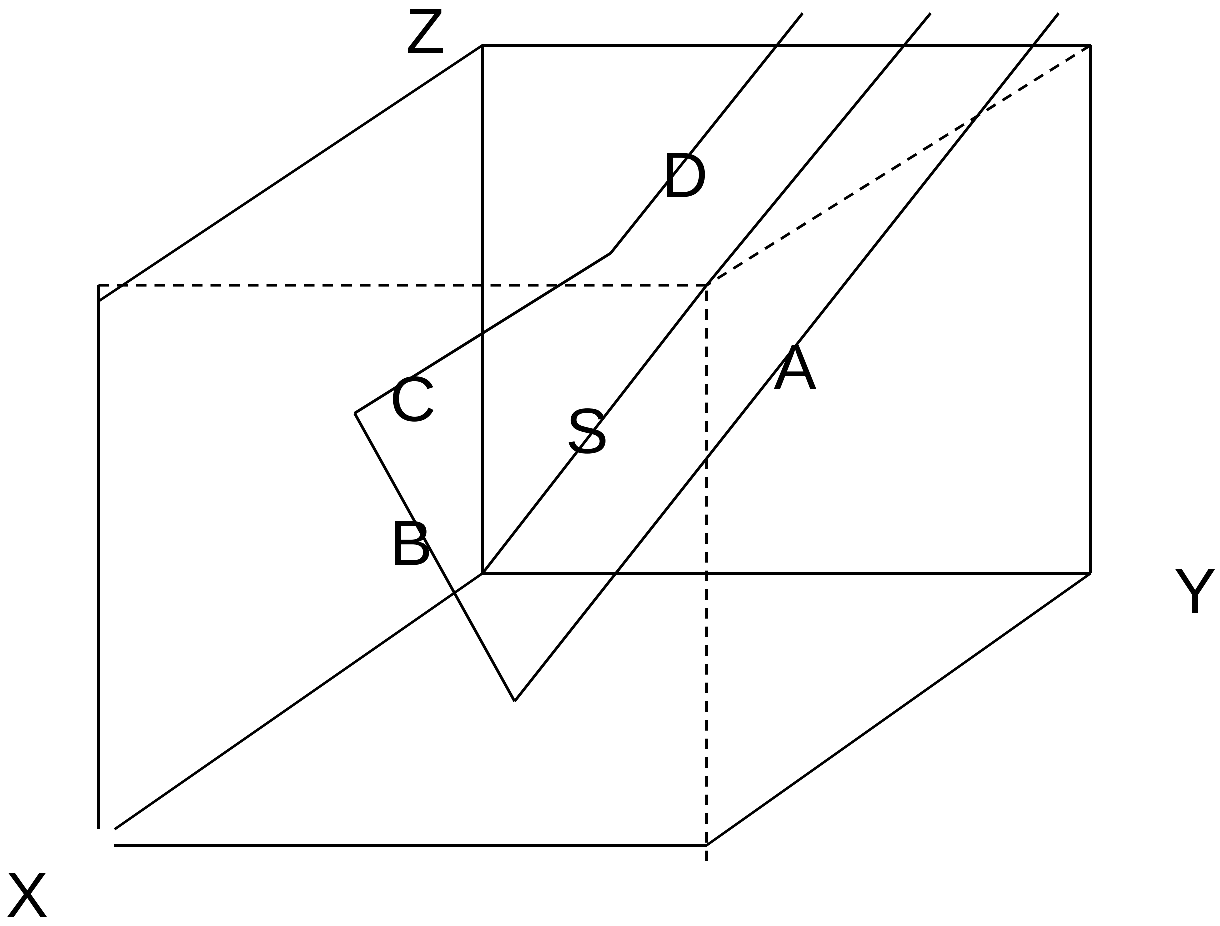
Optical Design of Lares Retroreflector Array

- 1. Introduction
- 2. Retroreflection
- 3. Diffraction pattern of cube corner
- 4. Lares cross section
- 5. Effect of thermal gradients
- 6. Velocity aberration
- 7. Range correction
- 8. Asymmetric reflectivity
- 9. References

1. Introduction

- Sphere with high mass to area ratio
- Covered uniformly with retroreflectors
- Design similar to Lageos
- Uncoated cubes corners for thermal reasons
- Dihedral angle offset of 1.50 arcsec to account for velocity aberration

2. Retroreflection



A retroreflector with three square orthogonal mirrors.

