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THE POLARIZATION BEHAVIOUR OF CUBE CORNER RETROREFLECTORS USED IN SLR SATELLITES

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INTRODUCTION

We have investigated new techniques to perform distance measurements between the SLR station and a satellite, and among them one requires to know the change of polarization of a laser beam due to the reflection on a cube corner retroreflector (CCR). This paper relates the results, both theoretical and experimental, that may help to understand the effect of CCR. The situation is considerably complicated by the fact that the CCR used in geodetic satellites have no reflecting coating on the back faces, so as to avoid CCR whose front face are far from the laser direction (typically more than 20E) of being active. In this case, the successive reflections on a dioptre not far from the limit angle induce a strong additional ellipticity (which is not the case with metallic coatings). Thus we have computed what happens for (i) a linear polarization and (ii) a circular polarization at various incidence angles, and we have checked some results with limited experimentations : The discrepancies are very limited, but we have not been able to find a good explanation for them.

POLARIZATION OF THE LIGHT AND TOTAL REFLEXION ON A DIOPTRE

If we consider the electric field **E** of an electromagnetic wave, **E** is perpendicular to the direction of propagation, and for its components E_x and E_y, a comprehensive way to describe the polarisation will be to use the 4 Stokes parameters (2) :

$$s_1 = E_{ox}^2 + E_{oy}^2$$
$$s_2 = E_{ox}^2 - E_{oy}^2$$
$$s_3 = 2\ E_{ox}\ E_{oy}\ \cos(\Delta_y - \Delta_x)$$
$$s_4 = 2\ E_{ox}\ E_{oy}\ \sin(\Delta_y - \Delta_x)$$

with :

$$E_x = E_{ox}\ .\ \cos(\omega t - \Delta_x)$$
$$E_y = E_{oy}\ .\ \sin(\omega t - \Delta_y)$$

The interaction with a dioptre may be modelled by the so-called Mueller matrix (ref. 1 et 2), acting on the Stokes parameters, the main computation problem being to check carefully the reference frame changes between each reflection. We have chosen to display the results on the Poincaré sphere, on which :

- The latitude angle is the Arctg of the ellipticity.

- The longitude is the orientation of the main axis of the ellipse.

For example the two circular polarisations are the two poles, and on the equator we find linear polarisations.

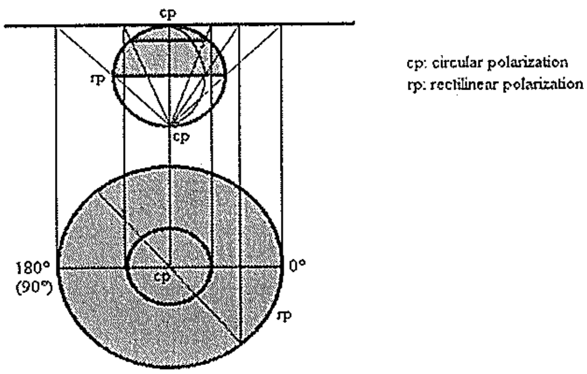


Figure 1 : Polar stereographic projection of the Poincaré sphere

The results of our computations are displayed using a polar stereographic projection, generally limited to the upper hemisphere : the largest circle represents the equator and thus, linear polarisations, and the central point represents the upper ("North") pole and thus a circular polarisation.

THEORETICAL COMPUTATIONS

We have first defined a reference frame linked to the RCC, each of the Ox, Oy and Oz axis being the intersection of two reflecting faces. The optical problems due to the crossing of the front dioptre have been neglected, as the incidence angles are low and the induced additional ellipticity seems very small.

The direction of the incident ray is provided through 2 angles :

- The angle between the incidence plane, normal to the front dioptre, and a reference plane (including Ox) also normal to the front dioptre : the azimuth.

- The angle, within this incidence plane, between the incident ray and the normal to the front dioptre : the angle of incidence.

