

Calculation of dielectrophoretic potential generated under illumination patterns on x- and z-cut LiNbO_3 ; application to photovoltaic particle trapping

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Summary

The dielectrophoretic potential generated near the surface of a z-cut LiNbO_3 by photovoltaic charge transport has been calculated for first time. The procedure and results are compared with the ones corresponding to x-cut. Differences in the position, sharpness and time evolution are reported, and their implication on particle trapping are discussed.

Introduction

Trapping of micro- and nanoparticles on surface of photovoltaic crystals by illumination (often known as optoelectric tweezers) is an innovative issue with basic and technological implications. Charged particles are directly attracted by the electric field generated in the crystal (electrophoresis), and non charged particles are polarized and also attracted by the field by dielectrophoresis (DEP) [1]. So far only x-cut Fe:LiNbO_3 had been used for dielectrophoretic trapping [1, 2, 3, 4]. Only recently, neutral particles have been successfully trapped on the surface of z-cut Fe:LiNbO_3 with diverse 2D patterns [5].

In this work, calculation of the dielectrophoretic potential near the surface of illuminated crystal in x-cut is presented. Similar work has been recently developed for x-cut crystal [6]. However, the geometry of the charge transport in z-cut produces several differences in the calculation procedures as well as in the resulting attractive patterns.

Calculation procedure

In order to obtain the DEP potential near the crystal surface, a former calculation of the charge transport inside the crystal is needed. To this end, the time evolution of the internal electric field is calculated in each point of the crystal surface by integration of the Kukhtarev equations. In z-cut geometry charge separation occurs perpendicular to the surface. This produces a surface charge distribution in both faces of the sample

Once the surface charge is determined in each point, the electric field outside the crystal is calculated as explained in [6]. The results for sinusoidal light patterns with high modulation ($m = 0.95$) are shown below.

Time dependence

Since LiNbO_3 has a saturable photovoltaic effect, time exposition plays an important role. Fig. 1 shows the electrophoretic potential near the surface at different times, being τ the characteristic time for the kinetics of the photovoltaic field build-up. Distance to the

surface is $\Lambda/100$ being Λ the light pattern wavelength. At short times, potential shows a sinusoidal shape, with high contrast but low depth, which should produce a weak particle trapping at potential minima. As time increases, the depth of the minima also grows. For time $t \sim 4\tau$ potential well begin to broaden. For much longer times contrast vanishes and homogeneous trapping should occur. Unlike the x-cut, when saturation happens, the surface becomes equally charged. Consequently homogeneous trapping should occur, without any pattern.

Trapping position and distance dependence

Fig. 2 shows the electrophoretic potential at different distances from the crystal in both z-cut and x-cut. In order to maximize the trapping contrast, illumination time is chosen $t = 10\tau$ for z-cut and $t \rightarrow \text{inf}$ for x-cut. The most noticeable difference between them is a phase shift of the potential minima. In x-cut minima appears in the darker areas whereas in z-cut the potential minima are located on the maxima of light intensity. Therefore the traps for particles are in different position with regard to the light pattern.

The second difference is a stronger decay of the potential with the distance to the surface in z-cut configuration. This difference should not affect the strength or sharpness of the particle trapping. Anyway a shorter extent of the dielectrophoretic effect could turn into a lower amount of particle trapped in low particle density media.

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References

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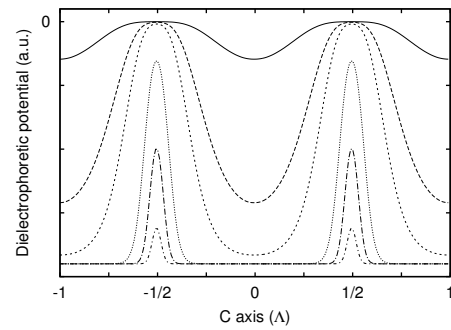


Fig 1. DEP potential in z-cut LiNbO₃ for $t = \{0.5, 2, 4, 20, 100\}\tau$ (descendig plot in graph)

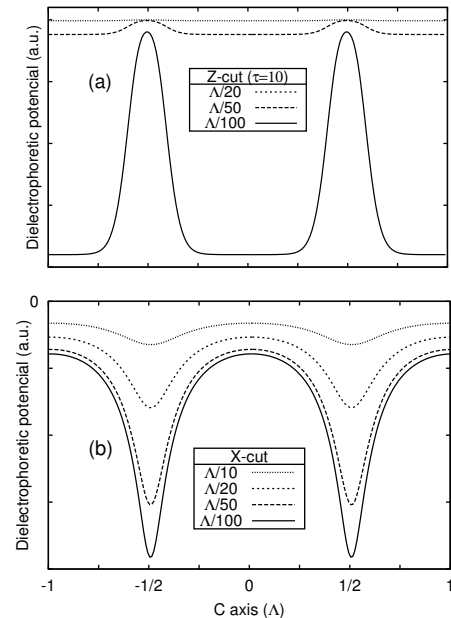


Fig 2. DEP potential at various distances of (a) z-cut and (b) x-cut LiNbO₃