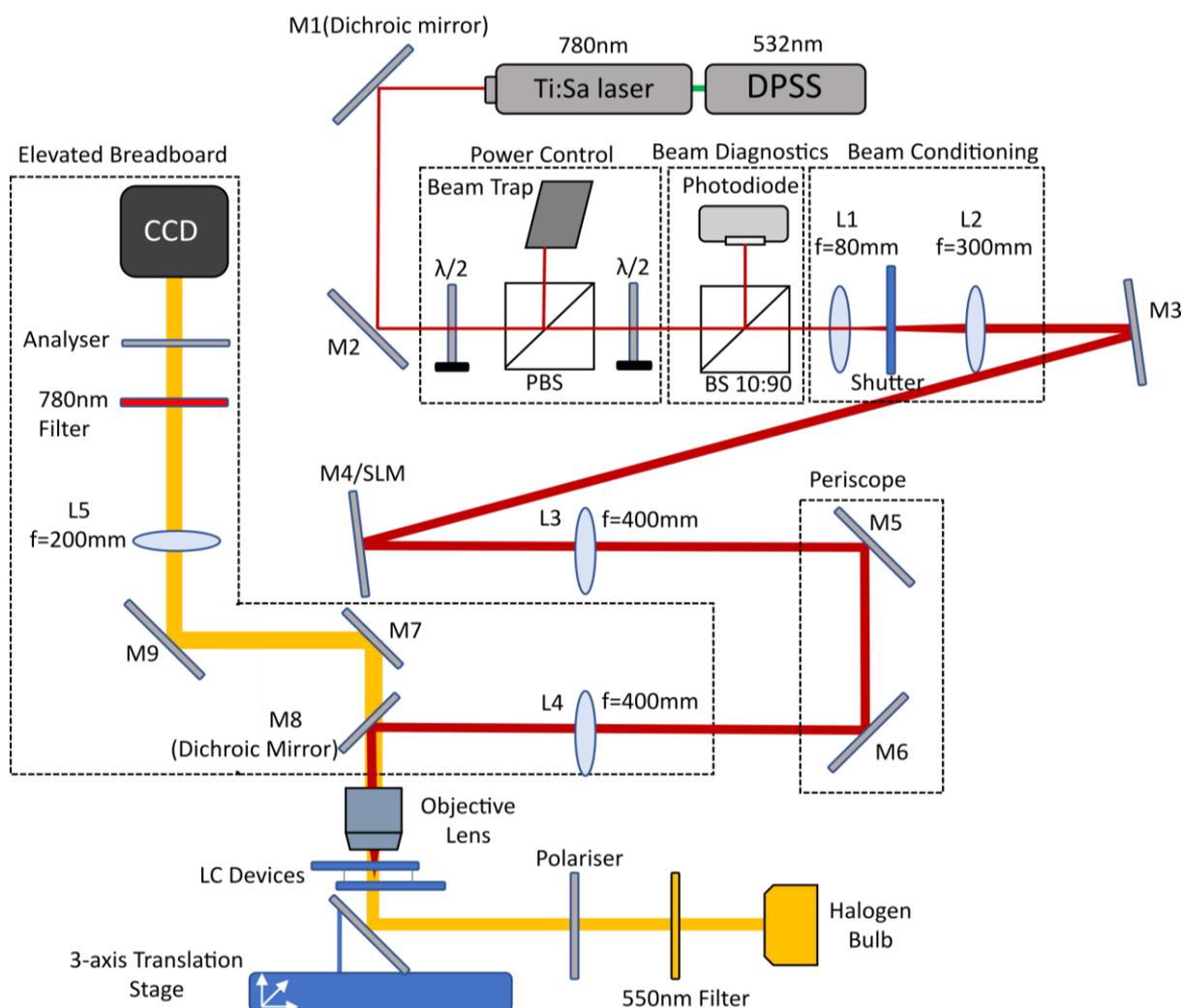


## Supplementary Materials

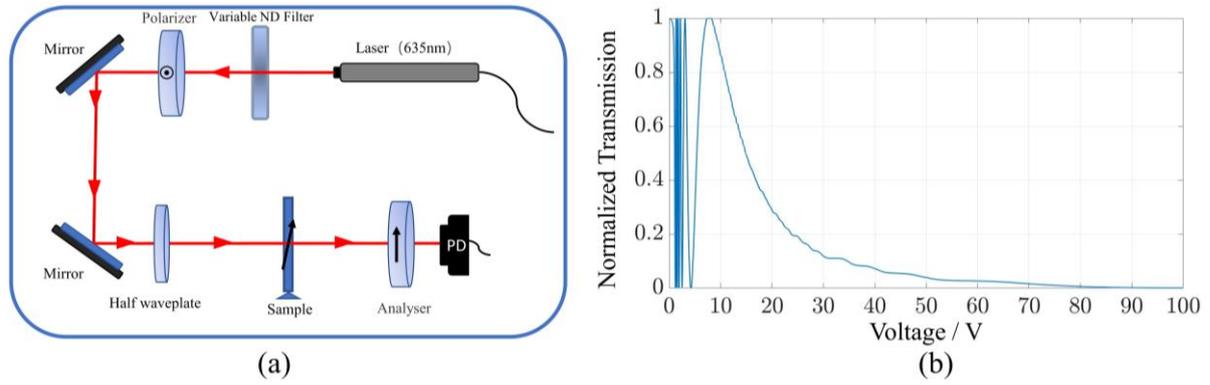
# Laser Written Stretchable Diffractive Optic Elements in Liquid Crystal Gels

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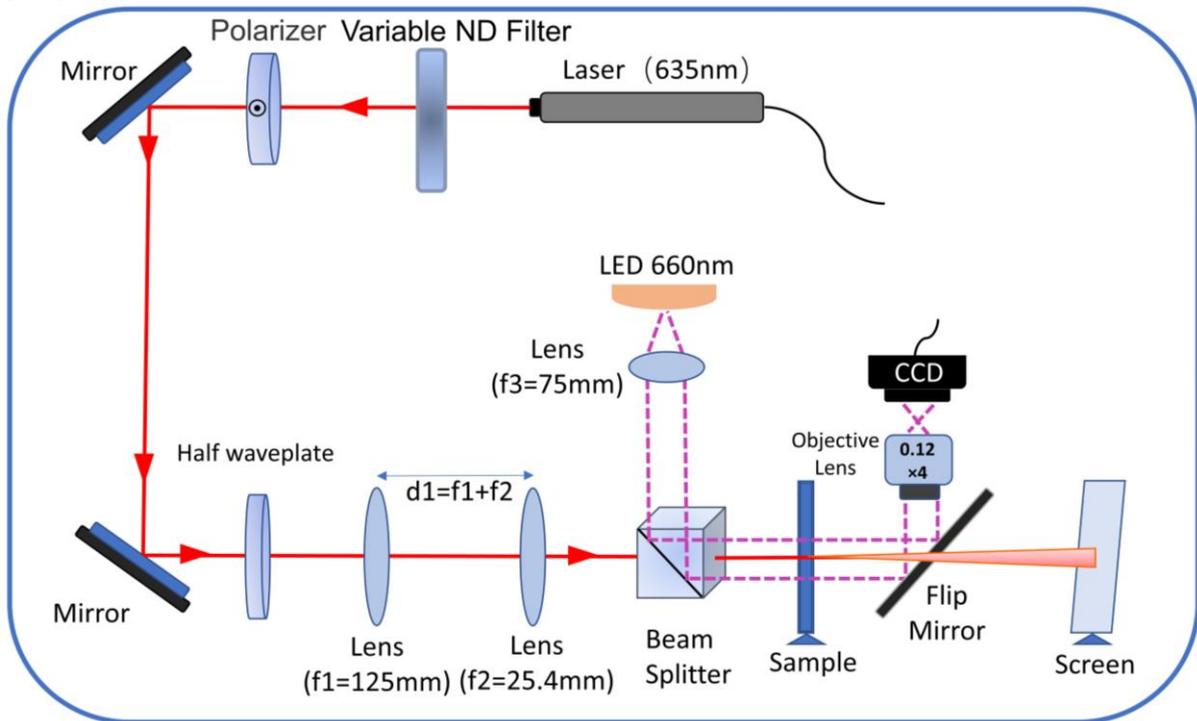
**Figure S1.** Schematic of the optical layout of the two-photon polymerisation direct laser writing system. The main subsystems are highlighted by dashed rectangular frames. The red lines refer to the path of excitation for the two-photon absorption (TPA) process at  $\lambda = 780$  nm as the beam from the Ti:Sapphire laser propagates to the LC samples. The yellow path represents the illumination of the sample and image capture with the CCD camera.



