A New Ray Trace Computer Program For Radiation safety

PhotonMEADOW23

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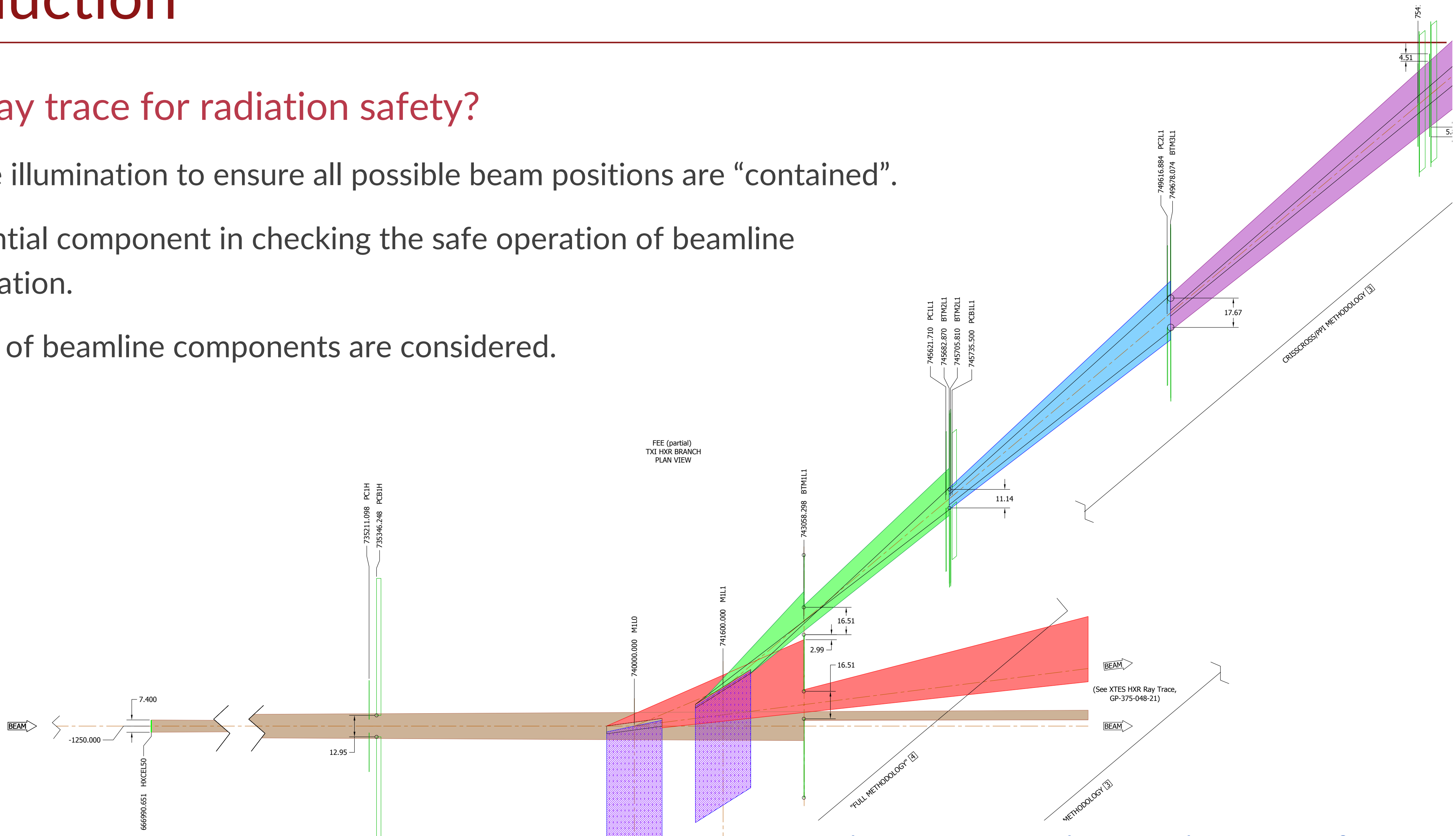
Introduction

What is ray trace for radiation safety?

- Estimate illumination to ensure all possible beam positions are “contained”.
- An essential component in checking the safe operation of beamline configuration.
- Motions of beamline components are considered.



