SAND2020-6221C

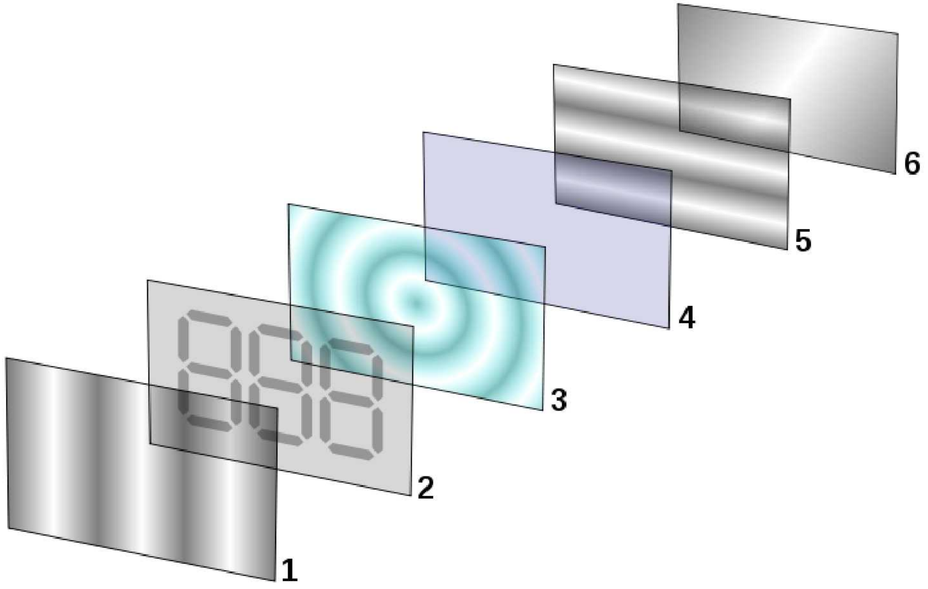
Charge-Transfer Liquid Crystals for Re-Writeable Waveguides

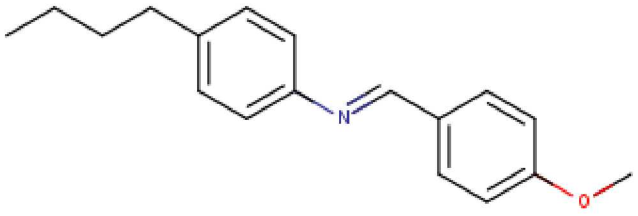
Michael Wood[1], Joseph J. Reczek[2] & Bryan Kaehr[1]

1. Advanced Materials Laboratory, Sandia National Laboratories, Albuquerque, NM
2. The Department of Chemistry and Biochemistry, Denison University, Granville, OH

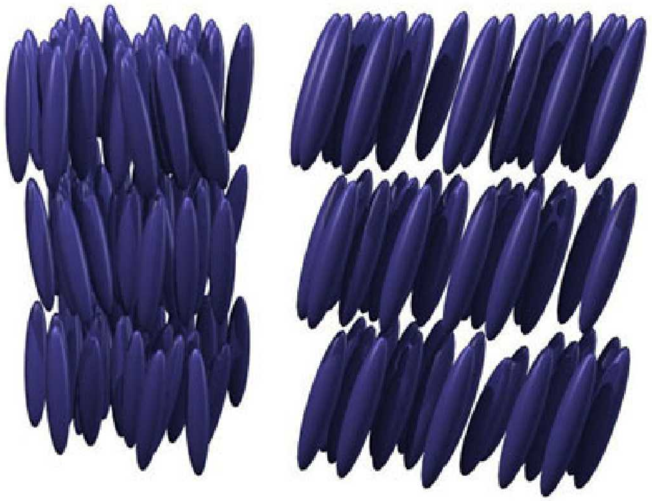
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Liquid crystals are a ubiquitous optical technology





Chemical structure of N-(4-Methoxybenzylidene)-4-butylaniline (MBBA)



alignment in the smectic phases

Liquid crystal displays

1.Polarizer with a vertical axis to polarize light as it enters.
2.Glass substrate with transparent electrodes . The shapes of these electrodes will determine the shapes that will appear when the LCD is switched ON.
3.Twisted nematic liquid crystal.
4.Glass substrate with common electrode film (ITO) with horizontal ridges to line up with the horizontal filter.
5.Polarizing filter film with a horizontal axis to block/pass light.
6.Reflective surface to send light back to viewer.