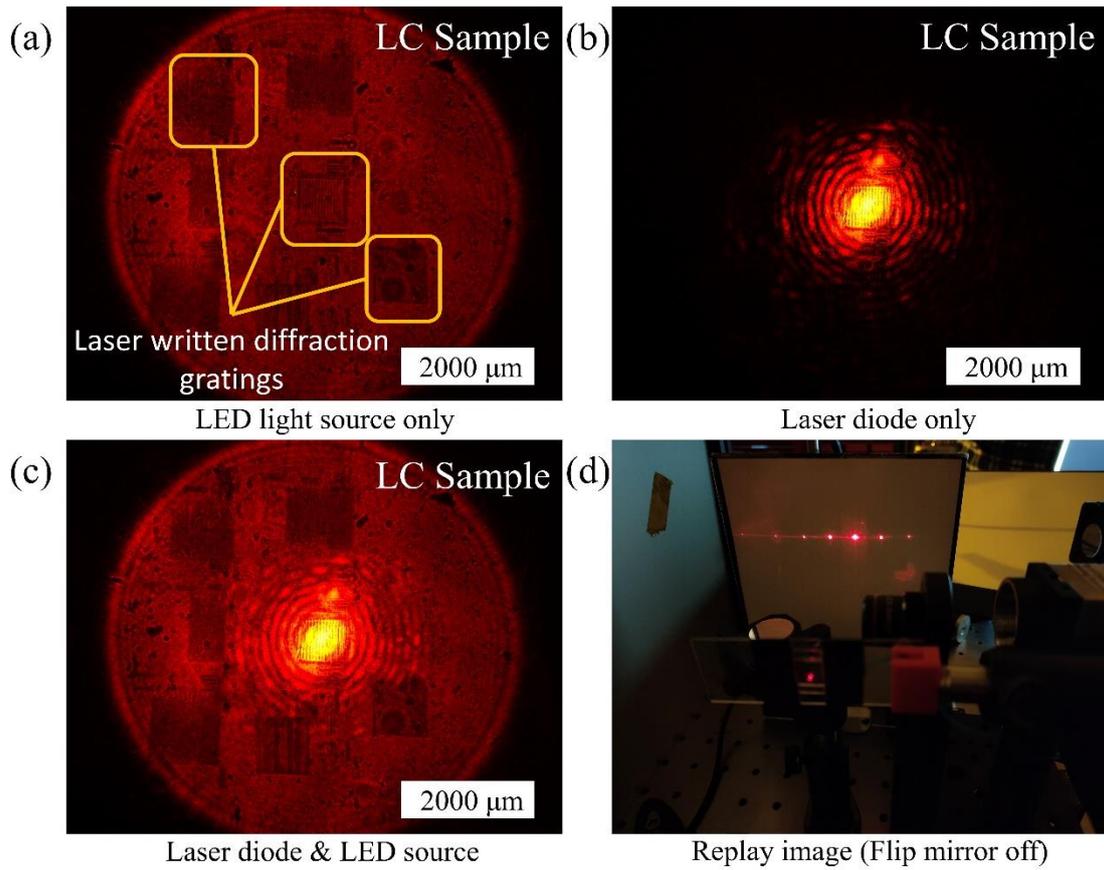
**Figure S2.** a) Schematic of the experimental setup used to record the transmission of monochromatic light through the polymerizable LC when sandwiched between crossed polarisers. ND: neutral density filter; PD: photodiode. The light from the laser first travels through a polarizer used to provide linear polarised light before the beam is attenuated by a variable neutral density (ND) filter (Thorlabs NDC-50C-4). The beam then propagates to the LC sample and through an analyzer that is crossed with respect to the first polariser before the intensity is then recorded by a photodiode. The LC sample was positioned at  $45^\circ$  respect to each one of the polarizers. b) Normalized transmission as a function of voltage for the LC mixture. The transmission decreases to zero when the sample is subjected to a voltage amplitude of 100 Vrms corresponding to a homeotropic alignment of the LC director.