Example: TXI HXR partial section, by Peter Stefan

Introduction

Objectives

- Reduce human effort in generating ray trace drawings
  - Historically a labor-intensive process performed by selected few. Turn around time on the order of weeks (to month), depending on the complexity.
- Reduce error due to human factors
  - Multiple short-cut methods which are scenario-dependent, relying on human decisions.
  - Purely manual graphical construction, very error prone.
  - Working under anamorphic view complicate matters further.
- Apply a consistent methodology.
- Interface with database for robust data input (work in progress).

Introduction

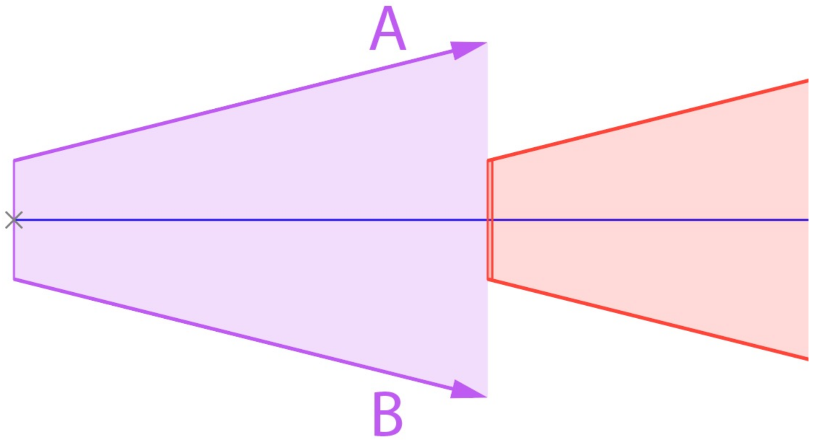
Challenges

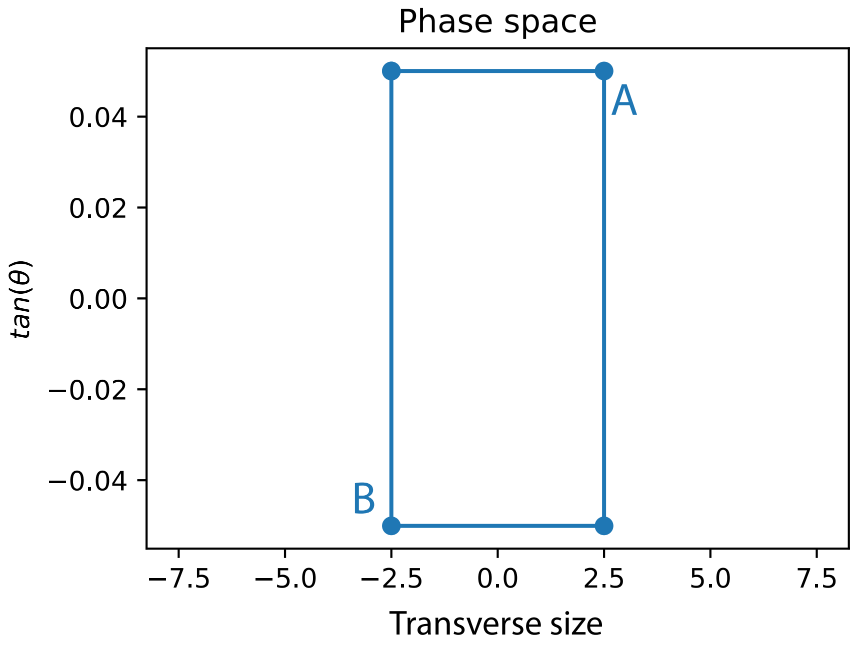
- Must fulfill all output requirements of the manual ray trace.
- The input data must be representative.
- The program must be efficient, and sufficiently accurate.
- All beam possibilities must be explored with a given source property and component configuration.
  - Sampling method -- risk of under sampling
  - Wave front propagation -- computationally expensive
- Optical component motion further complicates matter by introducing degrees of freedom in the "configuration space".
  - How to explore the configuration space?

Implementation

Potential solution

- Uses ray-based method (geometric ray tracing).
- Propagation of boundaries in **phase space**, instead of real space.
    - Treats intensity as a binary field.

