OPOSSUM - An Open-Source Optical Simulation Tool for High-Energy, High-Intensity Laser Systems

THRILL
TECHNOLOGY FOR HIGH-REPETITION-RATE INTENSE LASER LABORATORIES

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OPOSSUM
Open-source Optics Simulation System and Unified Modeler

Introduction

Within the **THRILL** project, several collaborators work together to advance the **T**echnology for **H**igh-**R**epetition-rate **I**ntense **L**aser **L**aboratories with the goal to provide solutions for high-energy amplifiers, beam transport and stabilization of large aperture/high energy beams, develop large-area optical coatings, and ultimately to design two new high-energy laser facilities for Eu-XFEL and FAIR.

As these modern laser systems are becoming increasingly more sophisticated, target on specific characteristics and generate costs in excess of several tens of millions of dollars. Such systems must be planned rigorously to not only reach the wanted outcome, but also to avoid wasting time, money and resources.

Therefore, to evaluate, support and guide the design processes, full-scale modeling of the laser systems, a digital- twin is indispensable.

OPOSSUM - Yet another simulation tool?

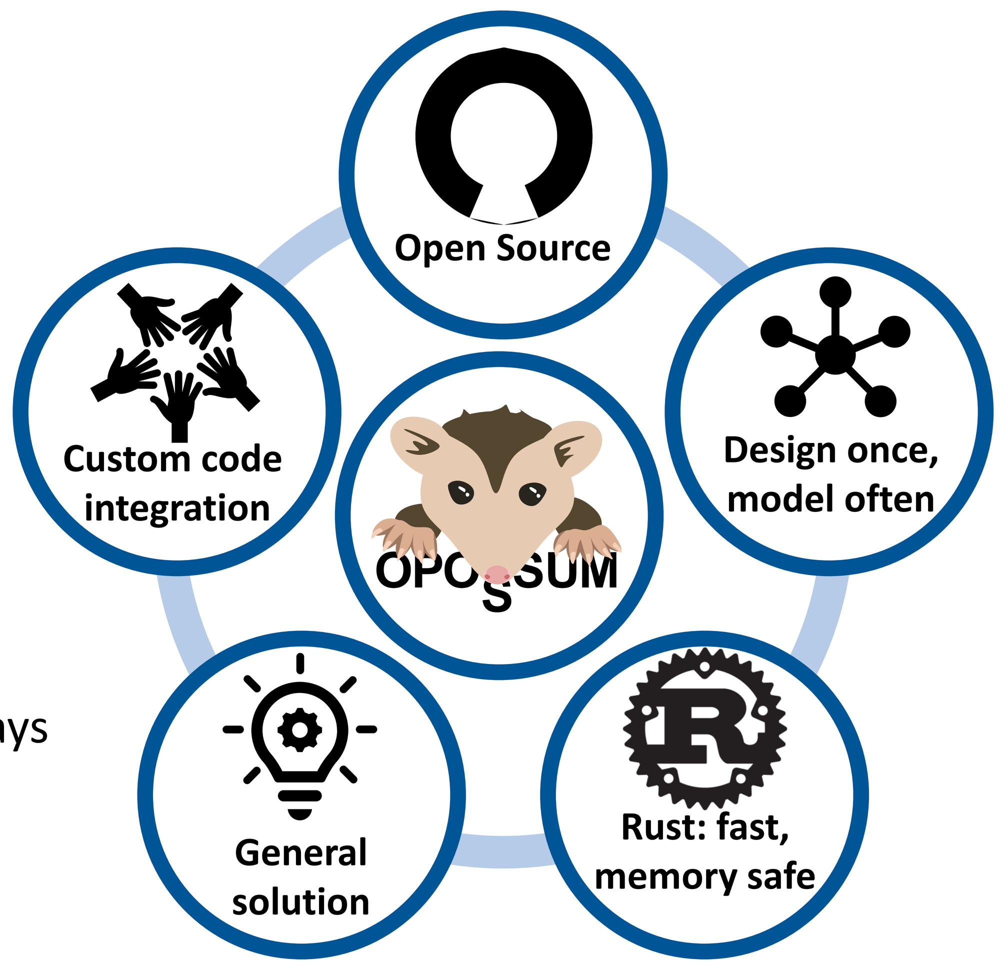
There is a plethora of optical simulation software which may be classified into two main groups:

Proprietary	Open Source / Custom code
General or specific modeling	Mostly specific modeling
Expensive	Free
Hard / impossible to integrate	Integration generally easier, still often non compatible with other code
Maintained well	Often not well maintained

The approach of **OPOSSUM** tries to combine the best out of both worlds:

Goals:

- Easy custom code integration: platform approach
- Holistic simulation of large-scale laser facilites
- Simulation of multiple, parallel beam paths
- Decouple system design from modeling: setup design once, model/analyze in numerous ways
- Accessible for all
- Modern backend with high maintainability



Current Status

Codebase

- > 630 unit tests: > 90 % code coverage by unit tests
- > 280 tickets closed
- > 1200 repository commits
- > 30.000 lines of code, written in Rust
- v0.5.0 on gitlab:

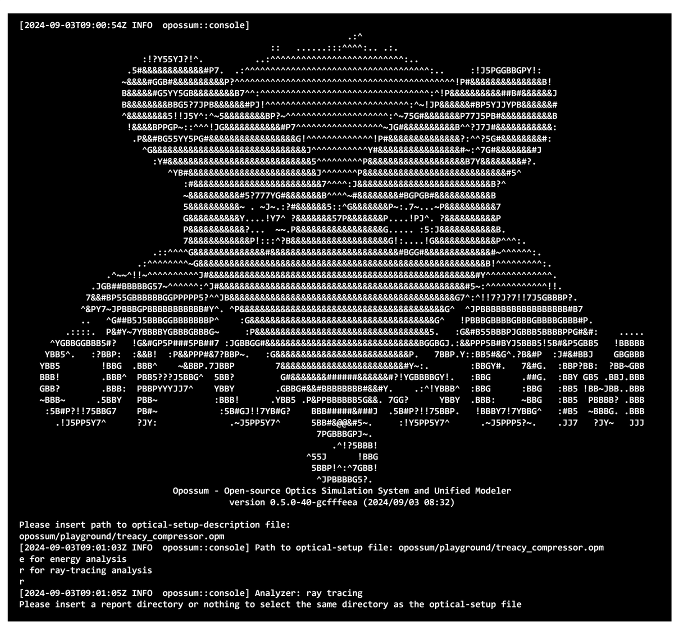


Fig. 1: Command line interface of OPOSSUM

Usability

- Command line interface, currently only for rust-users
- Automatic alignment by distance from last node + orientation of next node
- Several optical and detector nodes: lenses, mirror, gratings, beam-splitters, fluence detector, wavefront detector, spot diagram
- Infinite nesting of related nodes as groups
- As for now only sequential ray-tracing
- Html-based report generation
- MaterialDB to select from in progress: https://git.gsi.de/phelix/rust/materialdb_frontend

The Workflow principle

- Design of complete system as a set of sub-systems, e.g. a compressor:
- Each optic defined as node, sub-systems as node-group
- "light" propagates as data between nodes in a flow graph

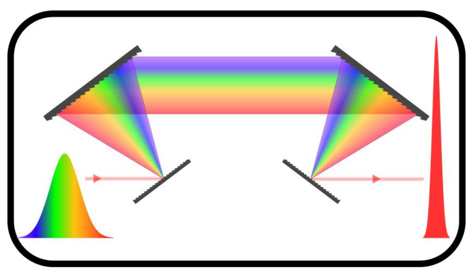


Fig. 2: Compressor schematic

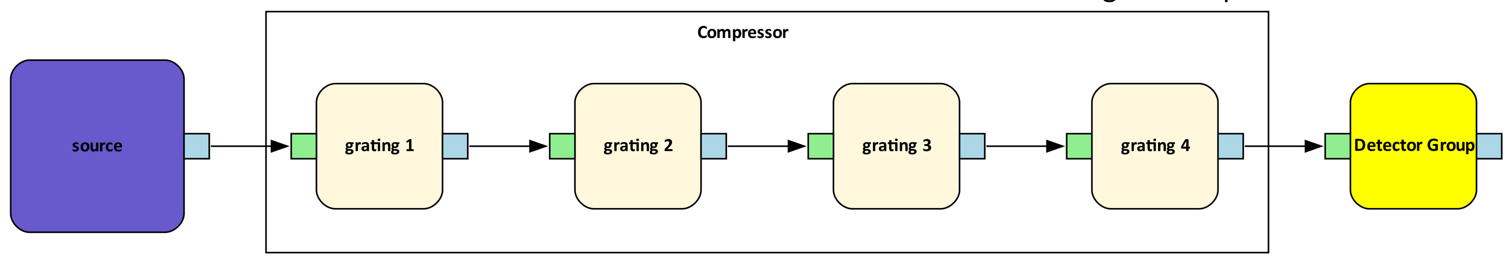


Fig. 3: Node-based representation of the compressor in Fig. 2

- After setting up: analyze with different analyzers, e.g. Energy, Ray-Tracing etc.
- Inspect analysis report in web browser:

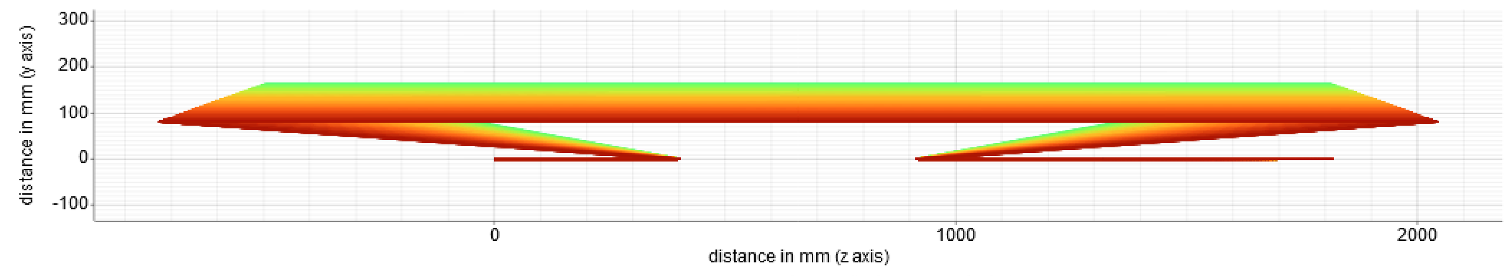


Fig. 4: Top-view ray-tracing plot of the models' compressor.
The compressor definition required only 10 lines of code to define the grating alignment and positioning

Example

Rebuilt of real-world system "HHT sensor" at PHELIX:

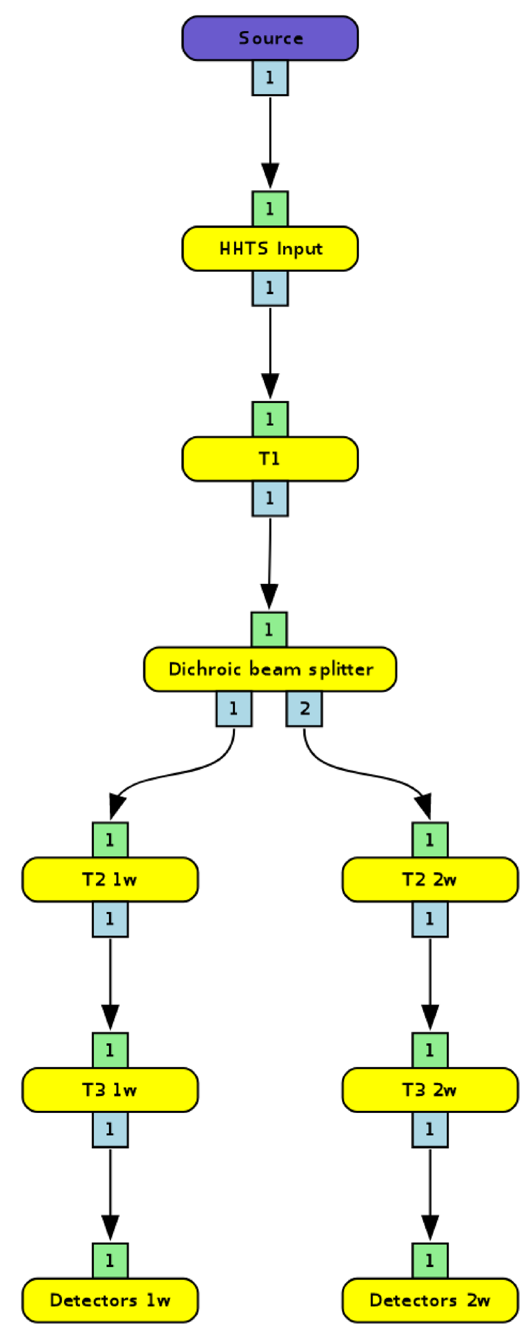


Fig. 5: Graph representation of HHT sensor

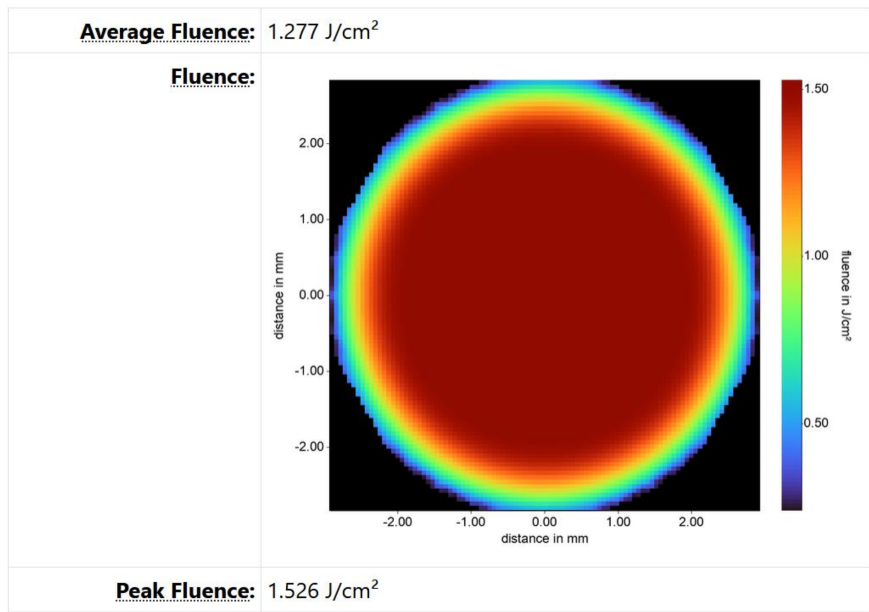


Fig. 6: Fluence monitor report from "Detectors 1w". Fluence is constructed by ray energy an associated area by Voronoi-cell creation.

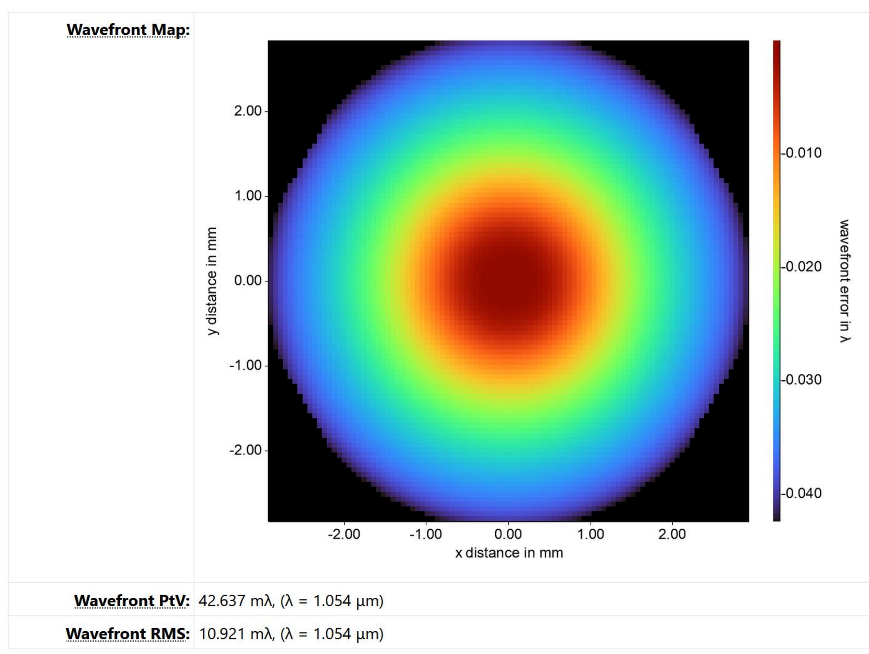


Fig. 7: Wavefront monitor report from "Detectors 1w"

Outlook

In Progress

- Ghost-focus analyzer to estimate risk of laser-induced damage
- Polarization handling
- Advanced optical coating definitions
- Additional nodes: parabolas, polarizers, etc.

Near Future

- GUI implementation for drag & drop optical-system design
- Three-wave mixing node for SHG, OPA, etc.
- Simple amplifier model

Long term

- Full GUI usability
- Propagation models: Complex ray-tracing, Beam and Wave Propagation method
- Non sequential ray-tracing, e.g. for flash-lamp illumination

Ideas for further developments or code to implement?
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PHELIX

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