LOPSIMUL: Quick Numerical Simulator of Multi-Foil Reflective Optical Systems

Vladimír Tichý, René Hudec

Czech Technical University in Prague
Faculty of Electrical Engineering

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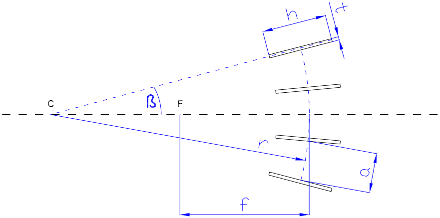
One-dimensional Schmidt lobster eye

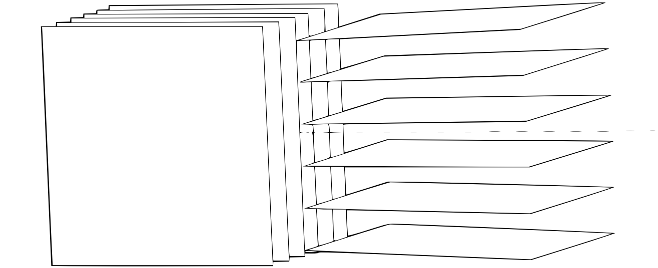


The system is composed of flat rectangular mirrors forming an uniform pattern around of a virtual cylinder of centre **C**. This set of mirrors is called stack. Point **F** is the focus.

- r radius of the system
- a mirror spacing
- t mirrors thickness
- h mirrors depth
- N number of mirrors
- β is angle position of a mirror; it is equal to grazing angle β if beams are parallel

Lobster optics is intended mainly for X-rays. Its main advantage is wide field of view

Two-dimensional Schmidt lobster eye



Two orthogonally arranged stacks of mirrors form two-dimensional lobster eye.

Why to develop a new algorithm and program

Motivation

Develop the quick algorithm and consequently the software mainly for Schmidt and Angel lobster eye (usually used for X-rays).

Result

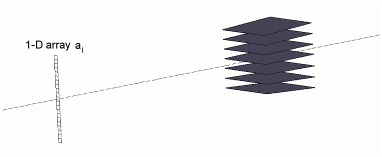
Extremely quick software, computing time is usually in order of seconds or less than one second on a common personal computer. The ussage is more general than the lobster eye.

Ideas of the algorithm

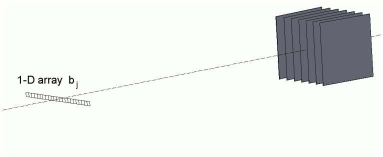
- Separation of dimensions: 3D problem $\rightarrow$ two 2D problems that represents a small approximation
- Calculation of borders of reflections and shadows only that does not represent an approximation for flat mirrors.

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.

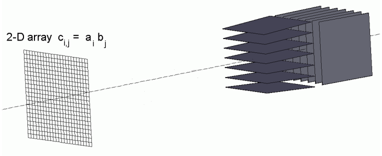
Separation of dimensions



(a) First (horizontal) subsystem



(b) Second (vertical) system

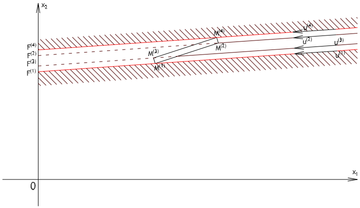


(c) Full 2D system

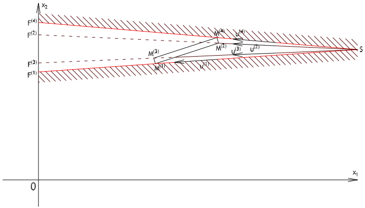
Figure: Separation of 2D system into two 1D systems

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 $\mathbf{M}^{(1)}$, $\mathbf{M}^{(2)}$, $\mathbf{M}^{(3)}$, $\mathbf{M}^{(4)}$.



