Tests of Lobster Eye X-Ray Optics Prototype for Nano-Satellite Missions Based on New Technology

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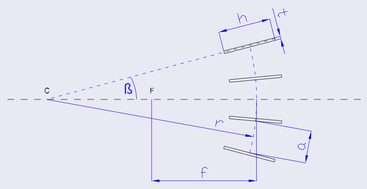
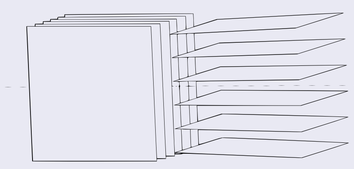
Schmidt lobster eye principle



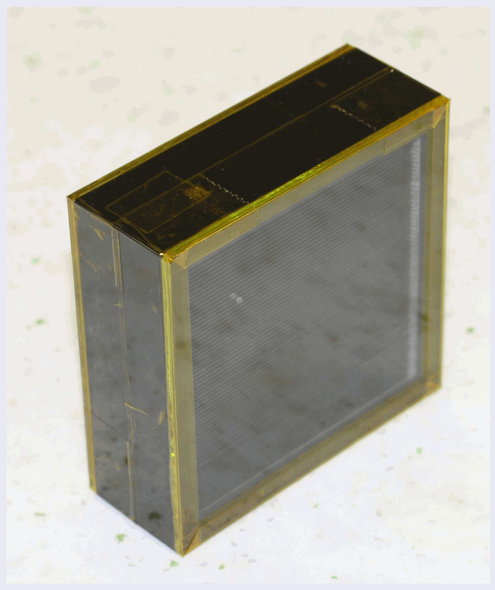
Basic one-dimensional system is composed of flat rectangular mirrors forming an uniform pattern around of a virtual cylinder of centre **C**. This set of mirrors is called stack. Point **F** represents the focus.



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

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

Prototype one-dimensional optics module



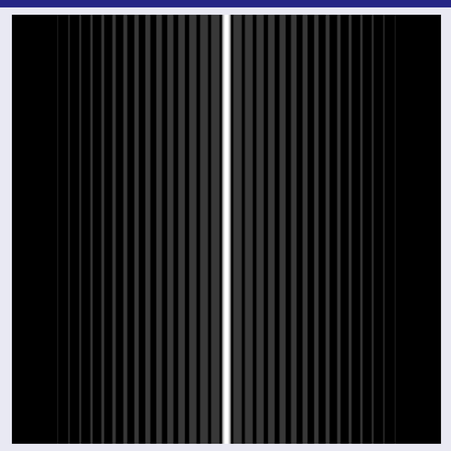
Parameters

- Focal length ***F*** = 215mm.
- Input aperture 87x84mm.
- Composed of ***N*** = 66 glass mirrors of depth ***h*** = 24mm and thickness ***t*** = 0.28mm coated with gold.
- Mirror pitch ***A*** = 1.33mm.
- Outer dimensions 95.8x95.8x26mm without external housing. It allows application on 3U or larger CubeSat.
- Intended for X-ray energy 1keV but test is possible in wider range.
- Calculated field of view 10.4°.
- Calculated effective collecting length 1.6cm at 1keV.
- Corresponding effective collecting area 2.4cm^2 for 2-D system.

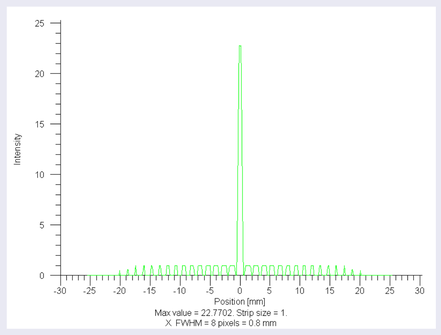
Mirrors are necessary to place to their designed positions with precision in order of microns. Therefore, the prototype is based on new technology. This technology is registered as

- Czech patent CZ 310 015 B6
- Czech utility model CZ UV 36 961
- German utility model application 20 2023 107 238.0

