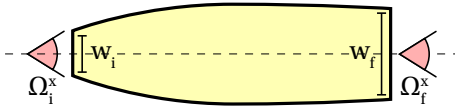

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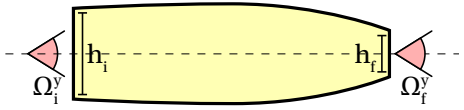
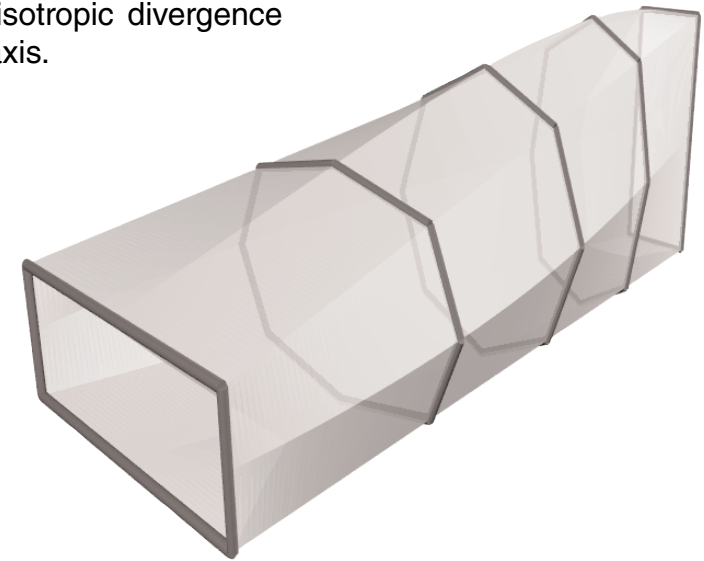
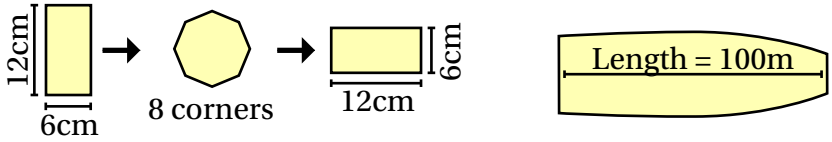


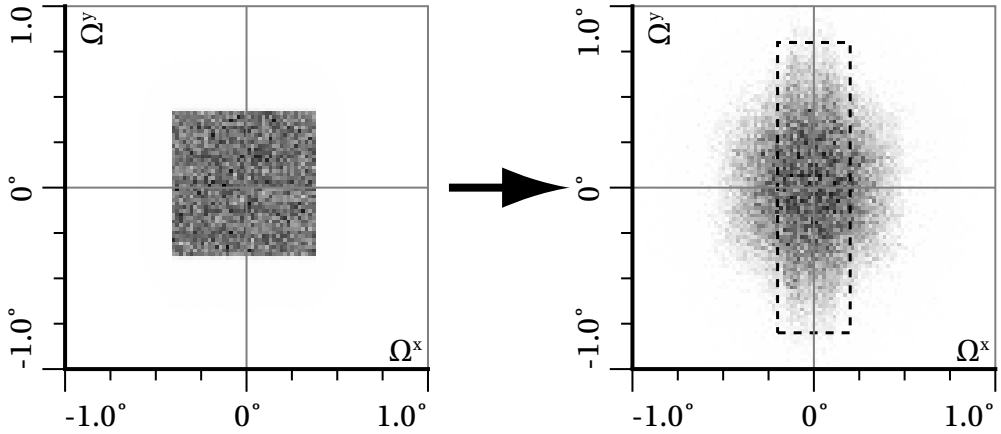


Neutron guides with adiabatic shape transformation

Simulation results

Monte Carlo simulations using McStas neutron raytracing package:

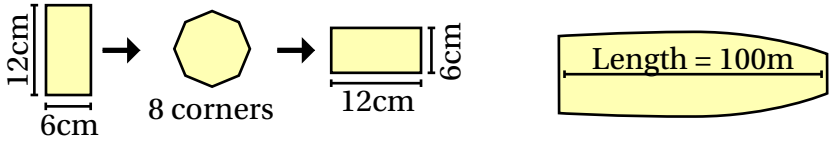




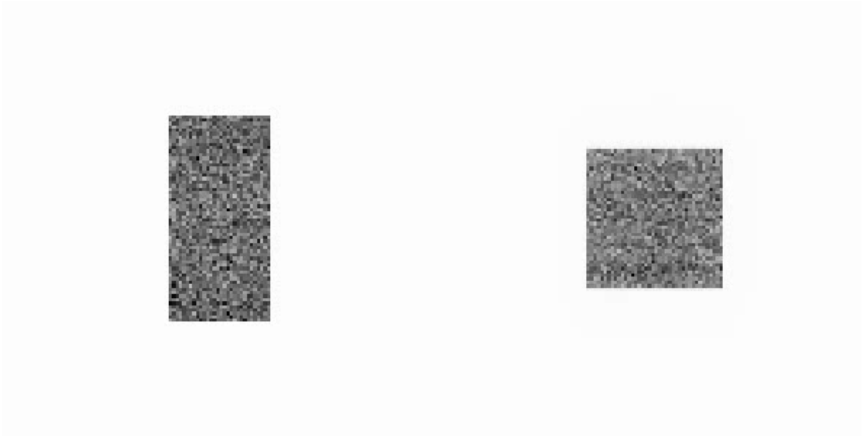
Neutron guides with adiabatic shape transformation

Results – Animation

Simulations using McStas neutron raytracing package:

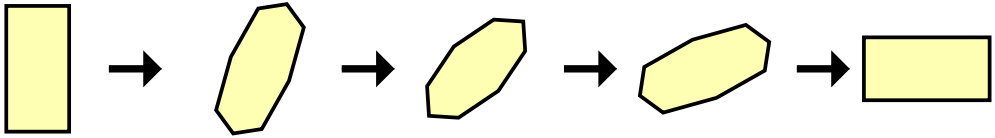


Cross-section (left) Divergence distribution (right)



Twisted adiabatic shape transform guide

One can improve results by introducing an additional “twist”:



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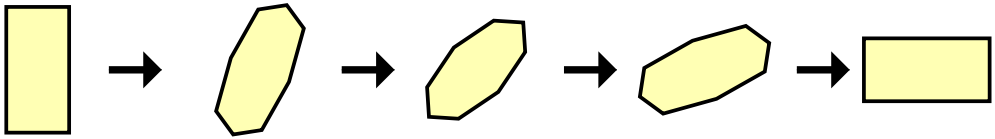

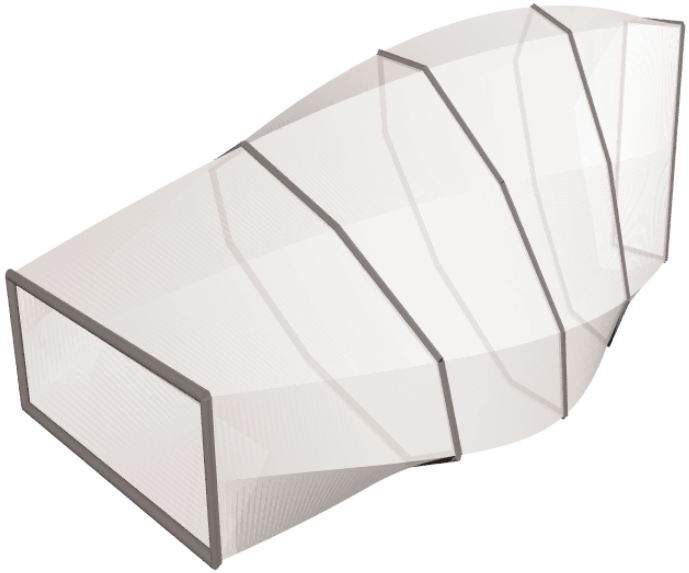

Twisted adiabatic shape transform guide – Animation

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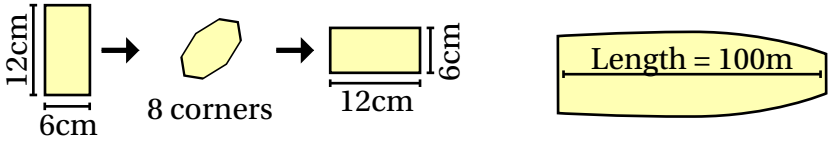

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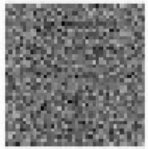

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Summary

– Concept does work, vertical divergence can be reduced (gain up to 2.5 for small div.).

– Guide has to be long enough (> 70m).

– Guide is difficult to build, but it is not impossible ($\rightarrow$ bent supermirrors).