<b>Glass cell</b>	Instec LC2-20.0 (20 $\mu\text{m}$ )
<b>The thickness of the LC Layer</b>	20.66 $\pm$ 0.01 $\mu\text{m}$
<b>Grating period</b>	12 $\mu\text{m}$ (65 strips with 64 gaps)
<b>Size of gratings</b>	768 $\mu\text{m}$ $\times$ 768 $\mu\text{m}$
<b>Orientation of the laser polarization relative to the alignment direction</b>	Perpendicular
<b>Written region</b>	within the bulk
<b>Writing voltage</b>	100 Vrms at 1kHz
<b>Writing speed</b>	100 $\mu\text{m/s}$
<b>Writing power at fabrication plane</b>	48 mW
<b>Distance between diffraction gratings and screen</b>	22.5 $\pm$ 0.1 cm

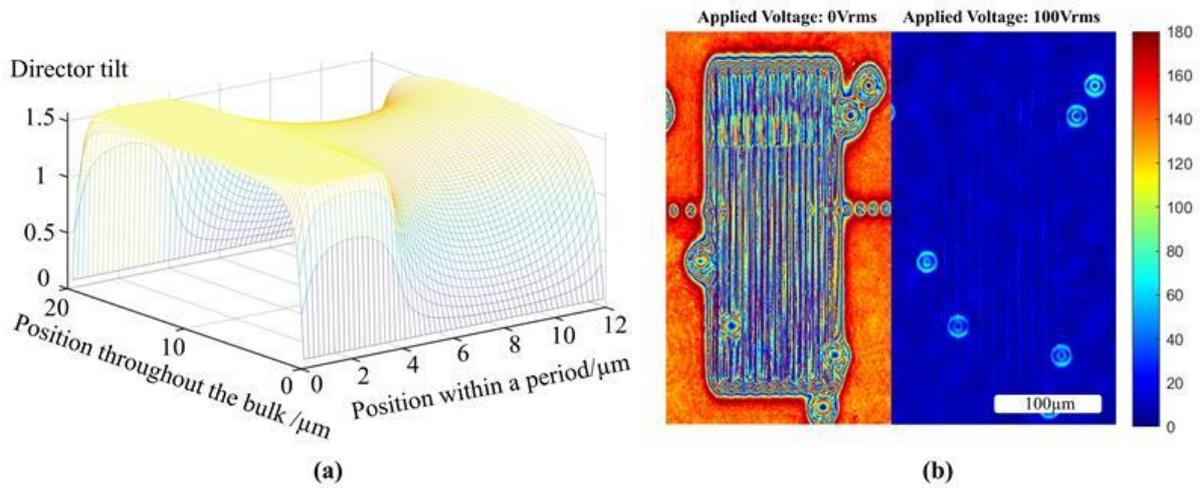
**Table S1:** Fabrication parameters in the laser written gratings test.