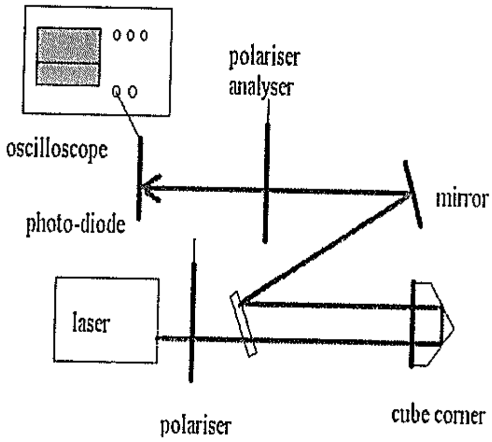
For each situation, we have six possible enchainments of faces, that are never commutative. The only simplifications of a systematic analysis of all directions are, in circular polarisation :

- a 120E rotation on the azimuth reproduces the same pattern,

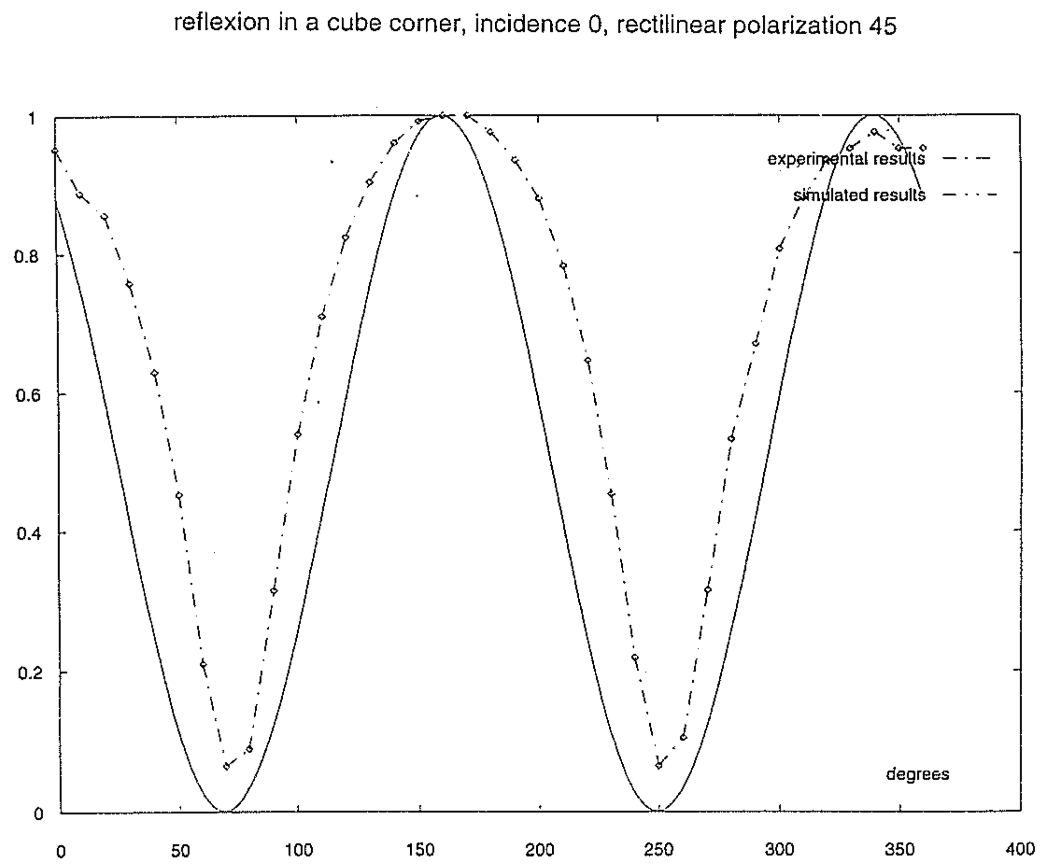
- a symmetry relative to each of the three planes normal to the front dioptre and containing Ox, Oy or Oz provides a symmetric pattern.