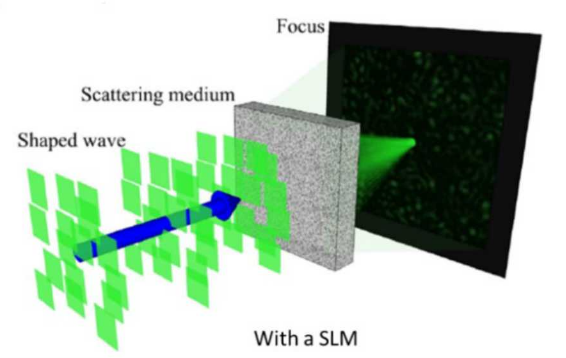
Curved 4.7" OLCD — 4.7" OLCD with 10mm bend radius — Curved 12.1" OLCD

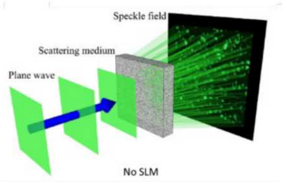
FlexEnable’s glass-free organic LCD (OLCD)

Source: wikipedia.org

Liquid Crystals Optics/Waveguides

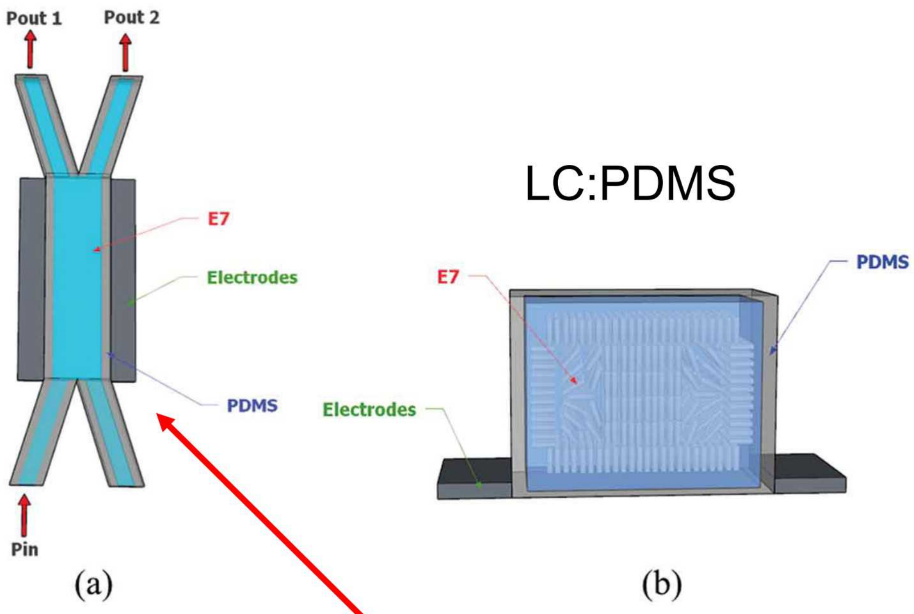
- Polarizers
- Filters
- Laser stabilizers
- Shutters
- Spatial Light Modulators





Hemphill, et al *Journal of biomedical optics* 21.12 (2016): 121502.

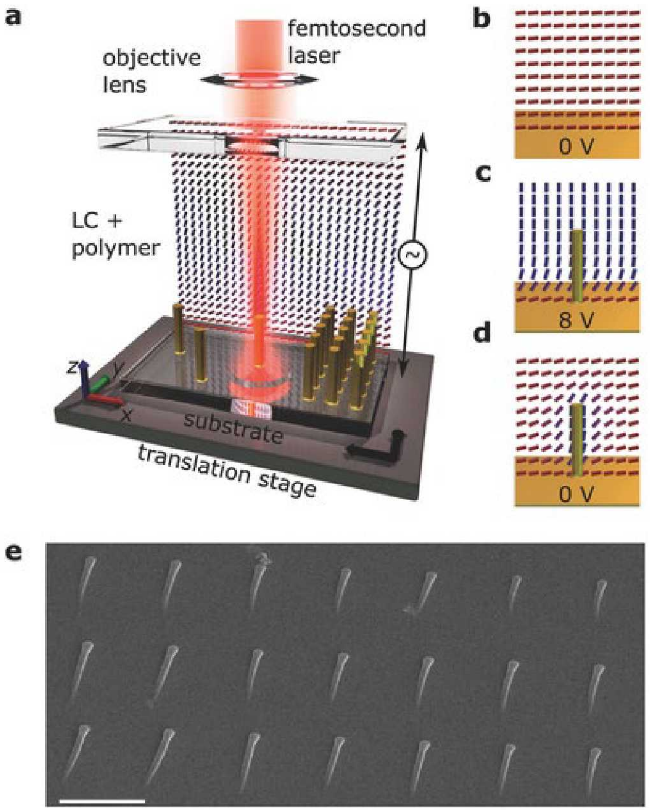
LC:PDMS



Directional coupler

Asquini, Rita, et al. *Liquid Crystals* 45.13-15 (2018): 2174-2183.

