LOPSIMUL: High Computing Rate Numerical Simulator of Multi-Foil Reflective Optical System

Vladimír Tichý[1], René Hudec[1,2]

[1]Czech Technical University in Prague, Faculty of Electrical Engineering
[2]Astronomical Institute AS CR Ondrejov

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Why to develop a new algorithm and program

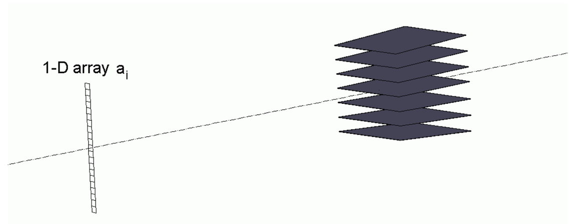
The idea was to develop the quick algorithm and consequently the software which is optimized for Schmidt and Angel lobster eye (usually used for X-rays). As result, the software is extremely quick, computing time is usually in order of seconds or less than one second on a common personal computer. The usage is more general than the lobster eye.

Ideas of the algorithm

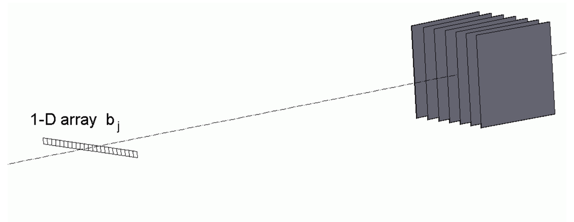
- Separation of dimensions: 3D problem → two 2D problems that represents a small approximation
- Calculation of borders of reflections and shadows only that does not represent an approximation for flat mirrors.
- Usage of suited formalism (operations known from complex numbers are applied to vectors) makes the equation even simpler.

The algorithm and consequently the software is possible to use for these types of optics that allows these simplifications. It covers any multi-foil optical system consisting of one or two orthogonally arranged stacks of flat mirrors. It is e.g. a case of optics that is similar to Schmidt lobster eye but spaces between mirrors are not equal. K-B system can be simulated in an approximation when curved mirrors are replaced by set of flat surfaces.

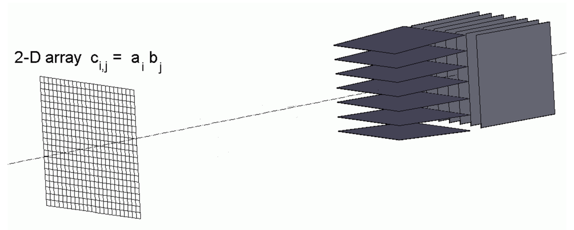
Separation of dimensions



First (horizontal) stack



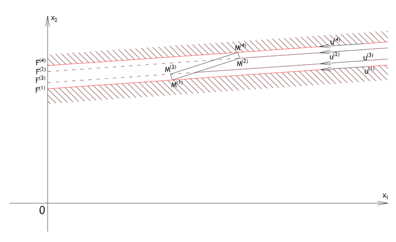
Second (vertical) stack



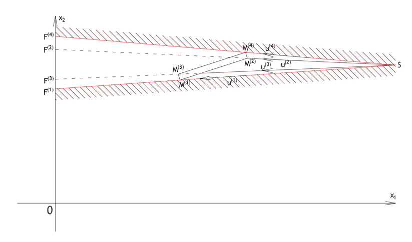
Full 2D system

Calculation of positions of shadows

It is useful to begin the calculations by calculating the position of the shades of mirrors. The mirror can have non-zero thickness and its border is defined by points $\mathbf{M}^{(1)}$, $\mathbf{M}^{(2)}$, $\mathbf{M}^{(3)}$, $\mathbf{M}^{(4)}$.



Parallel beams



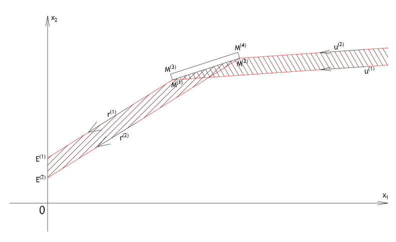
Divergent beams

Equation for position of points $F^{(j)}$ is simple:

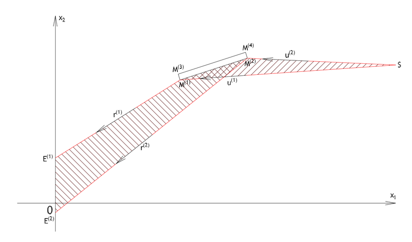
$$F_2^{(j)} = M_2^{(j)} - M_1^{(j)} \frac{u_2^{(j)}}{u_1^{(j)}} \quad (1)$$

The shadow lays between the minimal and maximal value of $F^{(j)}$, $j = 1 \dots 4$.