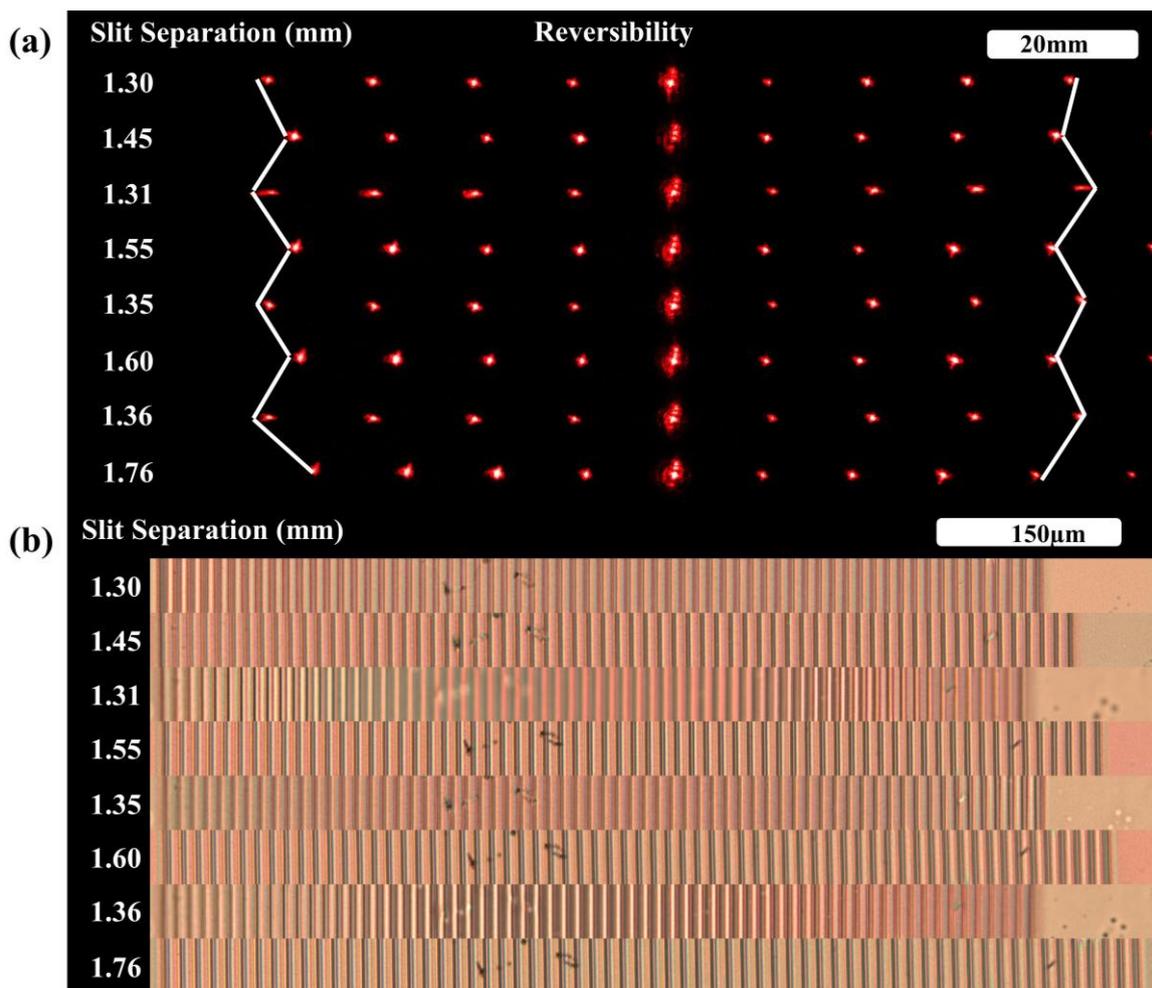
**Figure S3.** Schematic of the optical setup for characterizing the diffractive optical elements. The red solid line in the optical path represents the emission from the laser diode ( $\lambda = 635 \text{ nm}$ ), while the purple dashed line indicates the illumination path from the LED light source with a central wavelength of  $\lambda = 660 \text{ nm}$ .