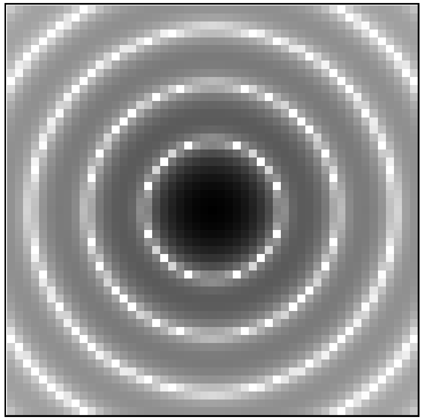
Retroreflection

- A retroreflector consists of 3 perpendicular mirrors
- Each reflection reverses one component of the velocity vector with components Vx,Vy,Vz.
- After three reflection the components of the velocity are -Vx,-Vy,-Vz so the light is traveling back to the source.
- Light enters along line A and is reflected from the X-Y plane. It travels along line B and is reflected from the X-Z plane. It travels along line C and is reflected from the Y-Z plane. Line D is the retroreflected ray
- The ray S to the vertex is equidistant between the incident line A and the reflected line D

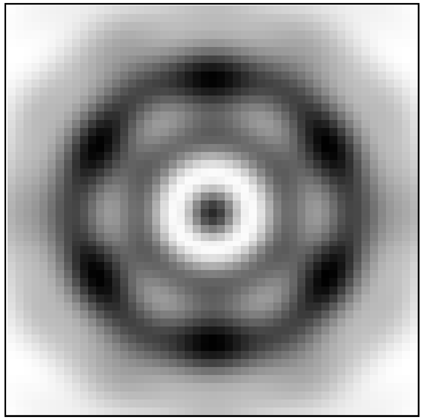
3. Diffraction patterns

- As a result of diffraction effects the beam spreads as it returns to the source
- The cross section of Lares is the sum of the diffraction patterns of all the active cube corners
- The position of the receiver in the diffraction pattern depends on the magnitude and direction of the velocity aberration

Coated cube corner

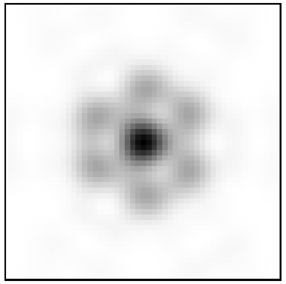


No dihedral angle offset

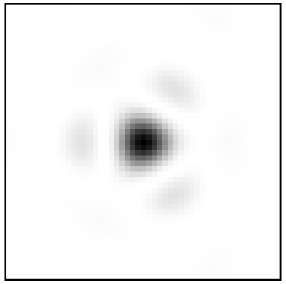


Dihedral angle offset

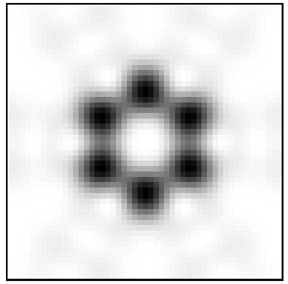
Uncoated cube corner
No dihedral angle offset
Circular polarization



Total energy

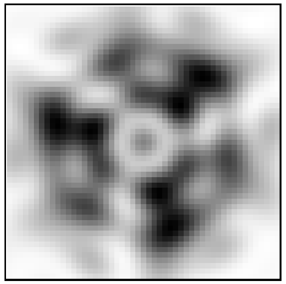


Parallel

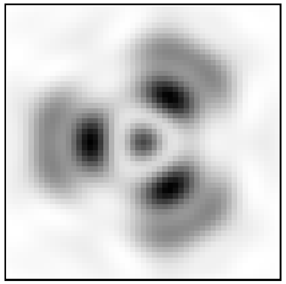


Orthogonal

Uncoated cube corner
Circular polarization
Dihedral angle offset 1.25”