(a) Parallel beams



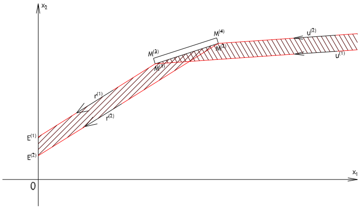
(b) Divergent beams

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

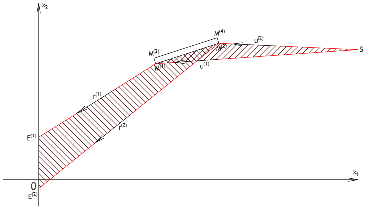
$$F_2^{(j)} = M_2^{(j)} - M_1^{(j)} \frac{u_2^{(j)}}{u_1^{(j)}} \quad (1)$$

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

Calculation of positions of reflections



(c) Parallel beams



(d) Divergent beams

Direction of the reflected ray is calculated by equation

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

Positions of the borders of the reflection are calculated by equation

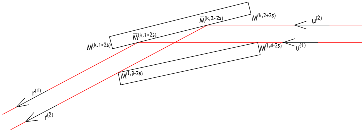
$$E_2^{(j)} = M_2^{(j+2s)} - M_1^{(j+2s)} \frac{r_2^{(j)}}{r_1^{(j)}} \tag{3}$$

Mirror direction vector $\mathbf{m}$ is defined as

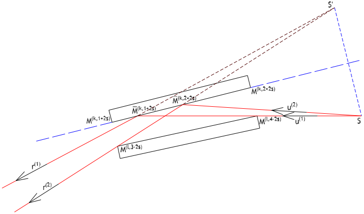
$\mathbf{m} = \mathbf{M}^{(2)} - \mathbf{M}^{(1)} / |\mathbf{M}^{(2)} - \mathbf{M}^{(1)}|$ or

$\mathbf{m} = \mathbf{M}^{(4)} - \mathbf{M}^{(3)} / |\mathbf{M}^{(4)} - \mathbf{M}^{(3)}|$.

Shadows between mirrors



(e) Parallel beams

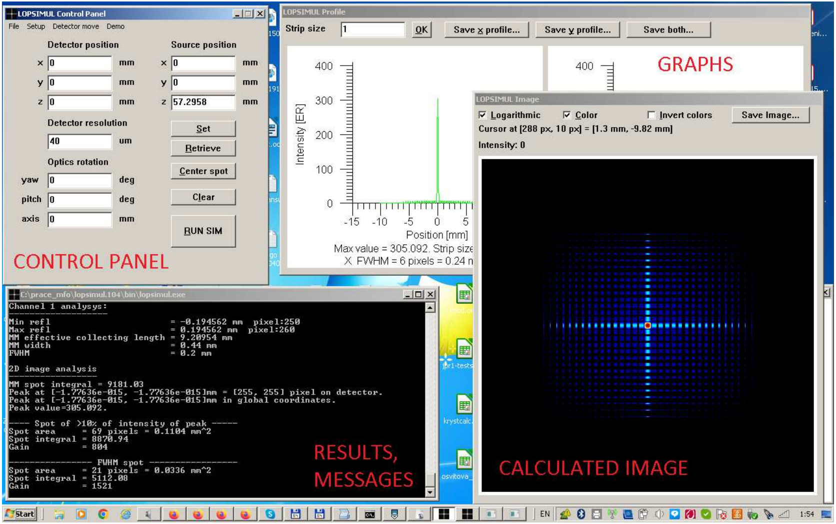


(f) Divergent beams

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.

Full description of the algorithm is published in paper Exp. Astron. (2016) 41:377-392; DOI 10.1007/s10686-016-9493-2

LOPSIMUL - Overview



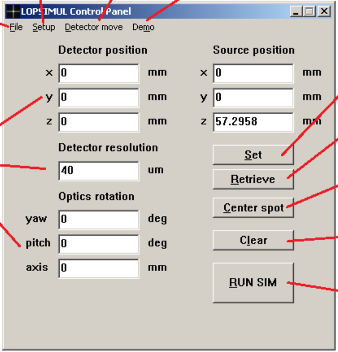
LOPSIMUL - Control panel

Setup:
- optics arrangement, generation of lobster eye
- mirrors reflectivity
- source type (parallel, point, ...) and position
- simulation options
- simulation of manufacturing errors by generation of random deviations of mirrors positions