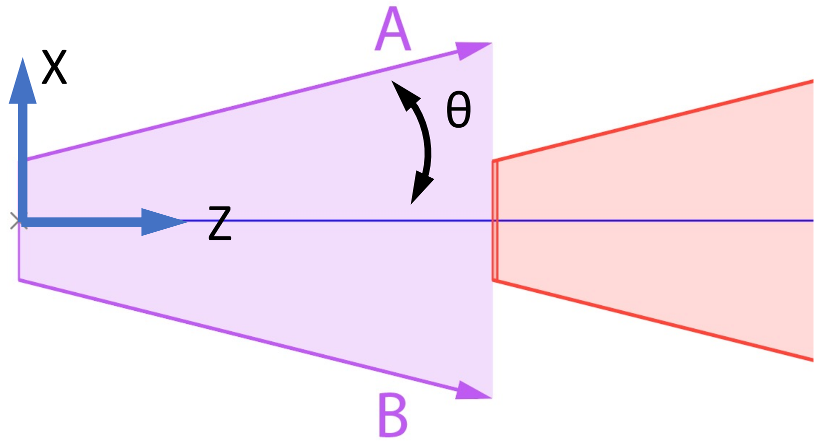


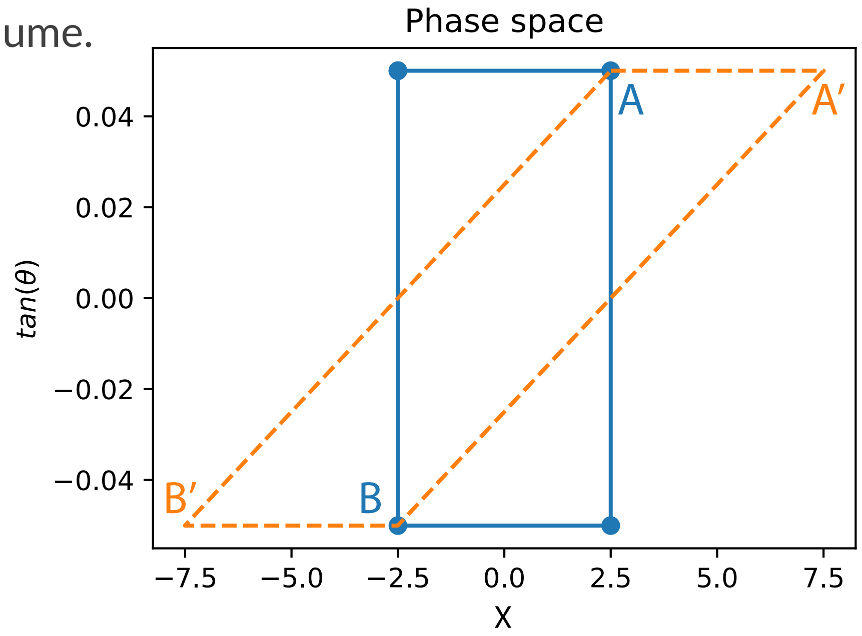


Implementation

2D phase space method

- The region contained in a 2D "fan" in X-Z plane is equal to a volume in X-Z-tan(θ) phase space.
  - tan(θ) preserves straight lines in free space propagation.
- A slice of volume at a fixed Z location is shown as a polygonal region in the X-tan(θ) plane.
  - Only convex polygon for simplicity.
- Illumination is considered "present" anywhere inside this volume.