Total energy



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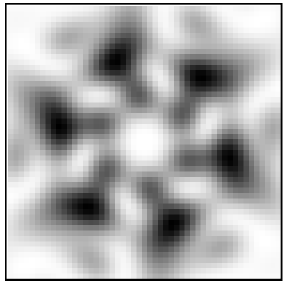
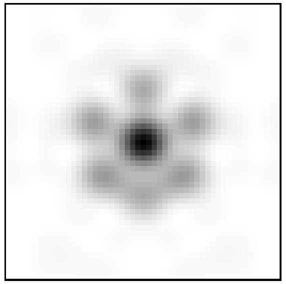
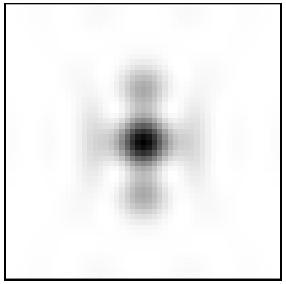


Orthogonal

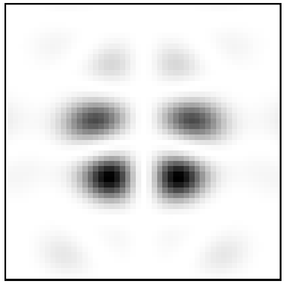
Uncoated cube
Linear Vertical Polarization
No dihedral angle offset



Total energy

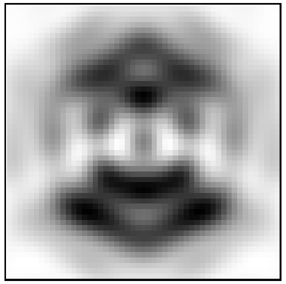


Parallel

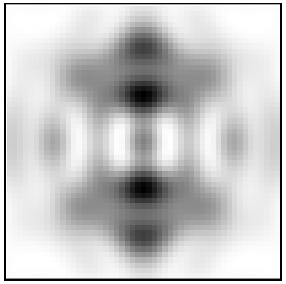


Orthogonal

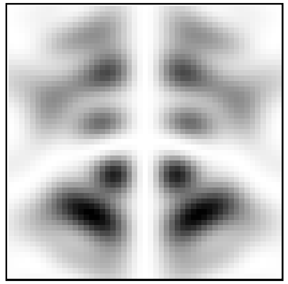
Uncoated cube corner
Linear vertical polarization
Dihedral angle offset 1.15”



