Current Status of Aurwatch-OWL Optics

ABSTRACT

The current status of the OWL Optical Design is discussed, and the results of a trade-off study are presented.

Current Status of Airwatch-OWL Optics

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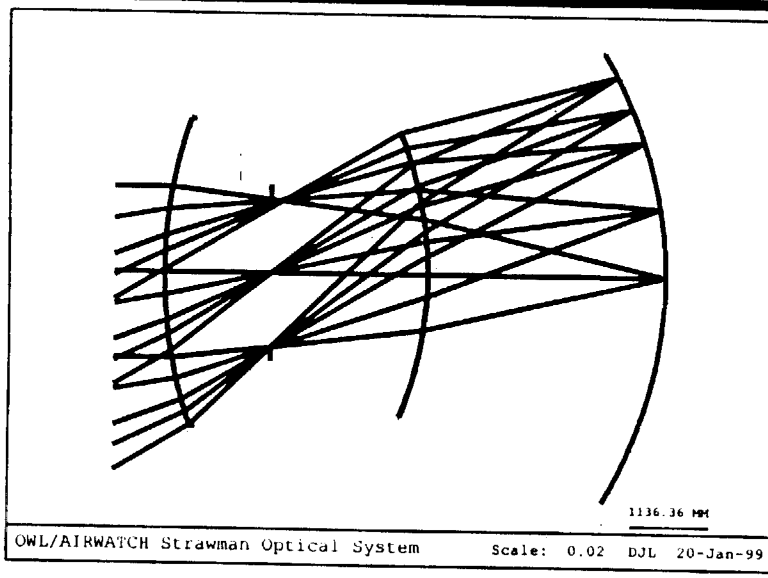
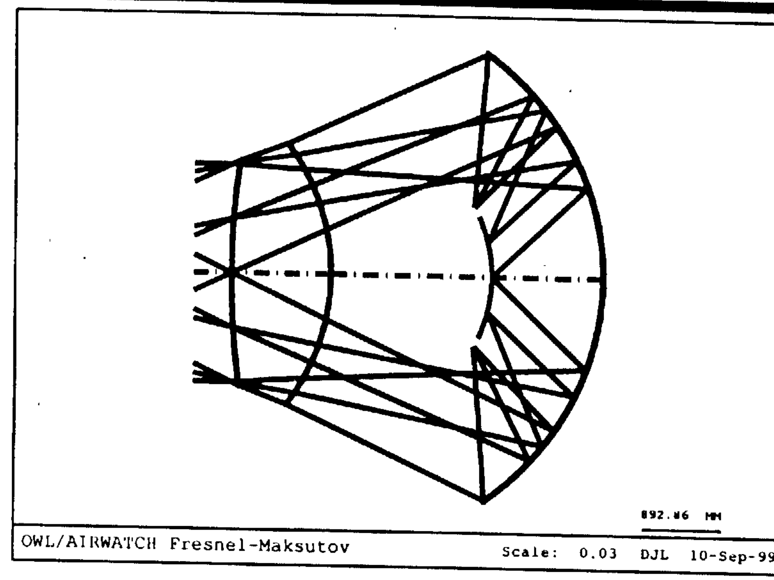
The OWL Mission Optical Requirements

- Estimated Flux of $2x10^{20}$ eV Cosmic Rays
  - →1 event per km^2 per steradian per 1000 years
  - →100 events/year => 250,000 km^2 must be observed

- Optical System Requirements
  - →Resolve 1 km^2 on the ground
  - →Large Field of View (60 degrees at 500 km orbit)
  - →Large Entrance Pupil (~2.5 meters at 500 km orbit)
  - →Signal is N_2 fluorescence (337, 357, and 391 nm)

Previously Considered Systems





- Double Fresnel Lens
  - → f/2.3
  - → 60° Field of View
  - → Back-cut losses
- Maksutov-Fresnel Hybrid
  - → f/0.6 (Decreased focal surface)
  - → 50° Field of View
  - → Back-cut *and* obscuration losses

Comparison of System Parameters

Parameter	Double-Fresnel Lens	Maksutov-Fresnel
Entrance Pupil Diameter, EPD (m)	2.5	3.5
Orbit Height, h (km)	500	605
Angular Resolution, (°)	0.1	0.08
Focal Length, f (m)	5.73	2.1
Image Pixel Diameter, d (mm)	10	2.9
Maximum Element Diameter (m)	4.48 (Lens) 6.62 (Detector)	7.18 (Mirror)

