Electrode-less liquid microlenses with tunable focal length and different shapes

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Summary

Tunable liquid lens fabrication and their interferometric characterization is presented. The pyro-electric properties and the periodic poling patterning of the Lithium Niobate substrate is used to select the shape and the focal length of the liquid droplet acting as a lens.

Introduction

Liquid lenses are becoming important optical devices in the framework of the adaptive optical devices, feasible applications ranges from mobile-phone cameras to biology. The main advantage is that is possible to change the focal length just changing the liquid shape [1-4]. Two main procedures are employed to change the shape of the liquid mass. The first is based on hydrostatic and/or pneumatic forces. Devices with flexible and elastic membrane able to change liquid shape are engineered [5-8]. The second is based on the electrowetting (EW) effect [9,10]. In the latter case electric forces instead of pressure force are used. We present a different approach demonstrating that is possible to obtain liquid microlenses using an EW process developed without electrode patterning. We will use the expression electrode-less configuration to underline that the electrodes were built into the crystal, used as substrate, through a micro-engineering process and were activated pyroelectrically by an appropriate temperature variation. [11-13]. The crystal employed was a periodically poled polar dielectric crystal (Lithium Niobate LN) it was used as substrate and the formation of sessile microdroplets was driven by the patterned surface charges induced by the pyroelectric effect. Depending on the patterned substrate we are able to fabricate single lens, array of thousand of microlenses or hemi-cylindrical and toroidal lenses. The magnitude order of these devices is about 100 μm. The fundamental physics responsible of the phenomenon leading to the formation of microdroplets was illustrated and investigated in Ref. [11]. Moreover we presented an optical characterization of this lenses in order to estimate the focal length variation of the microlenses. The optical characterization is performed by means of a Digital Holographic setup to calculate directly the focal length of the liquid lenses for different temperature and to characterize their optical goodness in terms of optical aberrations.

Experimental Results

The lens effect we observe happens when a PPLN crystal covered by a thin liquid film is subject to a temperature variation. To fabricate the PPLN substrate we employ both sides polished and 500 μm thick LN crystals. We periodically poled by standard electric field poling A standard mask lithography process was used to generate the desired resist pattern and the subsequent application of high voltage pulses led to the formation of the reversed domain grating. An oily substances (pentanoic acid) is deposited on the

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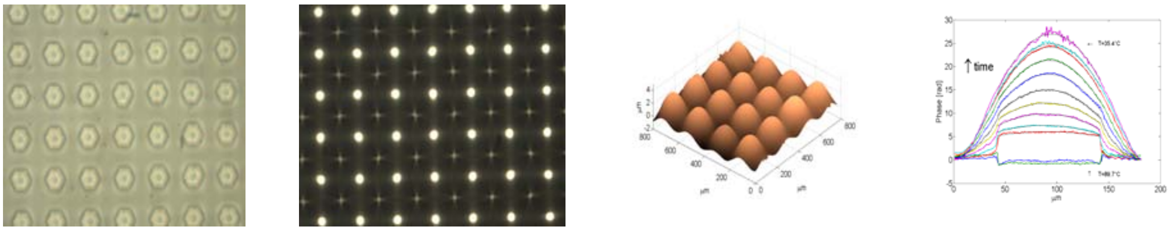
substrate as a thin film of about 100 μm (Fig.1(a)). An appropriate temperature variation of the PPLN substrate generates the pyroelectric effect which causes the formation of uncompensated surface charges able to activate an EW effect and generate liquid lenses on the LN substarte. Fig.2(c) shows the calculate phase curvature of the optical beam at device exit face.



(a) (b) (c) (d)

Fig. 1: Optical microscope images of the oil coated sample (a) before lens effect start and (b) after complete lens formation; (c) unwrapped phase distribution and (d) Experimental and fitted 1D profiles of the unwrapped phase distribution corresponding to the cooling process;

Moreover we investigate two different types of lenses: cylindrical and toroidal. During the temperature change we observed fast reshaping of the oil. In the cylindrical case, the process tends to an equilibrium state where the oil is gathered up in stripes along ferroelectric domain boundaries. These stripes exhibit lensing behaviour that we characterize by means of a digital holographic (DH) microscope.

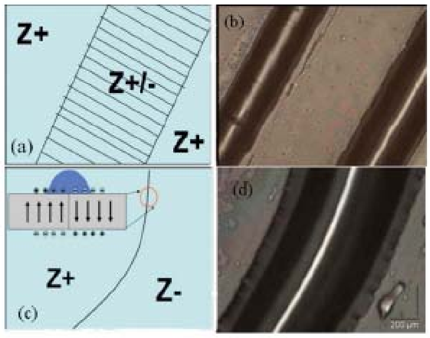


Fig. 2: Schematic pictures of the poled region for (a) the PPLN sample and (c) the single domain wall. Optical microscope image of cylindrical liquid lens (c) and toroidal lens (d).

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