The computations have been performed in C language, on a workstation, and some experiments have been performed in order to check the results. The one presented here (Fig. 3) is with a zero "incidence" and "azimuth" angles, in linear polarisation with the polarisation plane at 45E, 65E, 90E and 135E from the incidence plane. The experimental and theoretical curves (obtained by rotating a polarizing plate from 0 to 360E on the exit ray, the abscissa of the plot) show a small discrepancy that we could not explain completely, but which is not critical. The experimental device is the following (Fig. 2) :

Figure 2 : Experimental device for a null incidence over the front plane of a glass CCR



We present here the curves for 45° (Figure 3) :



RESULTS, AND CONCLUSIONS

Two series of results are proposed (next page), the first for an entering ray in circular polarisation, the second with linear polarisation. In each case the azimuth is given, the incidence angle varies from +13° to -13° (larger angles are useless because one of the reflections is no longer total).

The six enchainments of faces are always presented, but one has to remember that with SLR, in order to cancel the aberration due to the relative movement of the satellite and the station, all CCR are spoiled so that only one enchainment of faces is used at a time, for applications where the far field only is useful. But it is clear that in static applications, the six enchainments of faces produce a set of six different images where it generally does not exist any pair having exactly the same polarisation. This is an interesting optical situation as, on another hand, these six images are theoretically in the same wave plane.

When the incidence angle is low, the major conclusion is that **one enchainment of faces behaves not far from a quarter-wave plate**. But this is just a coarse approximation, and everyone may see that results vary very quickly in some geometric configurations.

We present here a large number of representations, under various situations. The main conclusion is that not metalled CCR are providing extremely complicated polarisation patterns in general. For SLR applications, we are lucky that only one enchainment of faces is simultaneously active. Nevertheless our results mean that it is not advisable to use laser modulation based upon polarisation modulation, as just a small variation of the incidence (which is impossible to control) creates strong modifications of the resulting polarisation.

Thus we propose to continue experiments with long laser pulses, modulated at a very high frequency, in a quasi-continuous mode, but with devices where polarisation of the return beam is not critical.

BIBLIOGRAPHY

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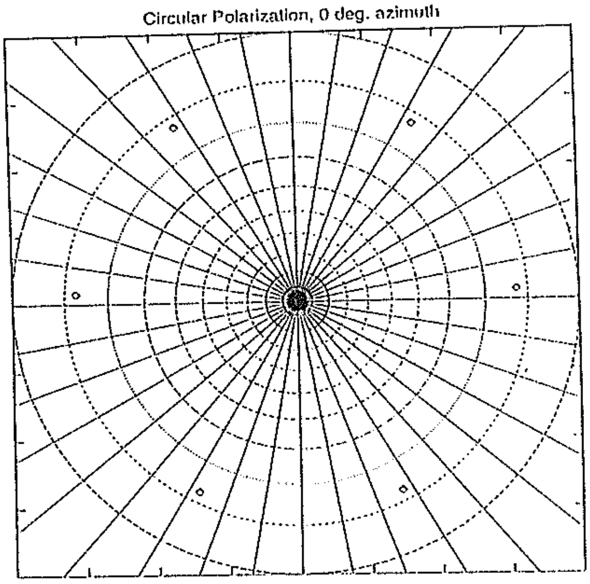
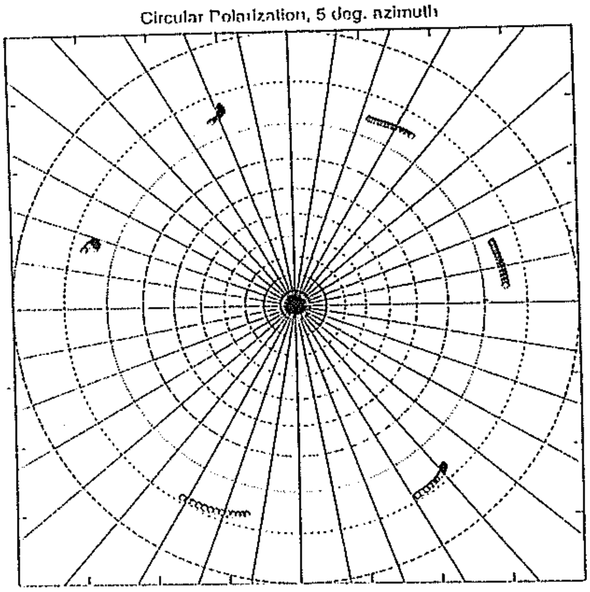
(2) **Clarke D., Grainger J.-F. 1971**. Polarised light and optical measurement, Pergamon press