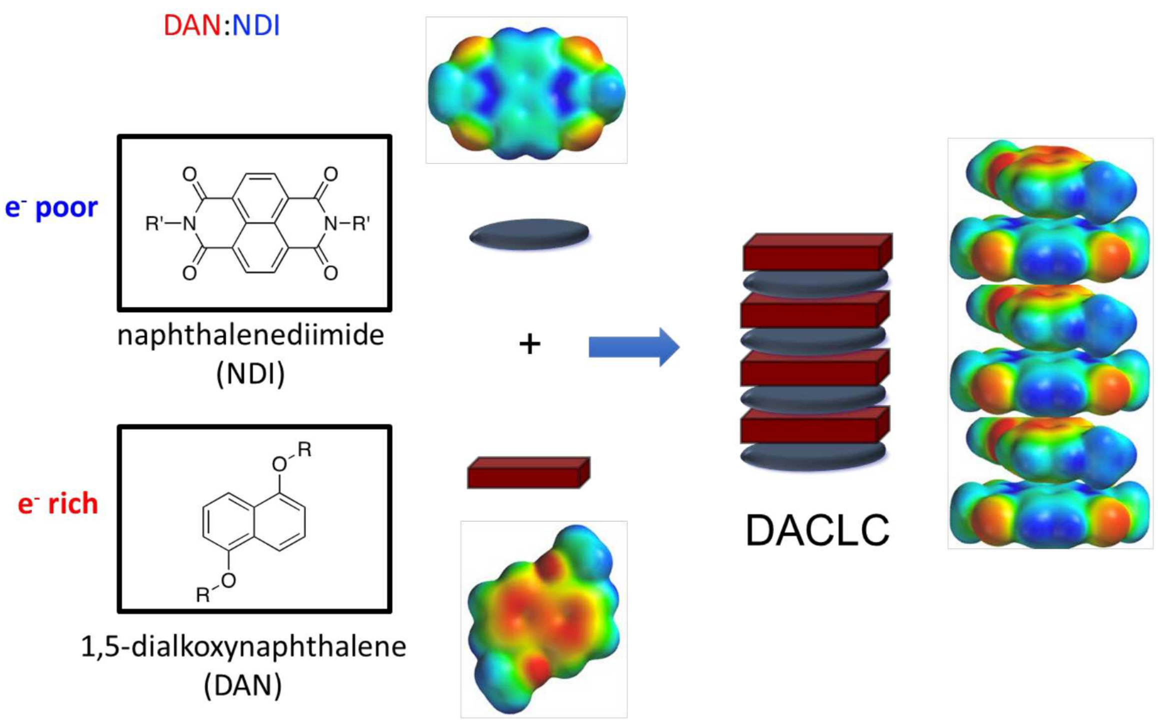
Direct-write LCs



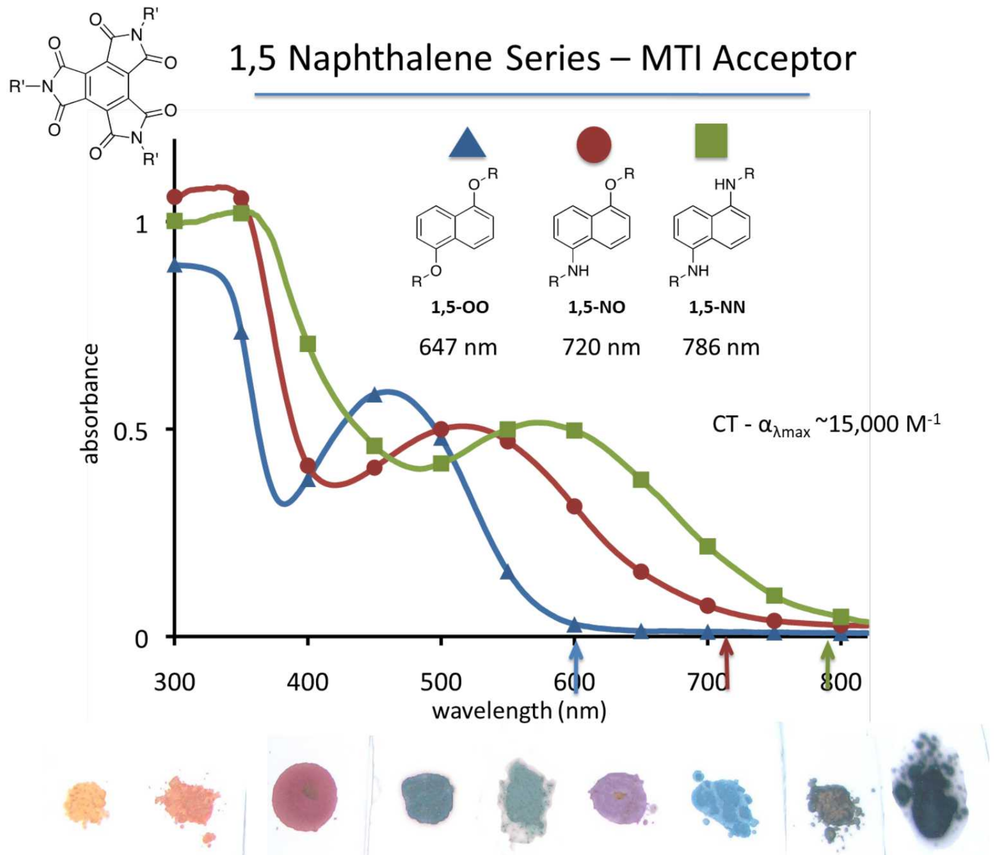
Tartan, C. C. *et al.* *Advanced Optical Materials* **6**, 1800515 (2018).