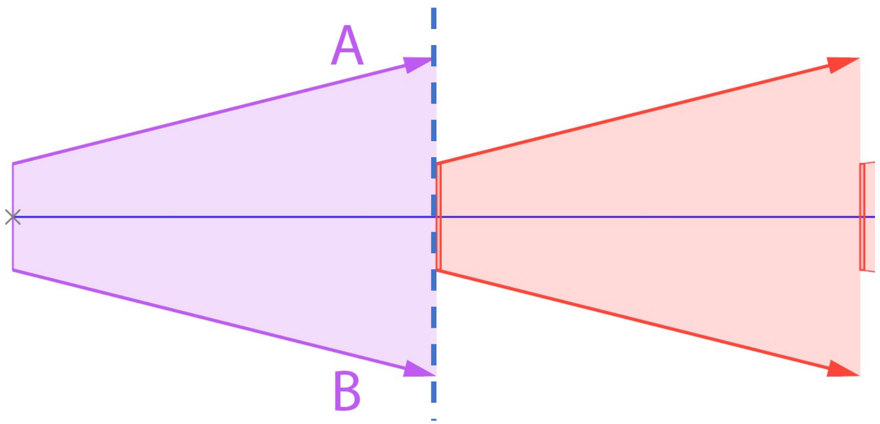


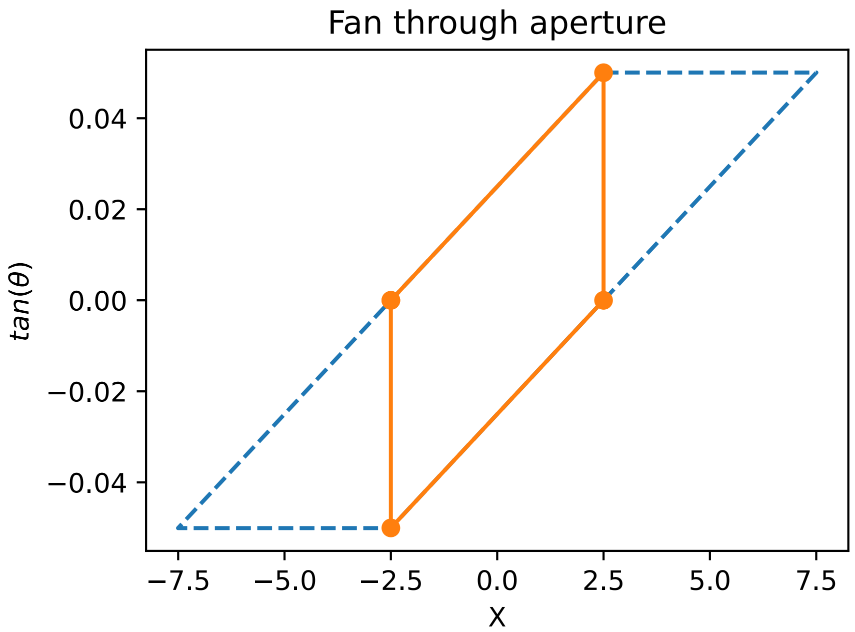


Implementation

Interaction with optical components (normal incidence)

- Phase space polygon is sliced by acceptance region of optical components
- Example: simple aperture of width=5

