Improvement of Decay Property of a Liquid Crystal Microlens with Divided Electrode Structure

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New driving methods for a liquid crystal microlens with divided electrode structure were proposed for the improvement of transient behaviors. With this structure, a field parallel to the substrates could be exerted, and in the presence of which, when the external driving voltage was switched off, the reorientation of director in the lens region became much faster, resulting in a decay time decreasing.

Introduction
As with other liquid crystal devices, a liquid crystal lens [1] and a liquid crystal microlens [2] work under very low voltages. However, in the case of a liquid crystal microlens, the response to external fields and the decay after the removal of the fields are rather slow. Many researches have been focusing on the improving of the transient behaviors of liquid crystal microlenses [3]. Here we report methods for faster decay for a liquid crystal microlens of divided electrode structure [4]. With this structure fields vertical to the external driving field can be created either by directly applying a voltage across the divided electrodes, or by inverting the phase of one of the two components of the driving field. We successfully realized a decreasing of decay time from more than ten seconds to several milliseconds.

Experiment
Fig. 1 shows the structure of the microlens. The cell thickness was 130μm and hole radius 300μm, and liquid crystal 5CB was filled in the cell. By rubbing the substrates, the director of the liquid crystal in the cell aligned parallel to them. The hole patterned electrodes coated on the upper and lower substrates were of identical shapes, and both were composed of two electrically divided parts. If a voltage \( V_1 \) across the substrates was applied through the two upper and the two lower electrodes, the director of the liquid crystal would tend to align with the electrical field, and a microlens was formed [2]. While \( V_1 \) was removed, the director would relax to its equilibrium state by Frank elastic torque, and the cell would no longer to be able to focus the light beam passing it. The decay process was generally very slow. In our experiments we made efforts to simultaneously apply a voltage \( V_2 \) across the two parts of the electrodes on both the upper and lower substrates immediately after \( V_1 \) was off, and a horizontal electric field component was produced which drove the director to align parallel to the substrates. The re-alignment of director was faster than the natural relaxing owing to the combined torque of both elastics and electricity, and hence the decay time of the microlens decreased. Two methods were employed to produce the horizontal electrical field, that is, either directly applying \( V_2 \) across the divided electrodes (method 1), or inverting the phase of one of the two
components of $V_1$, and simultaneously changing the amplitudes of both components from $V_1$ to $V_2$ (method 2). A He-Ne laser beam linearly polarized along the cell's rubbing direction was incident into the microlens. The decay times were measured by detecting the change of light intensity near the focal point.

**Results**

When $V_1$ was off and $V_2$ was on, the light intensity change near the focal point is shown in Fig.2 as an example of method 1 for $V_2 = 3V_{rms}$. The intensity fell from a high level to a low stable level, and in other words, the cell decayed from a "lens state" to a "non-lens state". The decay time of the microlens is defined as the time when 90% intensity drop reaches. In the experiments, we increased $V_2$ from 0 to $80V_{rms}$ and measured the corresponding decay times for both methods. The results are shown in Fig.3. From the figure we can see that the decay time decreased rapidly with the increasing of $V_2$. When $V_2 = 0$, that is, there was not a horizontal field, which was the case of a conventional liquid crystal microlens, the decay time of the lens was about 10.3 seconds. While $V_2$ increased to $80V_{rms}$, the decay time turned to be as short as about only 5.5 milliseconds (method 1), or 3.8 milliseconds (method 2). The decay property of the lens was improved obviously. Our methods have advantages over some others by which the improvements were at the cost of degrading the optical quality of the lenses. The alignment of director and the distribution of electrical field in the cell were complicated in present situations, but for the same $V_2$, method 2 should have resulted in a larger horizontal field than method 1. This could explain why at the same $V_2$, the microlens usually decays faster by method 2 than by method 1.

**References**