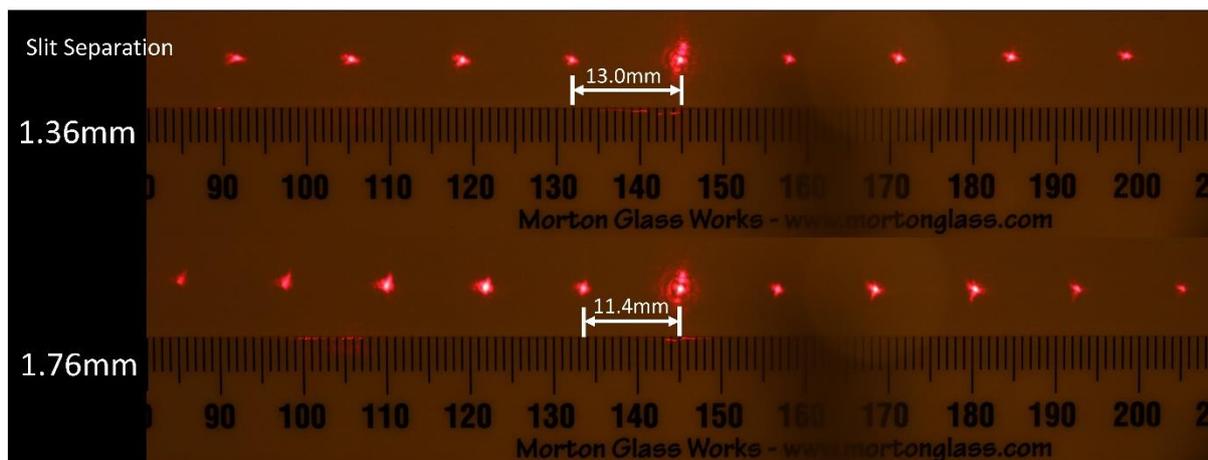
**Figure S4.** (a) An example photograph showing the diffraction gratings in the LC when observed using the system presented in Figure S3 with the LED source turned on. (b) An example photograph of the sample when the LED was switched off and the laser diode (used to observe the diffraction pattern) was turned on. (c) An example photograph showing the LC sample when both the LED and the laser diode were switched on. This enables the position of the laser beam relative to the laser-written diffraction grating to be determined. (d) A photograph of the experiment whereby the far-field diffraction pattern can be seen on a white screen.



**Figure S5.** a) The tilt in the LC director as a function of position within the cross section of a grating period. This shows that the LC director is tilted at  $\pi/2$  within the laser written regions but relaxes to a non-homeotropic alignment within the regions intended to be polymerized using UV illumination. b) The retardance distribution of a laser written grating in an LC sample before UV polymerization and delamination. The image on the left represents the phase retardance induced by the grating with a period of 12  $\mu\text{m}$  without an applied voltage while the image on the right shows the retardance when a voltage of 100 Vrms is applied to the LC. According to the comparison of the retardance distribution without and with a voltage, it's notable that the laser writing process locked-in a periodic phase profile which functions as a phase grating when no voltage is applied but that the grating vanishes when a large voltage was applied.



**Figure S6.** Photographs of the polarizing optical microscope (a) and the replay field (b) for all the extremes in terms of stretching and contracting the film for the three separate cycles. In (a), the fourth order spots are linked by solid white lines to highlight the tuning and reversibility of the film. (b) represents the polarizing optical microscope images which correspond to relevant far field images. In both methods, it can be observed that the diffraction grating is stretched further after each contraction.



**Figure S7.** Comparison between the initial diffraction pattern and the final extreme in terms of stretching.