- Electrical bias needed for orientation
- Limited reconfiguration

Donor-acceptor columnar liquid crystals (DACLCs)



Reczek, J. J., et. al., *J. Am. Chem. Soc.* **2006**, *128*, 7995-8002



Leight, K. R.; Esarey, B. E.; Murray, A. E.; Reczek, J. J. *Chem. of Mater.* **2012**, *24*, 3318-3328.

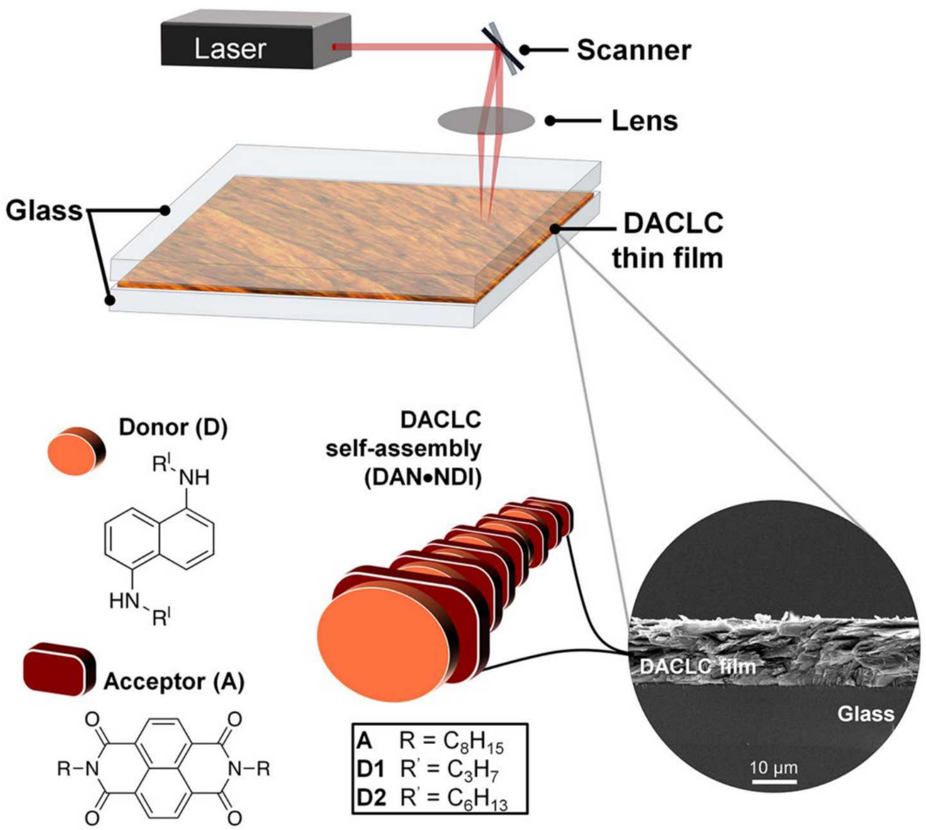
Donor-acceptor columnar liquid crystals (DACLCs): Self assembling 1D structures comprised of electron-rich and electron poor molecular precursors

DACLCs optical/electronic properties result from charge-transfer energy band following assembly and can be modulated via pendant groups to tune, for example, bandgap.

Directing the alignment of DACLCs is challenging

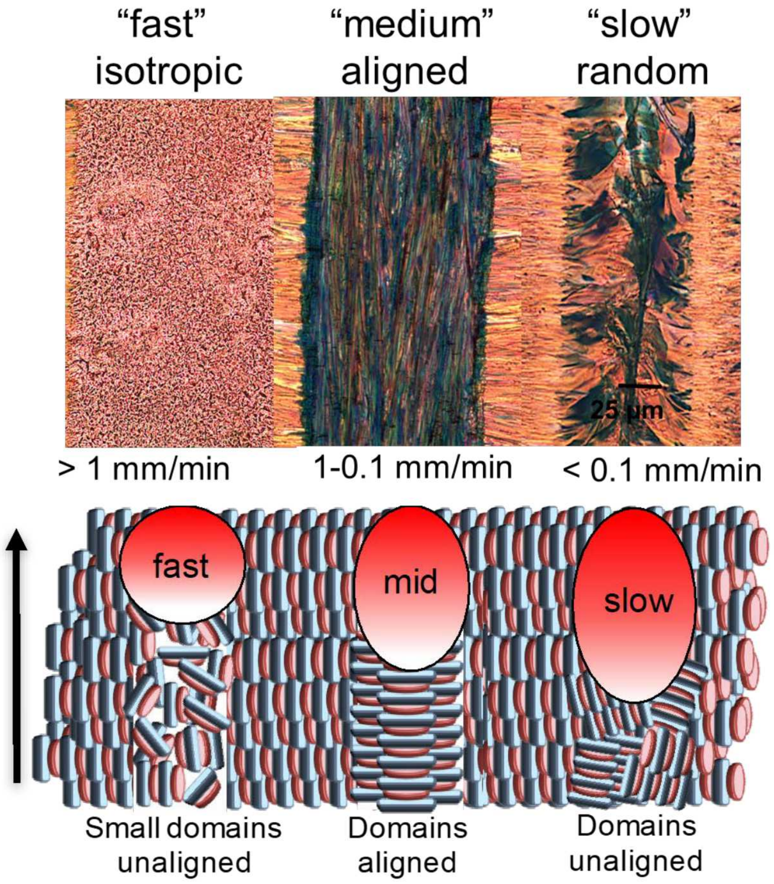
DACLC Reconfigurable Optical Polarizers

Writing scheme:

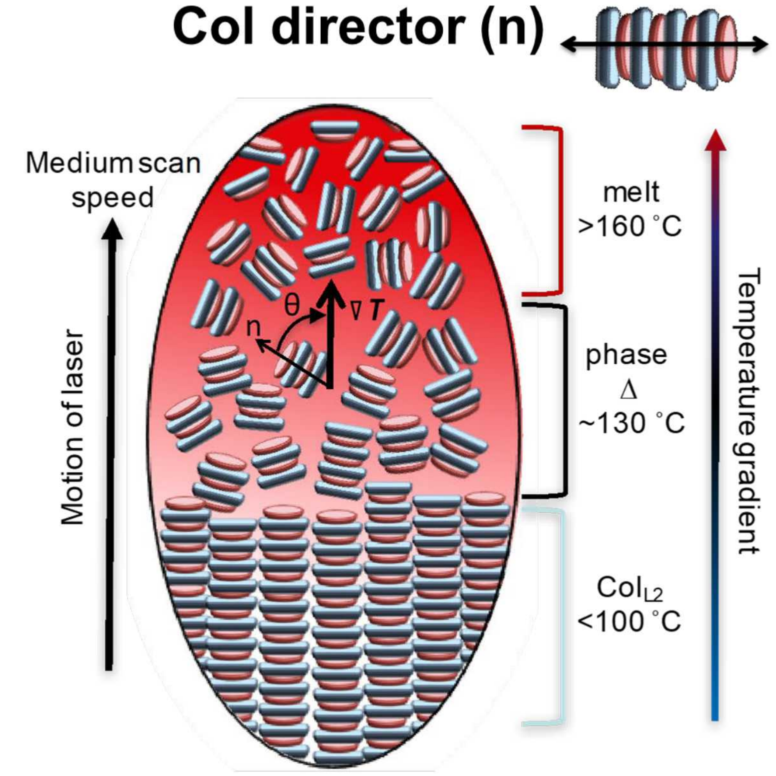


Laser heating is used to induce a directional thermal gradient that results in an ability to orient DACLCs into patterned regions of dichroic films. Fast cooling results in isotropic regions.

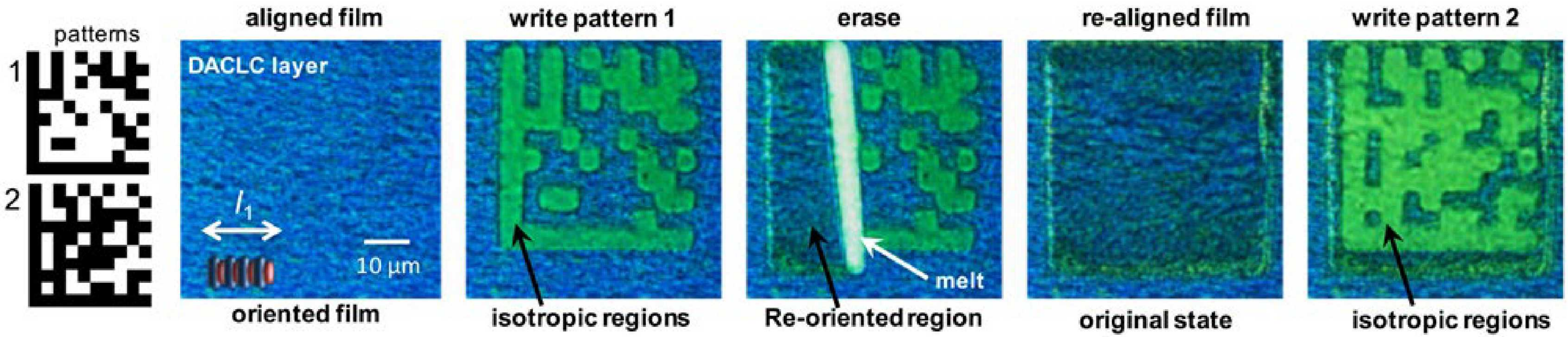
- **Rate affects cooling time and thermal gradient**