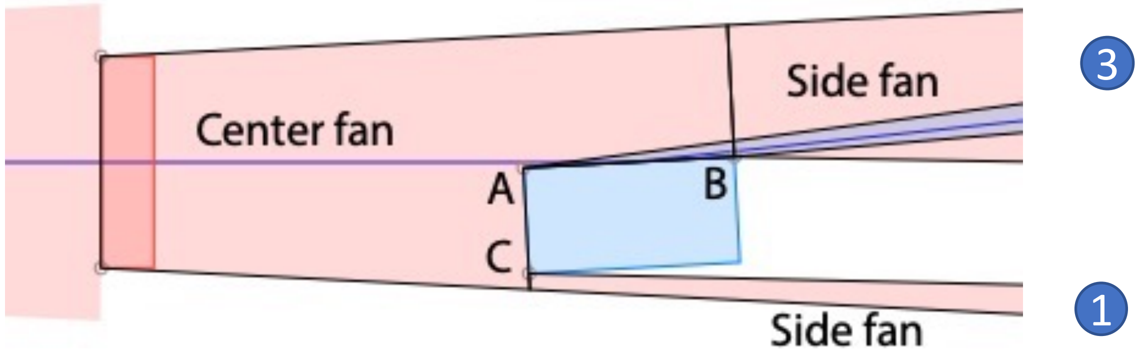


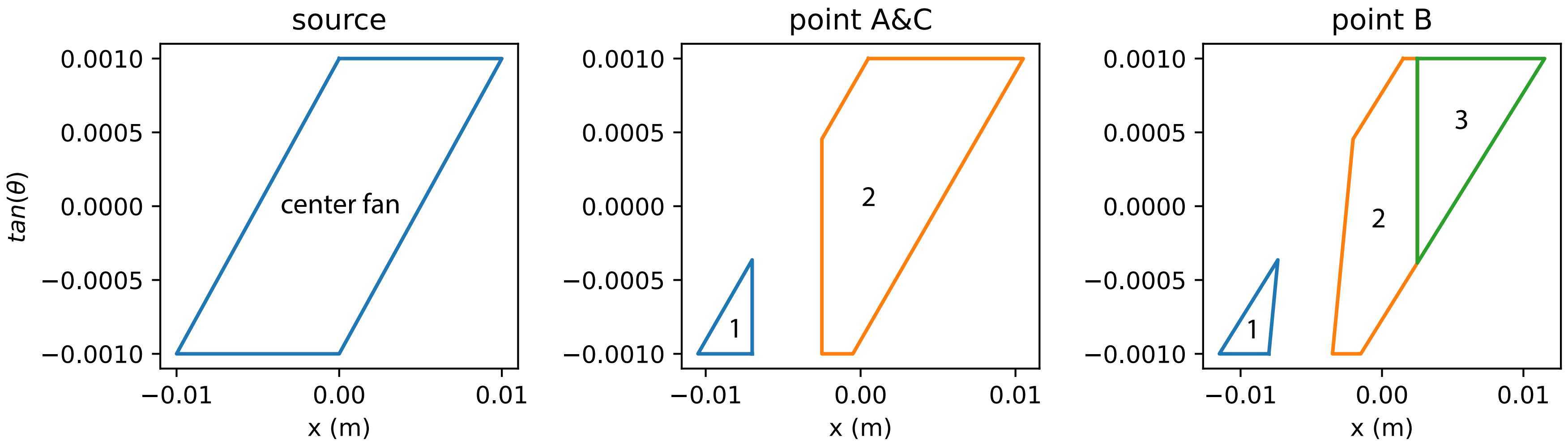


Implementation

Interaction with optical components (slanted)

- Boundary cut at different z location for slanted acceptance region

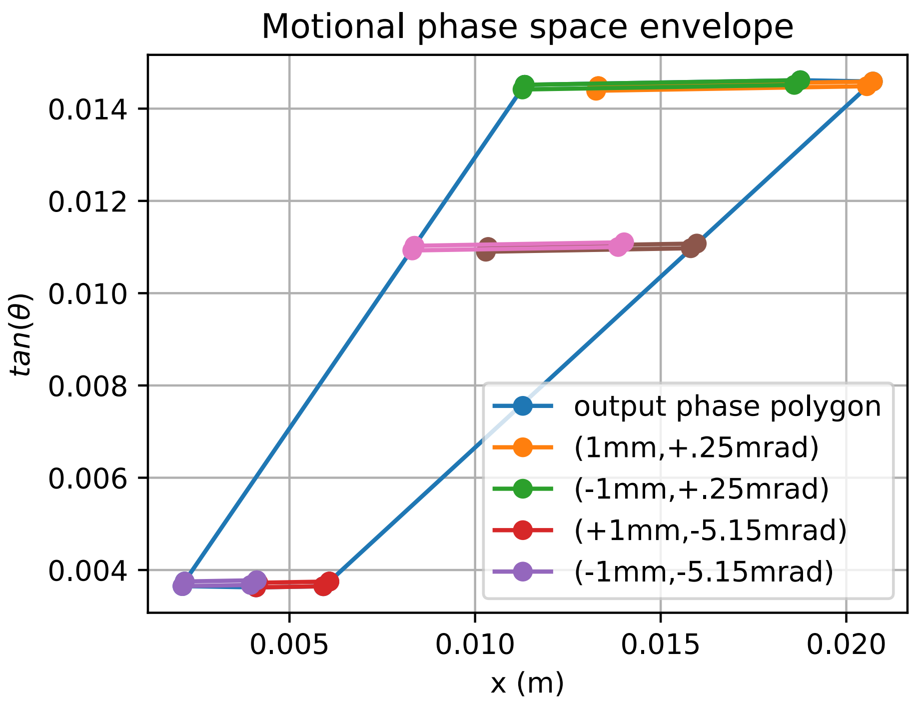




Implementation

Treatment for component motions

- Mirror reflection can be approximated as a linear transform in the X-tan(θ) phase space.
  - Error is on the order of $\theta^* L^2$ (~1e-6) depending on the angle (θ) and vertical length (L) of uninterrupted boundary.
- Mirror motions in 2 degrees of freedom may be considered as a rectangular region in the configuration space.
- The output fan can be constructed by combining all the phase points from all configuration vertices.
- Great reduction in iteration time as number of fans do not increase as N^M where N is the number of configurations and M the number of components with motion.



Implementation

Limitations

- Beam propagation is considered in 2D only. Cosine errors are treated for component configurations with out-of-plane location variations.
- Beam propagates strictly from left to right. Current program handles ray directions in 1st and 4th quadrants.
- No attenuation is considered.
- No intensity information is considered, apart from either being present or absent.
- Only geometrical propagation is considered. Coherence and diffraction phenomena are not considered.
- Perfect elliptical or parabolic shapes are assumed for the focusing optics. However, height variations are not considered for the acceptance region.

Demonstration

- Written in objective C (Cocoa, Xcode)
- Runs in Mac with native UI elements

RayTrace

V0.1.385