

Theia Primer

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Modeling Gaussian beams

- General astigmatic Gaussian beam in an orthogonal basis (k, e_1, e_2) :

$$E(\vec{r}, t) = \exp[i\eta(z) - i\frac{k}{2}{}^t(x, y)Q(z)(x, y)]e^{i(\omega t - kz)}$$

- (x, y) is the transversal coordinate in the (e_1, e_2) basis, Q is a symmetrical tensor:

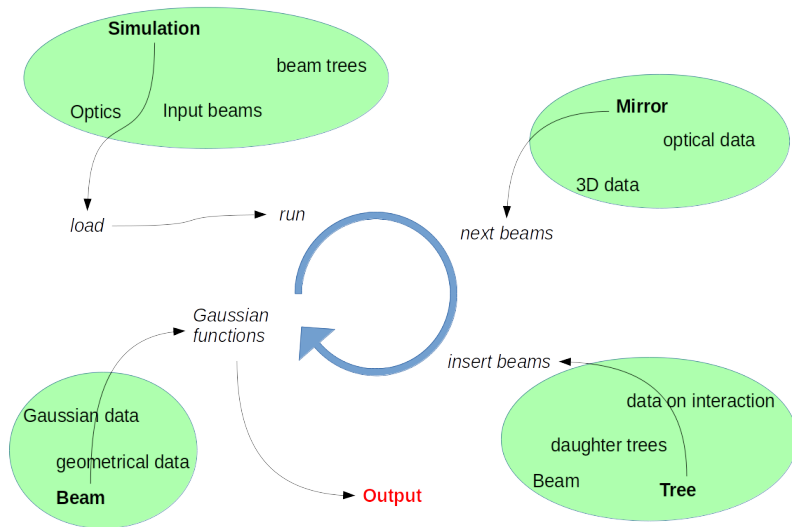
$$\begin{pmatrix} \frac{\cos^2 \theta}{q_x(z)} + \frac{\sin^2 \theta}{q_y(z)} & \frac{1}{2} \sin 2\theta \left(\frac{1}{q_x(z)} - \frac{1}{q_y(z)} \right) \\ \frac{1}{2} \sin 2\theta \left(\frac{1}{q_x(z)} - \frac{1}{q_y(z)} \right) & \frac{\sin^2 \theta}{q_x(z)} + \frac{\cos^2 \theta}{q_y(z)} \end{pmatrix}$$

- Specification parameters: $\theta, q_{x,y} \in \mathbb{C}$, (e_1, e_2) basis.
- **Approximations:** $\text{ROC}(\text{beam}) \gg \text{ROC}(\text{surface})$ (+ paraxial)
- Geometric optics: no approximation

What can it do?

Yes	No	Not yet
Non-sequential propagation	Higher order modes	Cavities
Sequential propagation	Beam saving	Interferences
General astigmatic beams	Surface action specification Grating surfaces (Polarization)	Export to CAD software

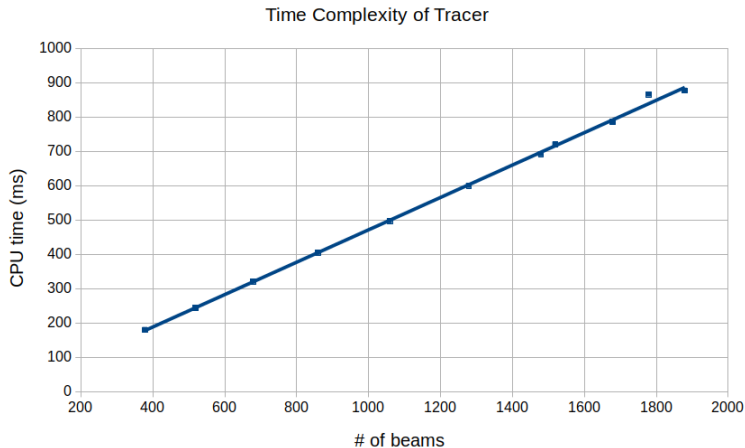
Data structures/algorithm/approximations



Demonstration

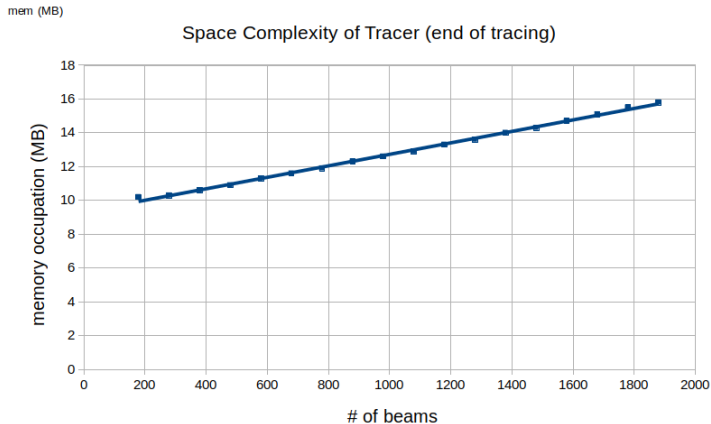
- Comparison with OptoCAD for 2D tracing (`telescope.py`)
- An example in 3D with spherical mirrors (`sphere.py`)

Benchmarking: time (i7/8GB)



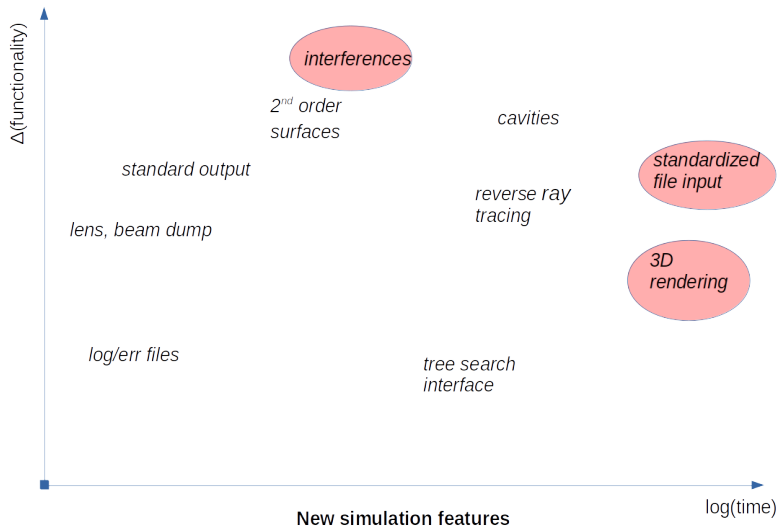
- $\text{CPU} = 0.47\text{ms} \times (\# \text{ beams}) \quad (R^2 = 99.95\%)$

Benchmarking: space (i7/8GB)



- Mem. = 9,3MB + 3,4kB/beam ($R^2 = 99.76\%$)

Next steps





Kochkina, Wanner, Schmelzer, Tröbs, Heinzl: *Modeling of the General Astigmatic Gaussian Beam and its Propagation through 3D Optical Systems*, Applied Optics 24 (2013)



Arnaud, Kogelnik: *Gaussian Light Beams with General Astigmatism*, Applied Optics 8 (1969)