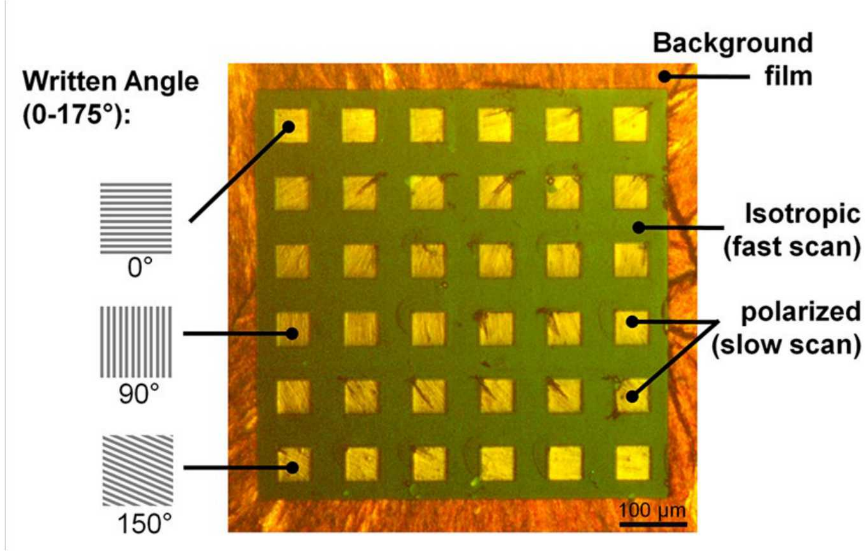


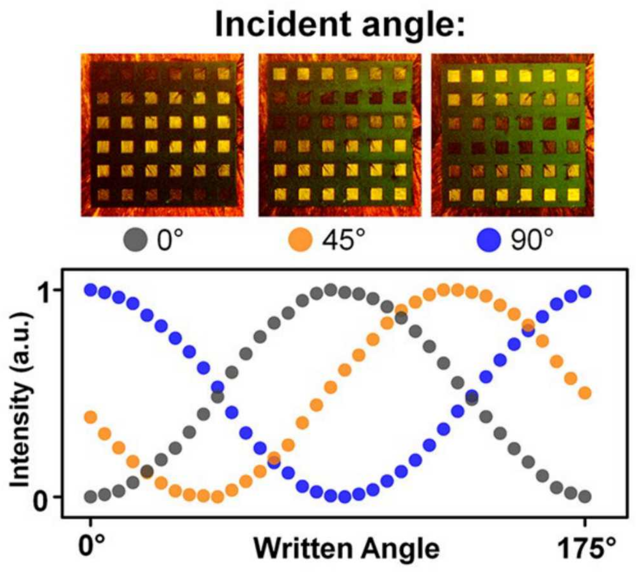
Thermal gradient orients the Col director (n)