Total energy

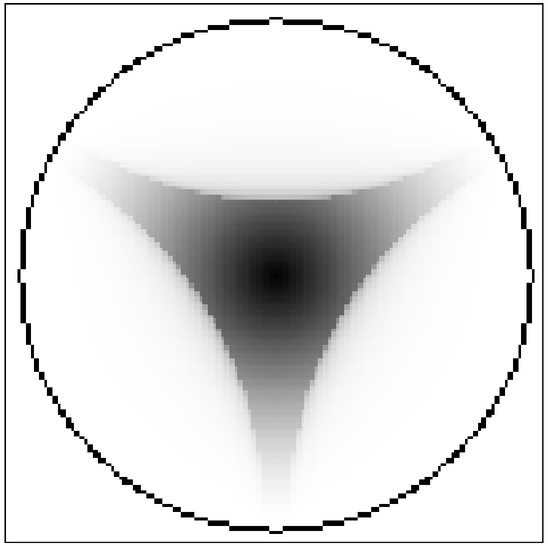


Parallel

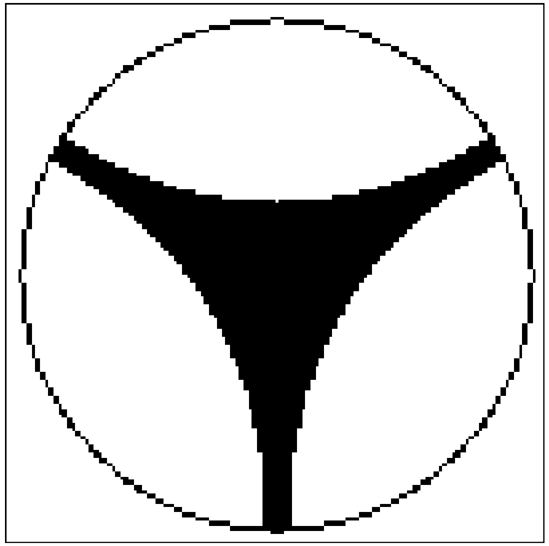


Orthogonal

Loss of total internal reflection



Energy



Region where TIR is lost

The coordinates are the direction of the incident beam

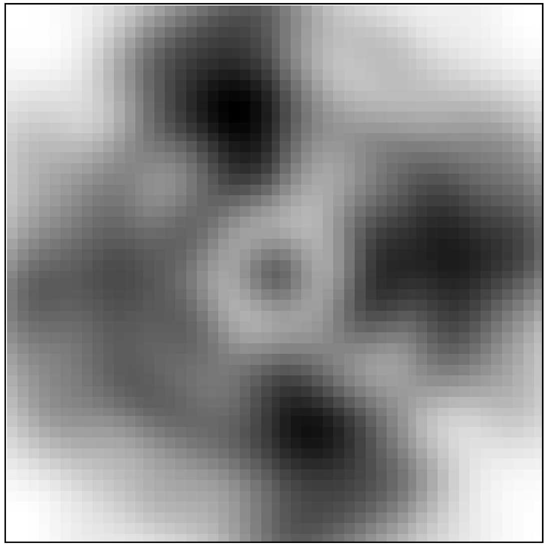
The radial distance is the angle from the normal (colatitude)

The azimuthal coordinate is the longitude of the incident bean

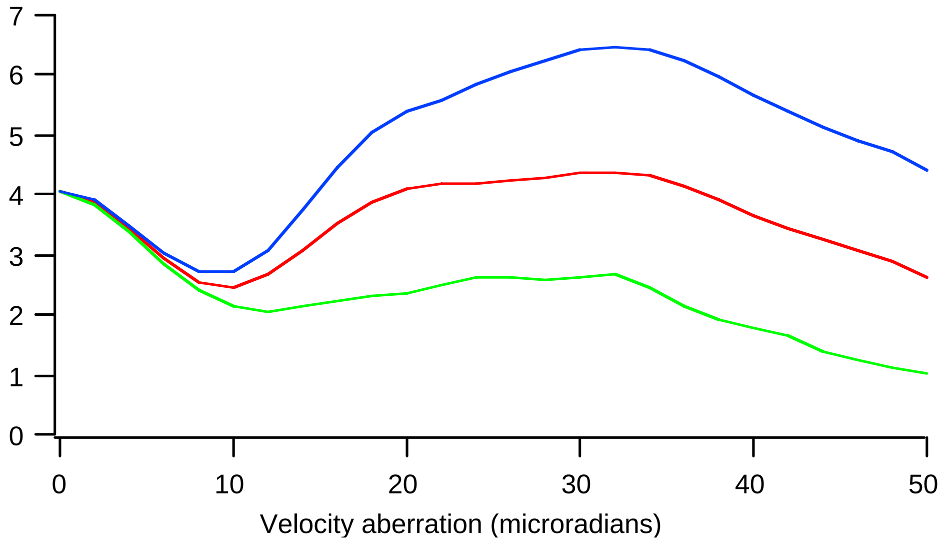
4. Lares Cross section

- The cross section is proportional to the intensity of the array diffraction pattern
- The array diffraction pattern is the sum of the diffraction patterns of all the cube corners.
- The cross section has been computed for various configurations and incidence angles