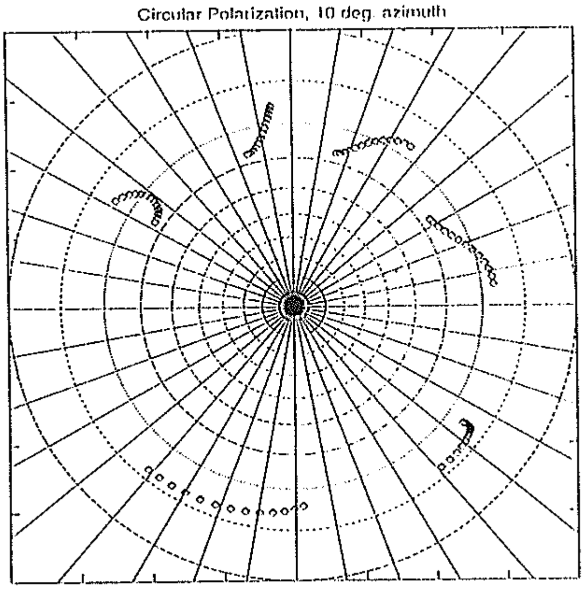
Circular Polarization, 0 deg. azimuth



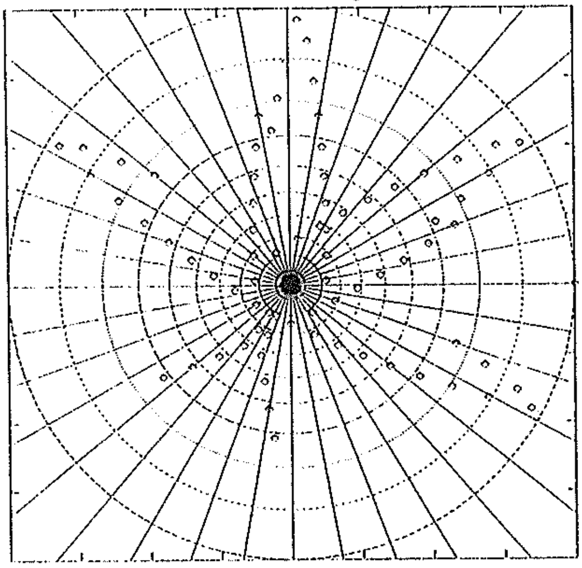
Circular Polarization, 5 deg. azimuth



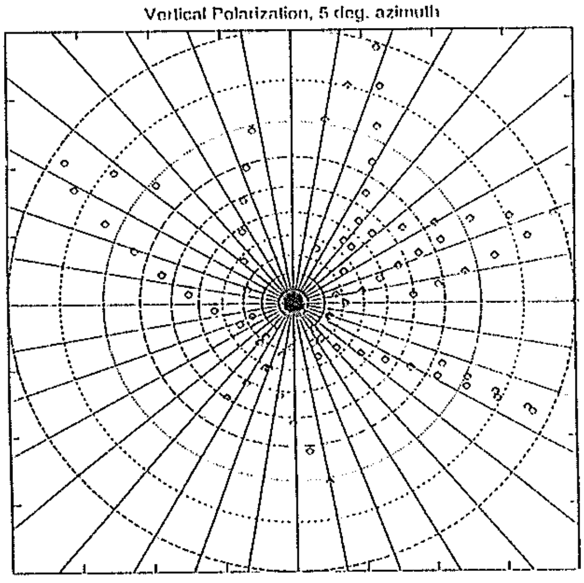
Circular Polarization, 10 deg. azimuth



Vertical Polarization, 0 deg. azimuth



Vertical Polarization, 5 deg. azimuth



Vertical Polarization, 10 deg. azimuth