DACLC Reconfigurable Optical Polarizers; Controlled Alignment



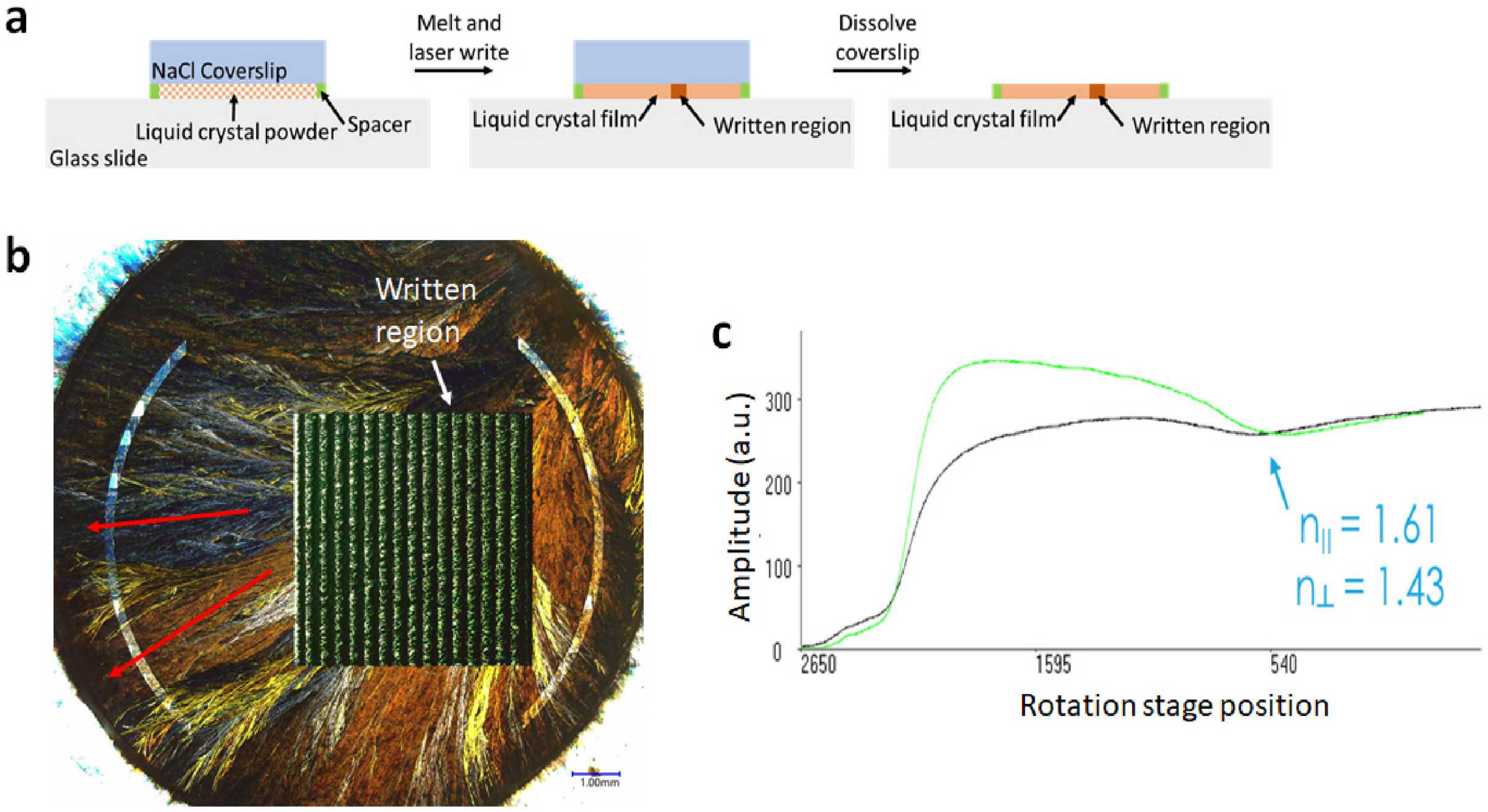


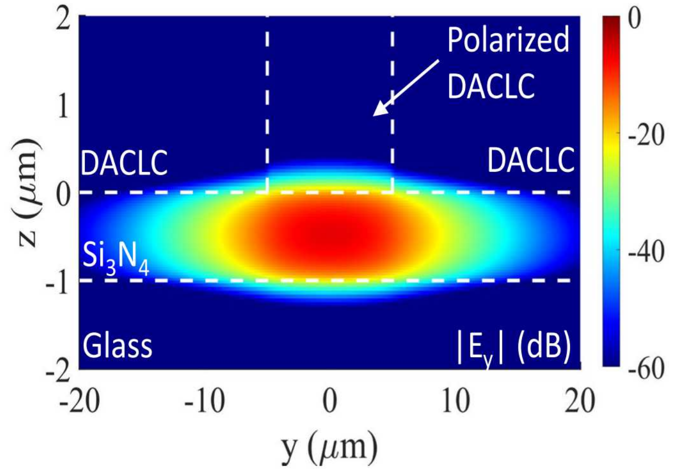


1. Van Winkle, M., Scrymgeour, D. A., Kaehr, B., & Reczek, J. J. (2018). Laser Rewritable Dichroics through Reconfigurable Organic Charge-Transfer Liquid Crystals. *Advanced Materials*, *30*(20), 1706787.

2. M. Van Winkle, H. Wallace, N. Smith, M. Wood, A. Pomerene, B. Kaehr, and J. J. Reczek,(2020) “Direct-write orientation of charge-transfer liquid crystals enables polarization-based coding and encryption” (under review)