Movements of detector of 0.1mm, 1mm, 1cm, 1m

Generate demo optics for first usage by new users

File menu (any mirror position is allowed if it is defined in the file)



Quick setup of main parameters

Use these parameters

Forgot these parameters

Center the spot (corner positions of reflections)

Clear the image

Run simulation (if "Auto run after data change" options is off)

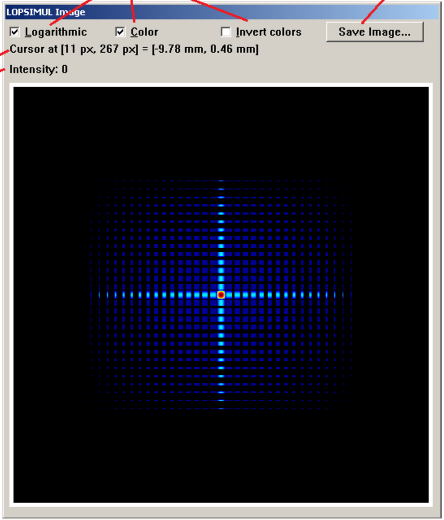
LOPSIMUL - options

- 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 - Image window

Imaging options

Save image dialogue



When mouse cursor is moved over the image, detector and real coordinates of the corresponding point are shown together with intensity

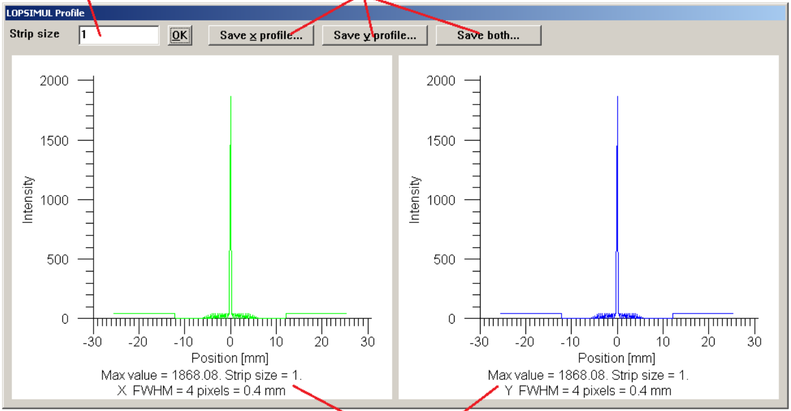
Currently, .bmp and .png formats are supported.

Data table as a text file that can be easily processed in other software is saved here, too.

LOPSIMUL - Graphs window

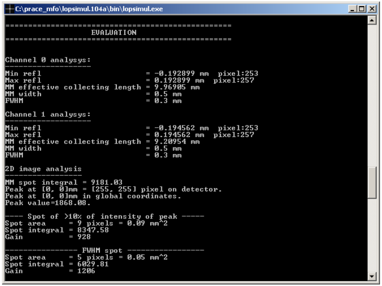
Data can be filtered - intensity values can be replaced by average values of a strip of pixels of given size. If strip size is set to 1, this filtration is not applied.

Save dialogues (.bmp, .png and tables in a form of text files to be processed by other software)



Maximal value (after the filtration) and FWHM are calculated and displayed.

LOPSIMUL - Results window



Channel analysis gives

- Min refl, Max refl = border position of all reflections.
- MM effective collecting length = effective collecting length[2] 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 = halfwidth of focal image.

LOPSIMUL - Results

The analysis of full 2-D image gives:

- MM spot integral = sum of intensities of all pixels laying within area bordered by Min refl and Max refl. I. e. it is total intensity in a rectangulare box bordered by all double-reflected rays.
- Peak position in pixel coordinates.
- Peak position in milimeters related to global coodinate system.
- Intesity of the peak.

For areas defined by FWHM and 10% rule, it is also calculated:

- Size of the area in pixels and square milimeters.
- Spot integral = sum of intensities of all pixels laying within this area.
- Gain

Where LOPSIMUL can be obtained?

- Downloaded 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.

THANK YOU FOR THE ATTENTION