Sample cross section matrix



Average cross section vs Distance from the center



Red = average around a circle

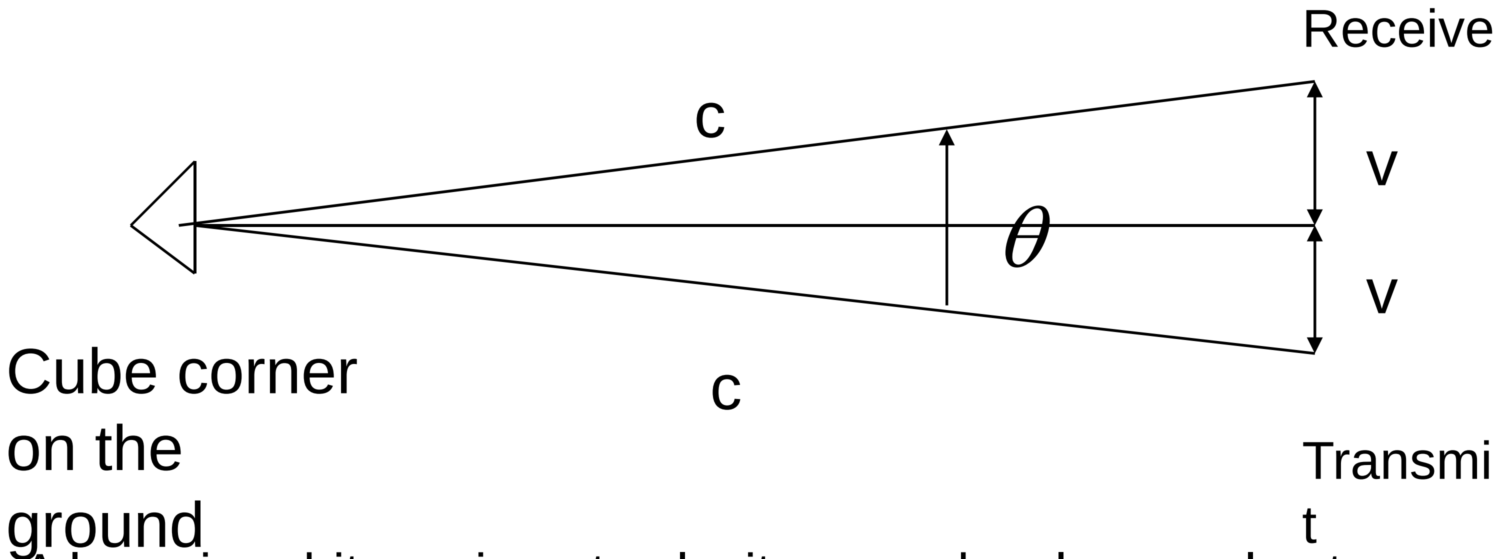
Blue = maximum around a circle

Green = minimum around a circle

5. Effect of thermal gradients

- Index of refraction of quartz depends on temperature
- Temperature gradients change the optical path length and distort the diffraction pattern
- The modeling is complex and the physical parameters uncertain
- Thermal vacuum testing needed

6. Velocity Aberration



A laser in orbit moving at velocity v sends a laser pulse to a retroreflector on the ground. The retroreflector returns the beam to the transmit point. The beam pattern of the cube corner has to be wide enough to reach the satellite which has moved a distance proportional to 2v. If the laser is on the ground the retroreflector returns the beam along the same line in its inertial coordinate system. This results in the same velocity aberration given by the equation

$$\theta = 2\frac{v}{c}$$

7. Range correction

- Range correction is the average position of the active cube corners on the satellite weighted by the signal from each cube corner
- The cube corners are distributed as uniformly as possible to minimize variations as the satellite spins.
- Range accuracy of Lares is about 3 mm

8. Asymmetric reflectivity

- If a ray entering the cube corner is reflected from all 3 reflecting faces the ray is retroreflected
- If the ray is reflected from only 1 or 2 of the reflecting faces the ray is deflected in some other direction
- Rays that are not retroreflected produce a momentum component perpendicular to the direction of the incident beam
- The effect is like wind on a sail

9. References

- 1. Method of Calculating Retroreflector Array Transfer Functions
- 2. Optical and Infrared Transfer Function of the Lageos Retroreflector Array",
- 3. Retroreflector Array Transfer Functions
- 4. Asymmetric radiation pressure on Lageos
- 5. Retroreflectors and satellite laser