Lobster Eye Optics & Biomimetics

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We present optic designs based on biomimetic, namely technical applications of animal eyes principles (here: Lobster Eyes) for the special application of wide field X-ray imaging. Thereby we show and discuss some experimental results and correlate them with simulations. Preliminary results of an ongoing study on other strange animal mirror eyes with potential scientific and technical applications are also discussed. Some of them are based on the principle of multilayer multi-mirror active optics arrangements. The Lobster Eye X-ray optics needs special reflective coatings for a better performance, which are currently developed within the Bavarian-Czech cooperation project JEUMICO.

1 Introduction

Understanding the very specific mirror eyes of sea animals may help to design and develop special optics for scientific applications. Prominent examples are Lobster Eye optics used in space-based astronomical wide field X-ray telescopes. The knowledge of strange animal mirror eyes has also potential for other scientific and technical applications. This field is very little exploited.

In this contribution we report on a small student project with the following goals:
(i) to understand the way animal mirror eyes work,
(ii) to learn about the advantages of these eye arrangements; and
(iii) to find out, whether these optic designs can be used in advanced optical devices, especially in space instrumentation.

2 Biomimetics of sea animals in general

Astronomical optics based on Lobster Eye design will go to the space soon. The Czech nano-satellite VZLUSAT1 will be launched in 2017 and the space mission BepiColombo will follow in 2018. The VZLUSAT1 mini-satellite has an 1D Lobster Eye module with a focal length of 250 mm onboard, and is composed of 182 wedges and 90 reflective double–sided gold-plated foils (thickness 150 microns). The entrance aperture of this X-ray optics is 29 x 19 mm, the devices outer dimensions are 29 x 31 x 60 mm. The active part of the foils is 19 mm in width and 60 mm in length, and the usable photon energy range is 3 keV to 20 keV [1] [2] [3]. The optical module is shown in figure 1; simulation results of the 2D Lobster Eye optics are depicted in figure 2 [4].

Fig. 1: *The lobster eye optical module for the VZLUSAT1 Cubesat satellite [1].*

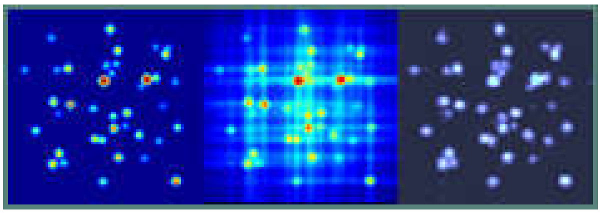

Fig. 2*: The star field (arrangement of star–like sources (left), image by Lobster eye (middle) with characteristics cross–like structures, and image after deconvolution (right).*

In nature there are also other mirror based animal eyes, mostly of sea animals as shown in figure 3. Some recent new discoveries are worth to be studied in detail for possible new technical applications.

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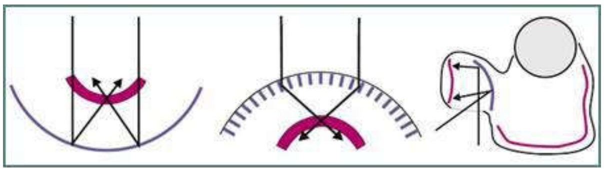

Fig. 3: Various types of sea animals mirror eyes. [5,6] and references therein.

A detailed investigation of such animal optics indicates that e.g. the eyes of lobster and crayfish act not only as imaging devices, they also provide image reconstruction respectively deconvolution in the lobster brain, an adaption to low or high levels of light, a protection against light damage, and they can even recognize polarized light.

3 Conclusion

Strange animal mirror eyes are challenging and little investigated. The new discoveries include possible multilayer, multi–mirror adjustable (active) optics in deep sea fishes. This field is worth to be studied, with potential of applications in optics/space optics, especially in low level light applications (deep sea and space). Lobster Eye optics may serve as an excellent example.

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