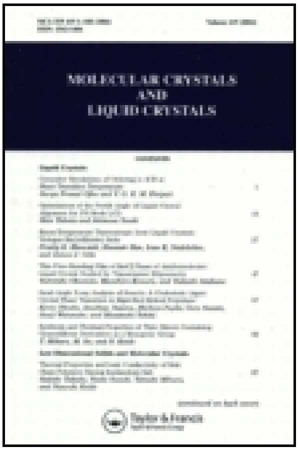


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# Investigation of Laser-Induced Spatial Patterns in "NLC—Feedback Mirror" System

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# INVESTIGATION OF LASER-INDUCED SPATIAL PATTERNS IN "NLC - FEEDBACK MIRROR" SYSTEM



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Abstract. Spontaneous hexagonal pattern formation in the transverse profile of a continuous laser beam reflected back by a planar mirror onto a nematic liquid crystal cell is experimentally investigated. The effect is proved to occur at pump intensities as low as $10\,\mathbf{W/cm^2}$.

Complex spatial structures arising in the transverse profile of the laser radiation in the nonlinear optical interaction are intensively studied in the recent years[1]. These structures are of significant interest for the fundamental investigation of spatio-temporal instabilities as well as for the application of such systems in the capacity of optoelectronic devices, and especially as pump beam modulators. The nonlinear interaction, that underlies these structures, enables to trace the dynamics of their instability. The first observation of pattern formation[2] has been made in resonator geometry under the conditions for optical bistability. Similar structures have been obtained also in a nonlinear Fabry-Perot cavity (FP cavity filled with a nonlinear medium)[3]. Later investigations revealed the pattern formation in four-wave mixing in atomic vapors as well as in other nonlinear media[4] under different experimental conditions (FP cavity, counterpropagating beams, feedback mirror etc.). The interest to the system containing Kerr medium and a feedback mirror have been largely evoked by the appearance of a report[5], where a relatively simple geometry (nonlinear slice with a single **100%** mirror) have been theoretically considered and numerically calculated.

Theoretical predictions made[5] have been experimentally realized in media with various mechanisms of Kerr nonlinearity[6].

Here we present the results of the experiment on hexagon formation in the transverse profile of cw laser beam of rather moderate power (**$P_{max}$~200 mW**) transmitting a nematic liquid crystal (NLC) film and then reflected back by a dielectric linear mirror with reflectivity **R=98%**. The spatial period of hexagonal lattice appeared to depend on the mirror-to-cell distance and on the pump intensity. The experimental arrangement, involving argon-ion laser, NLC cell, retroreflecting feedback mirror and registration system is sketched in Fig.1.



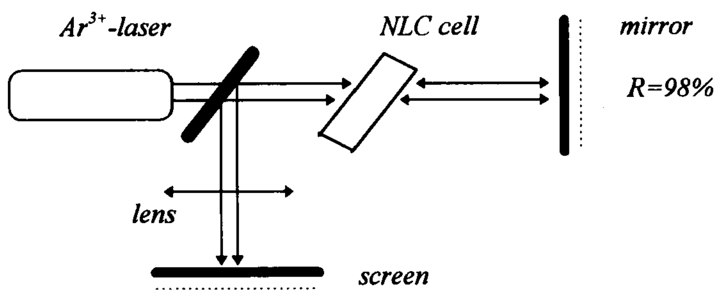


FIGURE 1 Experimental setup.

The beam of the laser, operating at **$\lambda = 515$nm** in $TEM_{00}$ mode, was sent at **$\alpha$=45$^0$** angle of incidence onto a 5CB NLC film. The cell-to-mirror distance could be varied from **5** to **10 mm**. The sample thickness used was **L=70μ** and **L=140μ** and was determined by the thickness of the spacer placed between the walls. Both cell walls were coated with HTAB surfactant in order to provide homeotropic (i.e. normal to the walls) initial alignment of the NLC molecules. The spotsize after spatial filtration of the beam was **750μ** (width at ½ maximum intensity). The light was linearly polarized in the plane of incidence, so that an extraordinary wave traveling through the sample induced the reorientation of the molecular director $\vec{\mathbf{n}}$. The latter caused the change of refractive index of the medium and therefore the nonlinear phase retardation of the transmitted beam. The NLC reorientation at weak pump power in this geometry is described by the equation[6]:

$$-\eta\frac{\partial\psi}{\partial t}+\Delta_{\perp}\psi-\frac{\pi^2}{L^2}\psi+\frac{\pi^2}{L^2}b\tilde{I}=0$$

where $\eta$ is the viscosity, $\psi=\beta\theta_{max}$ with $\theta$ being the small angle formed by $\vec{n}$ and the normal to the cell walls, $b=4\beta\sin\alpha\cos\alpha/(\pi\sqrt{\varepsilon_0})$, $\beta=4L\varepsilon_a\sin\alpha/(\lambda\varepsilon_e)$, $\varepsilon_0$ and $\varepsilon_e$ are the ordinary and extraordinary dielectric constants (for NLC 5CB $\varepsilon_0=2.37$ and $\varepsilon_e=2.99$, $\varepsilon_a=\varepsilon_e-\varepsilon_0$). Here we denote also $\tilde{I}=I_{total}/I_{Fr}$, where $I_{total}$ is the total laser intensity (sum of the initial and the reflected ones) and $I_{Fr}$ is the Freedericksz transition intensity threshold at normal incidence on the NLC cell. The numerical calculations showed [6] that the hexagonal structures in the reflected wave are found when a certain intensity threshold of the pump is reached (the temporal index in the exponent of the solution is assumed to be zero - stationary state. And indeed, we observed this patterns when a threshold value $I_{th}\sim 10\,W/cm^2$ was overcome, which we find to be consistent with the calculated value of Freedericksz transition threshold $I_{Fr}\sim 200\,W/cm^2$. The threshold intensity for pattern formation $\tilde{I}_{th}$ is determined by the following equations[6]:

$$\tilde{I}_{th}=\frac{L^2}{\pi\lambda dRb\cos(\Theta)}$$

where $\Theta=q_{th}^2\lambda d/2\pi$, and $q_{th}\sim\pi/\sqrt{\lambda d}$ is the pattern wave number at the threshold.