Simulations of full focal image



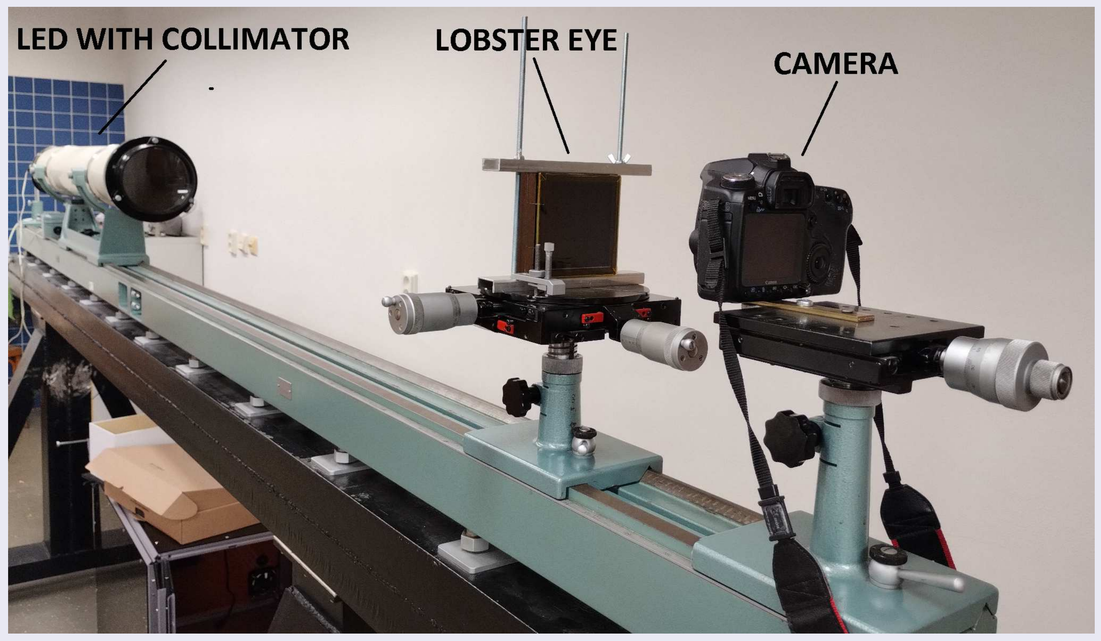
Focal image



Profile

Simulations are performed for X-rays at 1keV photon energy and detector of 5.12 $\times$ 5.12 cm of resolution 100 μm.

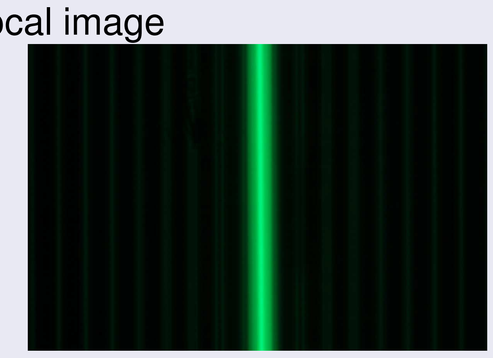
Experimental setup



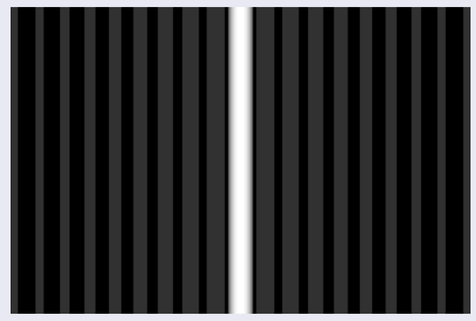
The lobster eye prototype was tested in optical laboratory of Faculty of Mechanical Engineering of Czech Technical University in Prague. Green high-power LED was used as light source. Focal length of the collimator was 1600mm. The image was taken by a camera Canon EOS 50D. This camera has a sensor of size 22.3 x 14.9mm and resolution of 4752 x 3168 pixels.

Results

Focal image

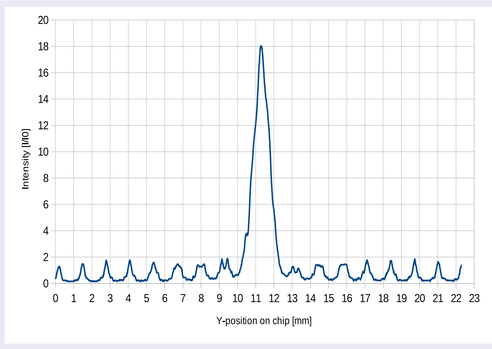


Experiment

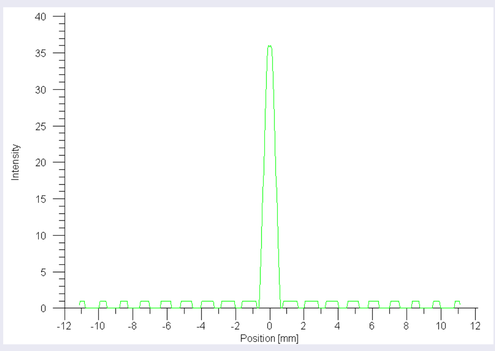


Simulation

Profile



Experiment, FWHM = 1.02mm



Simulations, FWHM = 0.71mm

Experimental image has little worse FWHM because of following reasons:

- Diffraction effects, they will not appear in X-rays.
- The light beam has same small divergency as LED chip has non-zero size. However, LED chip size is not known and therefore, it cannot be included into simulations.
- Simulation is done for mirrors of 100% reflectivity. For test in X-rays, the relevant reflectivity model will be included into the simulations.

For named reasons, vertical scales of graphs are not comparable.

Conclusions

- The prototype is operating.
- The technology is proved.
- Experimentally measured FWHM is little worse than result of ray-tracing.
- Much better results are expected in X-ray tests.

References

Simulations were done by LOPSIMUL software *www.lopsimul.eu* by simplified ray-tracing algorithm *Exp. Astron. (2016) 41:377-392; DOI 10.1007/s10686-016-9493-2*.

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