X/EUV and UV optics for miniature cubesats payloads

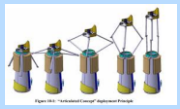
- R. Hudec, Astronomical Institute Ondrejov and Czech Technical University in Prague, Faculty of Electrical Engineering
- V. Daniel, VZLU Prague
- L. Pína , Faculty of Nuclear Science, Czech Technical University, Prague, Czech Republic
- A. Inneman, V. Maršíková, RITE, Prague, Czech Republic
- M. Urban, O. Nentvich, Czech Technical University in Prague, Faculty of Electrical Engineering
- T. Döhring, TH Aschaffenburg - University of Applied Sciences, Germany

Pico (Cube) and Nanosatellites

- Under development at many universities, mostly with involvement of students, education
- CubeSat standard size 1 liter volume i.e. 10 x 10 x 10 cm and typically 1.3 kg
- Multiple modules possible i.e. 3U = 3 modules/units
- i.e. 10 x 10 x 30 cm, typically up to 12U
- Picosatellite 0.1 to 1 kg, Femtosatellite 10-100 g, Nanosatellite 1-10 kg, Microsatellite 10-100 kg
- Recent technological progress allows use in astronomy and astrophysics

Why optics on Cubesats?

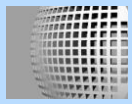
- In scientific imaging instruments, optics improves the signal-noise ratio
- This means small focal detector and hence smaller-lighter instrumentation if compared with instruments without optics use (e.G. coded masks)
- For minisat applications, the optics must be miniature …. hence need for sophisticated solutions such as improved reflectivity and increased effective area without increasing its size and weight
- The same for focal detector
- Alternative: deployable (i) optics (ii) payload length
- But: total weight is also an issue
- Cost factor (cubesats are typically low cost missions)



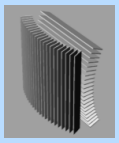
Cubesats optics requirements

- Small size typically aperture <10 cm, or deployable
- Lightweight
- Low cost
- High collecting/effective area within the size limits
- Able to survive in space environment (temperature cycles, vacuum, radiation)
- Able to survive launch (vibrations etc.)
- Lifetime > 2 years (e.G. Brite)
- TRL requirements are not so strict as for large satellites

Lobster-Eye (LE)



Angel design



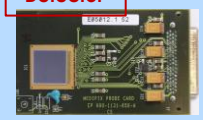
Schmidt design

- Novel wide field x-ray telescopes
- FOV of 100 sq. Deg. And more easily possible (classical x-ray optics only 1 deg or less)
- Analogy with lobster eyes

LE Telescope for Picosatellite

Tests of LE X-ray optics & Medipix detector at 8 keV

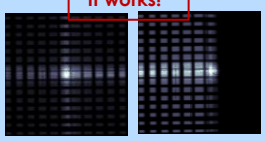
Detector



CTU Prague member of Medipix Collaboration

Optics

It works!



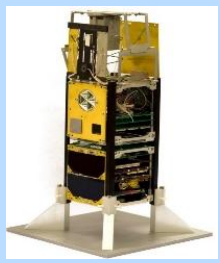
Feasibility study of small LE X-ray telescope for Picosatellite

LE f=25 cm, L=30 cm

Based on UWE concept, University of Würzburg, DE
LE module: F=25 cm,L=30 cm
Picosatellite 10 x 10 x 30 cm
Technological experiment but still some science

VZLUSAT-1 mission in space since June 23, 2017 launch … still in operation

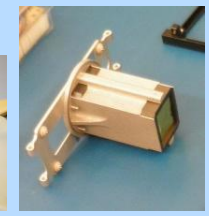
- Objective: development, manufacturing, qualification and experimental verification of products and technologies in Earth orbit (TRL increase)
- Main goal: verification of wide-field optical system for X-ray monitoring in energy range 3 - 40 keV which is based on Lobster Eye (LE) optics and Timepix detector
- Czech 2U CubeSat mission
- Launch in 2016 within QB50 mission

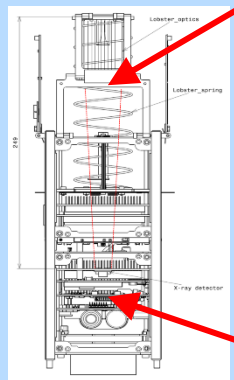


The devices with low TRL (Technology Readiness Level) are not accepted by space agencies …. This is why it is so difficult to use innovative technologies in space