System Characteristics

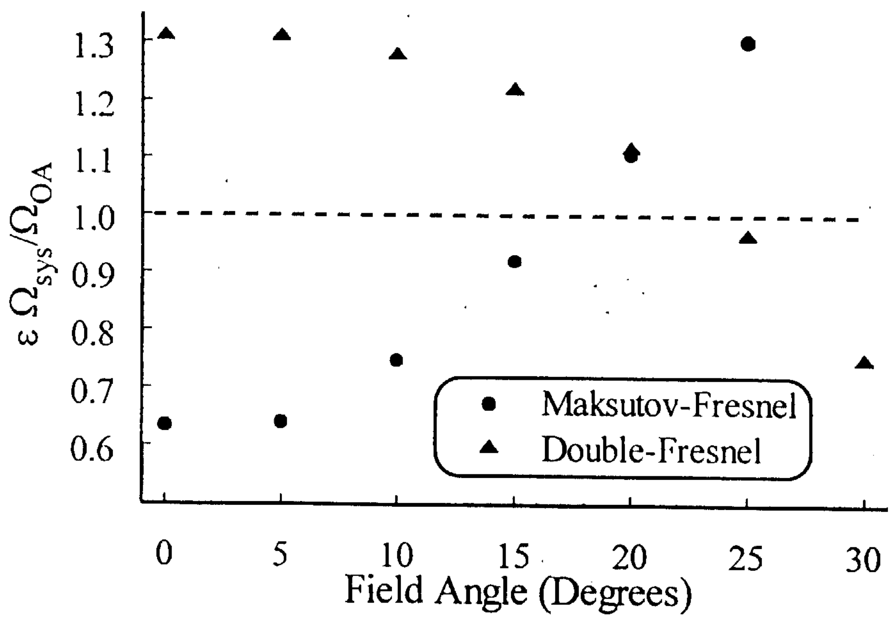
Double-Fresnel

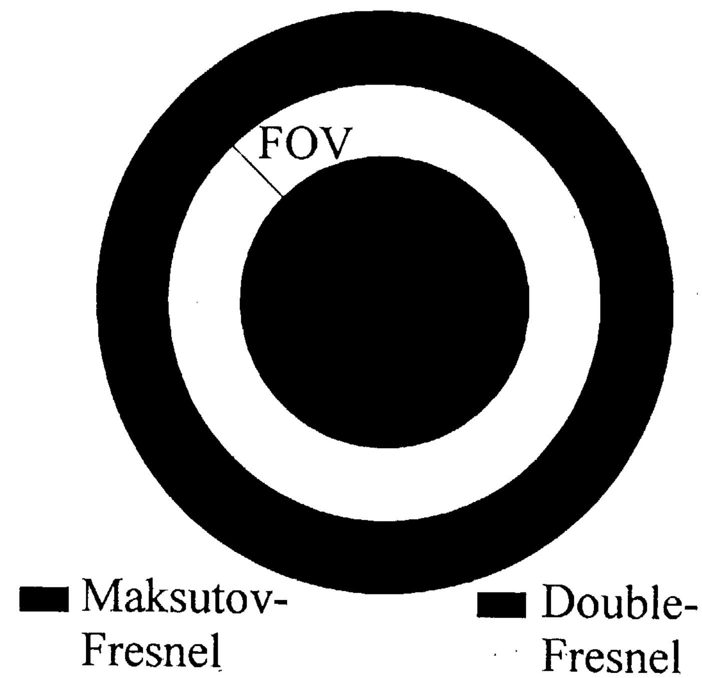
- Pro
  - → Two optical elements
  - → No central obscuration
  - → Reasonable angular distribution at focal plane
- Con
  - → Large focal surface
  - → Chromatic aberration limits the performance

Maksutov-Fresnel

- Pro
  - → Small f/# results in small focal surface
  - → Corrected for all wavelengths
- Con
  - → Central obscuration requires large entrance pupil
  - → Large angular distribution at the focal surface (result of small f/#)
  - → Large, aspheric mirror

Instrument Sensitivity





- Sensitivity relative to a "standard" OA system
- ε = optical efficiency
- Supersensitive fields of view
- Hybrid aperture scaled such that areas are the same

Baseline Optical System Performance

- Baseline collection solid angle is that subtended by a 2 meter, unobscured aperture at 500 km.
- Require 62.5% of FOV to be "supersensitive" (i.e., must collect and transmit more light than that collected by the baseline aperture).
- Initially, the three emission wavelengths (337, 357, and 391 nm) are weighted equally.