Calculation of positions of reflections



Parallel beams



Divergent beams

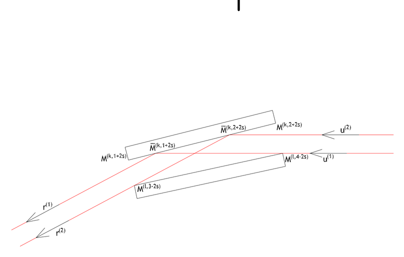
Direction of the reflected ray is calculated by equation

$$\mathbf{r}^{(j)} = \mathbf{m}\,\mathbf{m}\left(\mathbf{u}^{(j)}\right)^{*} \quad (2)$$

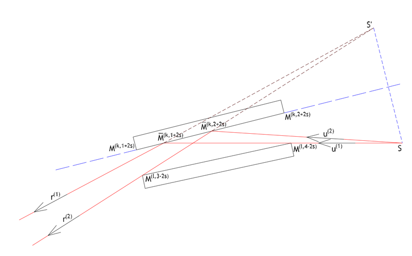
Positions of the borders of the reflection are calculated by equation

$$E_2^{(j)} = M_2^{(j+2s)} - M_1^{(j+2s)} \frac{r_2^{(j)}}{r_1^{(j)}} \quad (3)$$

Mirror direction vector $\mathbf{m}$ is defined as $\mathbf{m} = \mathbf{M}^{(2)} - \mathbf{M}^{(1)}/|\mathbf{M}^{(2)} - \mathbf{M}^{(1)}|$ or $\mathbf{m} = \mathbf{M}^{(4)} - \mathbf{M}^{(3)}/|\mathbf{M}^{(4)} - \mathbf{M}^{(3)}|$.



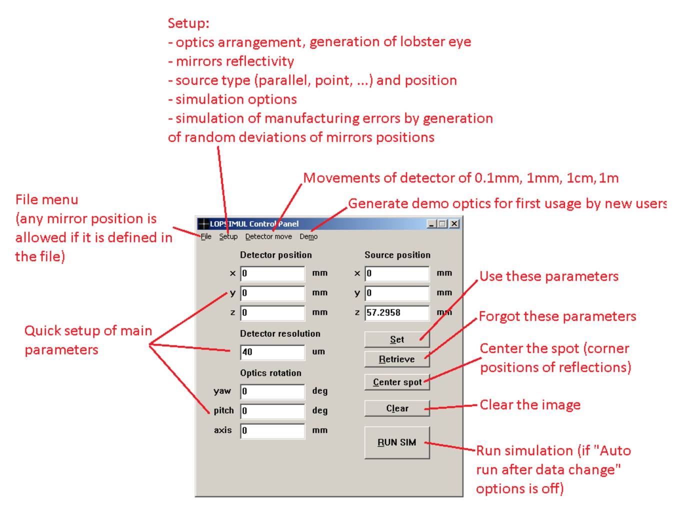
Parallel beams



Divergent beams

It can happen (in a case of lobster eye it commonly happens) that a mirror is not illuminated fully byt it is shadowed by other one. The full analysis of shadows between mirrors could be done. However, to save computing time, this analysis is done within a stack only and with the adjacent mirror only.