Lobster Eye X-ray optics for VZLUSAT-1

- 1D Lobster Eye module with focal length 250 mm
- Composed of 182 wedges and 90 reflective double-sided gold-plated foils (thickness 150 μm)
- Input aperture: 29x19 mm, outer dimensions: 29x31x60 mm
- Active part of the foils: 19 mm in width and 60 mm in length
- Energy range 3 to 20 keV





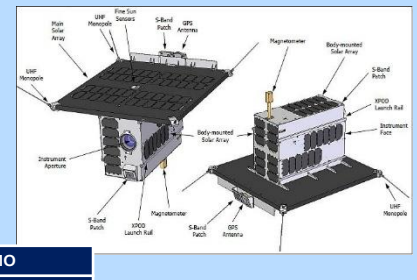
Lobster eye optics

- 250 mm focal length
- 4 - 20 keV energy range
- Pantograph based mechanism for the optics deployment
- X-ray beam goes through 5 other electronic boards

Timepix board 3

BRITE CZ X-UV - 16U CubeSat

Cubesat specification



	NEMO
Spacecraft Mass	15 kg
Spacecraft Volume	20 x 20 x 40 cm
Peak Power 25°C,BOL	50 W
Payload Mass	6 kg
Payload Volume	8,000 cm^3
Payload Power @ duty cycle	45 W @ 40% min, 65 W max
ACS stability	~2° (2) ~60" (3)
Downlink	32 k - 2 Mbps
Examples	NEMO-AM, GHGSat-D, NORSAT-1

Extending the BRITE network spectral coverage from VIS to UV and X-rays

UV LDS (Low Dispersive Spectroscopy) camera as Picosatellite payload (UV BRITE)

Motivation

- Does one can miniaturize UV telescope/camera as payload for small satellites? Miniature but still providing scientific results?
- Case study for BRITE CZ
- The UV-BRITE payload is the miniature UV spectrographic camera, significantly upgraded camera system which was used by NASA in Gemini 10, 12 and Skylab UV experiments led by Prof. Karl G. Henize

Configuration

- 3U to 8U cubesat
- Deployable mechanisms to extend length
- UV lens or folded reflector
- Aperture 3 to 10 cm
- Focal detector sCMOS detector
- eg e2V1 CIS101-00-*-M05 chip. This device has 1415 (H)×1430 (V) pixels each 14.81 μm×11.53 μm in size
- Objective prism or grating for spectroscopy

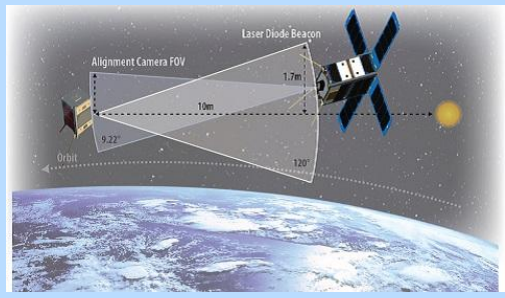
Recent News:

- Platform miniaturization…fast progress.. but what about payload miniaturization?
- Formation flying and fleets of cubesats (already available for non astrophysical, mostly commercial, applications)

Cubesats pair formation flying

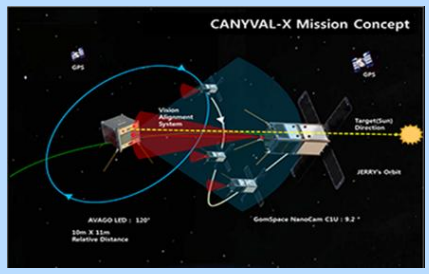
The CANYVAL-X (CubeSat Astronomy by NASA and Yonsei using Virtual Telescope Alignment eXperiment) mission will feature a pair of small satellites flying as a tandem telescope, one carrying the optics and the other carrying the detector
https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/canyval-x

Based on recent progress in control engineering … but the accuracy need to be tested



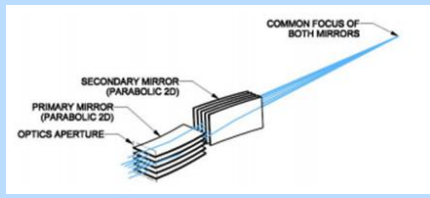
Tandem cubesats: coronagraph principle

Flying in formation allows one satellite to block a celestial target from the point of view of the other satellite. This coronagraph will enable astronomers to study objects close to a bright source, such as exoplanets near bright parent stars or the Sun's elusive corona.



Tandem flights with X ray Optics

- Perfectly suited for X-ray optics with large focal distances e.g. Kirkpatrick Baez (KB) Optics
- 1st cubesat with KB module, 2nd with suitable detector e.g. Timepix



2nd cubesat detector

1st cubesat KB optics multiply nested to achieve high effective area inside small aperture

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