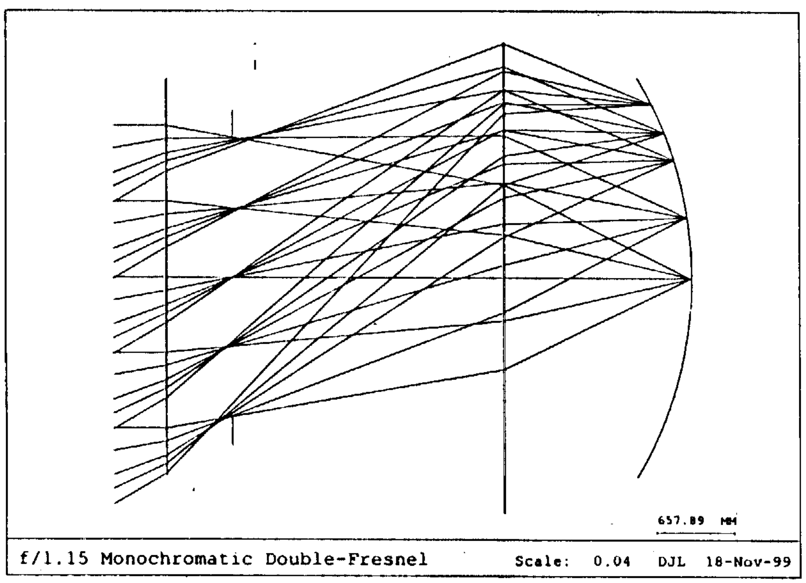
Research Goals and New Developments

- Goal 1: f/# reduction of the Double-Fresnel design.
- Goal 2: Investigate the trade-offs of FOV reduction with an increase in f/# in the Fresnel-Maksutov design.
- A new design technique employs diffractive optics to improve the performance of the Double-Fresnel system.
- Need to identify the technology necessary to manufacture the different systems.

Spectral Data

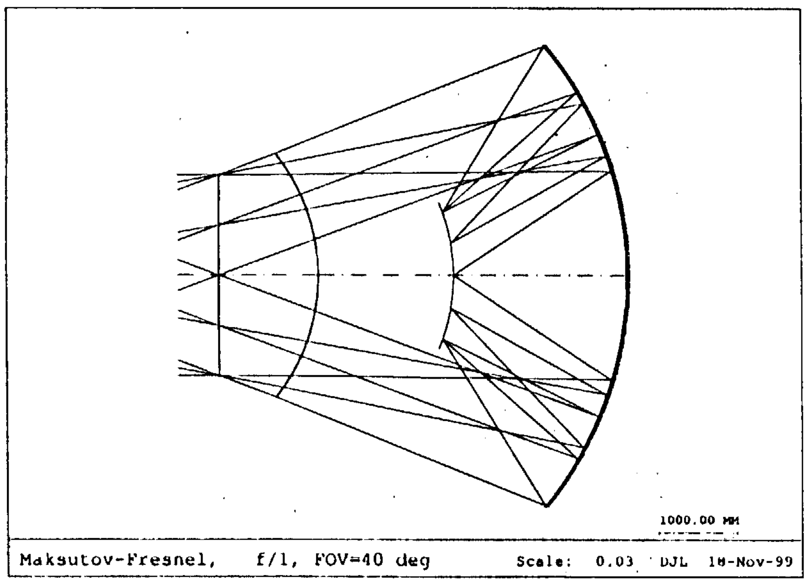
- BABY II Emission and Transmission Data (including effects of ozone transmission)
  - →391 nm -- 56.8% (67.6%)
  - →357 nm -- 26.5% (21.5%)
  - →337 nm -- 16.7% (10.5%)
- Does not account for losses in the lens material which will further favor transmission of the 391 line
- Data indicates that a quasi-monochromatic design may be feasible

Monochromatic Double Fresnel Lens System



- Flat Fresnel lenses make this system easier to manufacture.
- Near-telecentric design provides more uniform sensitivity.
- Designed to match hypothetical 6mm pixels.
- Maximum element diameter is less than 4 meters.

Reduced FOV Maksutov-Fresnel System



- Reduced FOV requires an increase in the orbit height (to ~ 800 km).
- Increase in f/# (to f/1) improves the angular performance across the focal surface.
- Requires an aspheric mirror which is 7 to 8 meters in diameter.

Diffractive Optics and a Return to Re-imaging Optics

- Re-imaging optics enable the size of the focal surface to be reduced.
- Previous attempts resulted in bulky and massive optics.
- The performance can be improved while system mass reduced through the use of diffractive optics.
- A design study has been initiated in which the optics are precisely matched to the detectors via diffractive optical elements.

Conclusions

- The scientific objectives of the mission determine the optical specifications of the system.
- Several design approaches exist for the optics.
- Current manufacturing technologies favor the Double-Fresnel lens design.
- More information regarding detector size, configuration, and sensitivity is required to select the best design.