LOPSIMUL windows



Control panel

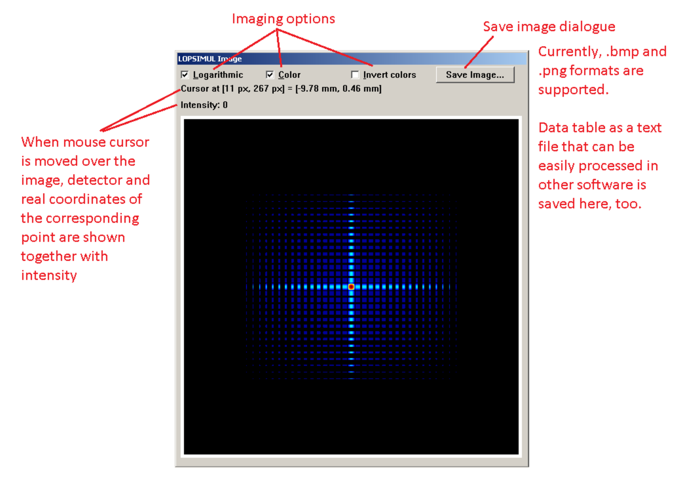
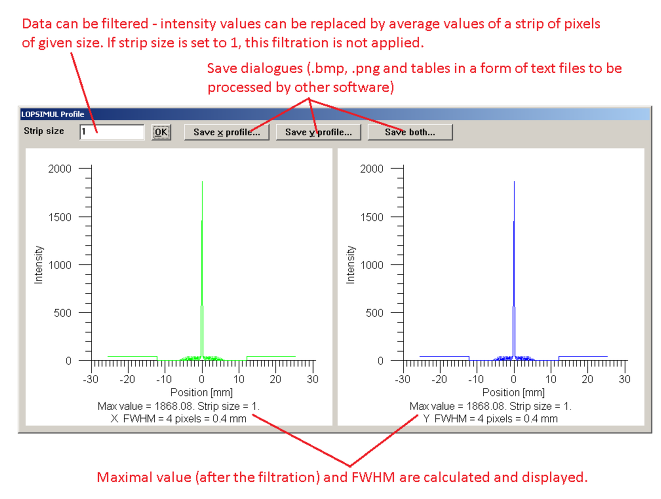
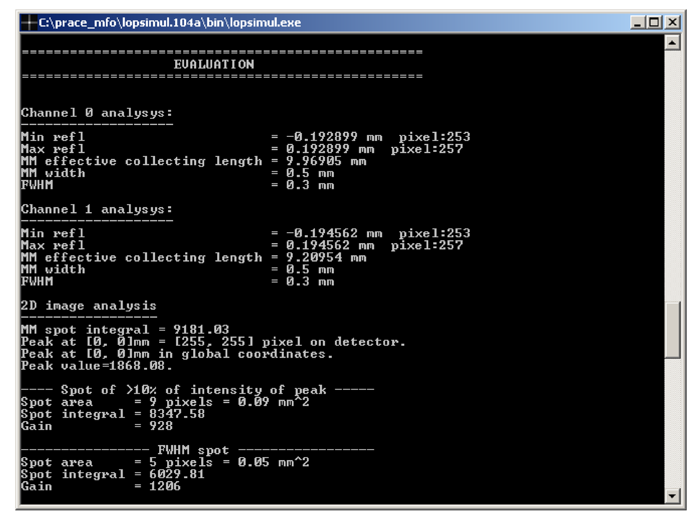


Image window



Profiles window



Console output

LOPSIMUL main features

- Integrated generator of lobster optics, other optics can be imported via input datafile. The datafile contains position of vertices of mirrors.
- X-ray sources: parallel beam, point, linear, "flower 7"
- Few built-in models of reflectivity, any model of reflectivity can be imported to the program in the form of data table grazing angle vs. reflecting coefficient.

LOPSIMUL results displayed in console window

Channel analysis gives

- Min refl, Max refl = border position of all reflections.
- MM effective collecting length = effective collecting length related to the area bordered by Min rel and Max refl, i.e. by border rays that are reflected.
- MM width = width of focal image bordered by Min refl and max refl. It is not exactly equal to difference of Min refl and Max refl because of non-zero pixel size.
- FWHM of focal image.

The analysis of full 2-D image gives:

- Effective collecting area at various conditions.
- Gain at various conditions
- Spot integral = total intensity in a spot at various conditions.
- Spot area at various conditions
- Peak position in pixel coordinates.
- Peak position in millimeters related to global coordinate system.
- Intensity of the peak.

LOPSIMUL terms of usage

Where LOPSIMUL can be obtained?

- Download at www.lopsimul.eu

How much does it cost?

- Usage of LOPSIMUL is free of charge.

There is an ask, anyway:

- If results obtained by LOPSIMUL are published anywhere (e.g. in article, paper, thesis, report, etc.), users are asked to mention there that this program was used and that the program uses simplified ray-tracing algorithm published in Exp. Astron. (2016) 41:377-392; DOI 10.1007/s10686-016-9493-2. Include citation of this paper and program homepage www.lopsimul.eu, please. Citations of more papers related to LOPSIMUL are welcomed.

Acknowledgments

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