The stable structures obtained in the near field at **d=5 mm** and **d=10 mm** for two values of the cell thickness are shown in Fig.2.

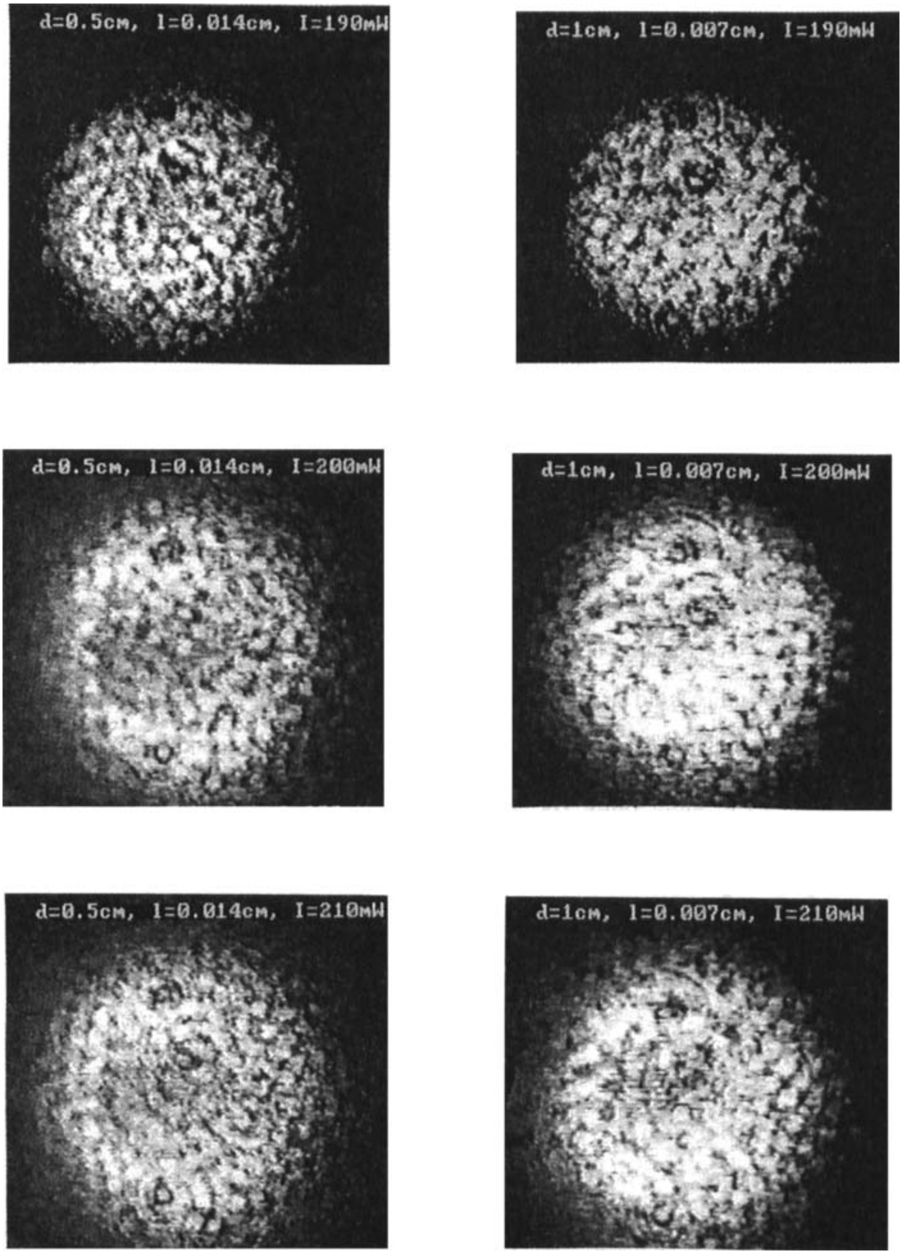


FIGURE 2 Patterns observed in the near field for different values of pump intensity, cell thickness and cell-to-mirror distance.

One can see that for greater thickness of the cell the structures are more inhomogeneous. We attribute the washing-out of the patterns at greater cell thickness (**L=140**$\mu$) to the inhomogeneity of NLC alignment, as well as to the thermal fluctuations. The presence of the latters are explicitly manifested in the output pattern. Besides this, in the case of **L=140**$\mu$ the patterns arise at over 1.5 times lower threshold power than that for **L=70**$\mu$. Note also, that the structures reach their steady state in rather long time **~0.5-1 min**, which increases with the increase of the cell thickness.

The spacing between the spots of the hexagonal structure increases as the cell-to-mirror distance is increased, which is consistent with theoretical predictions and earlier reported experiments. We observed also, that the increase of the pump intensity (above $\mathbf{30\,W/cm^2}$) leads to the disturbance of the hexagonal symmetry of the patterns and at last to their complete destruction.

In conclusion, our experimental results show that for the intensities as low as $\mathbf{10\,W/cm^2}$ the hexagonal patterns in the reflected beam are observed, and with the increase of the thickness of the NLC cell this value may be even reduced.

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