DACLC waveguides: Index Measurement



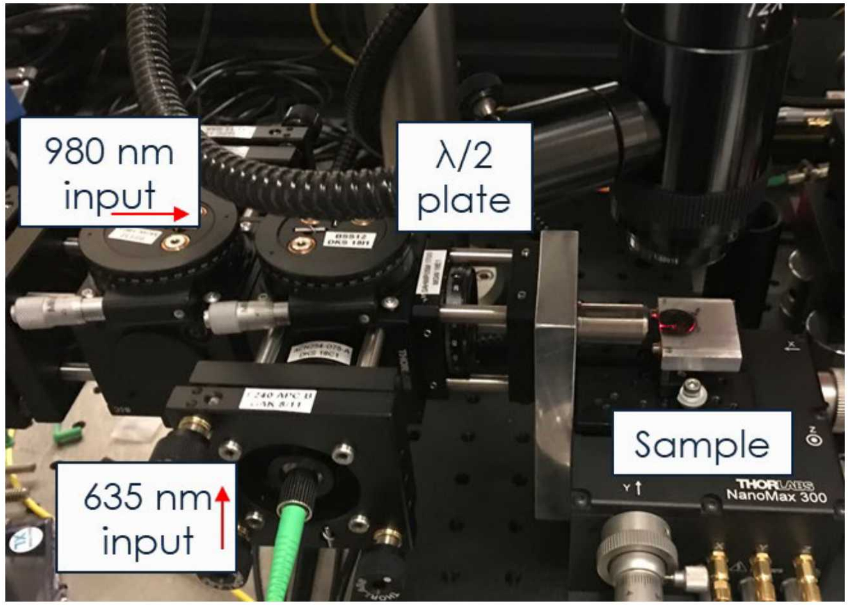


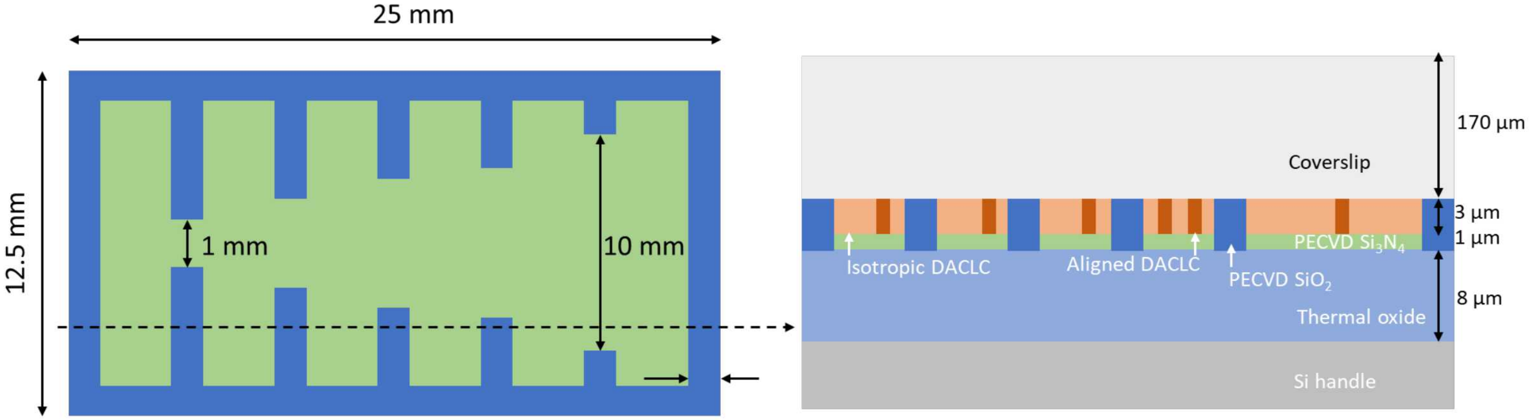
- Numerical solution for the strip-loaded waveguide mode in the LC film
- White lines show material boundaries

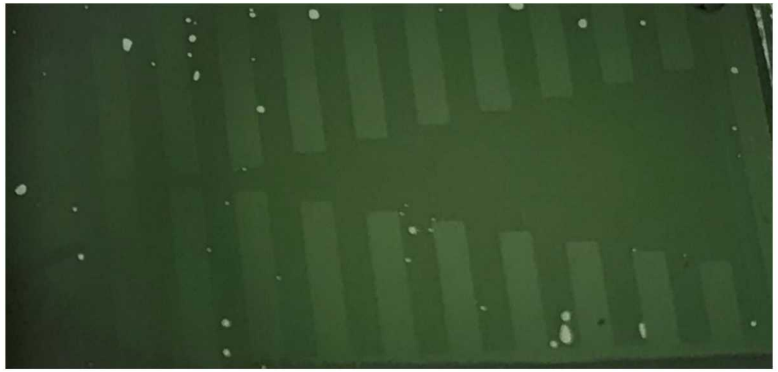
- Ellipsometry proved challenging
- Metricon prism coupling technique shows Δn 0.2 @ 688 nm

DACLC waveguides: Experimental Setup

Fiber-to-free-space end-fire waveguide coupling experimental setup





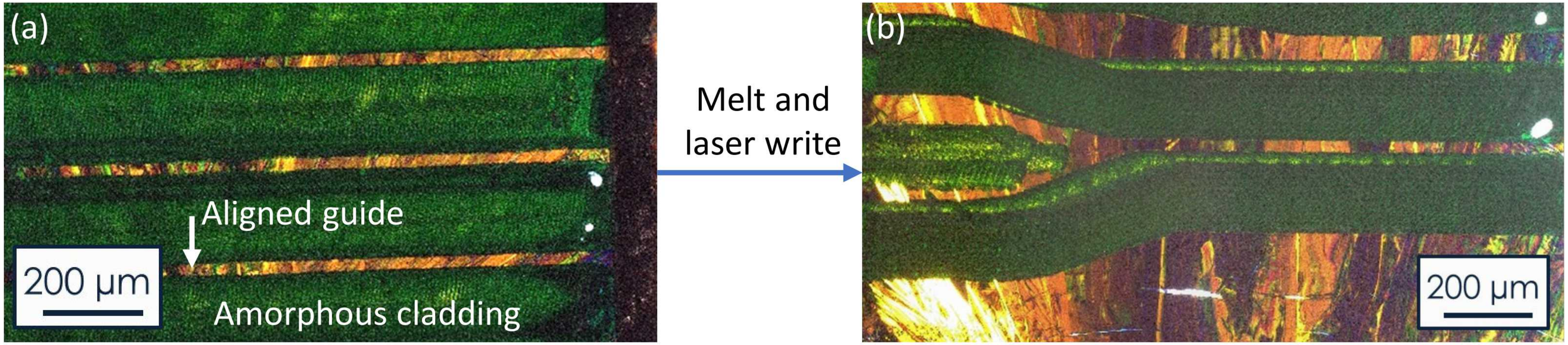


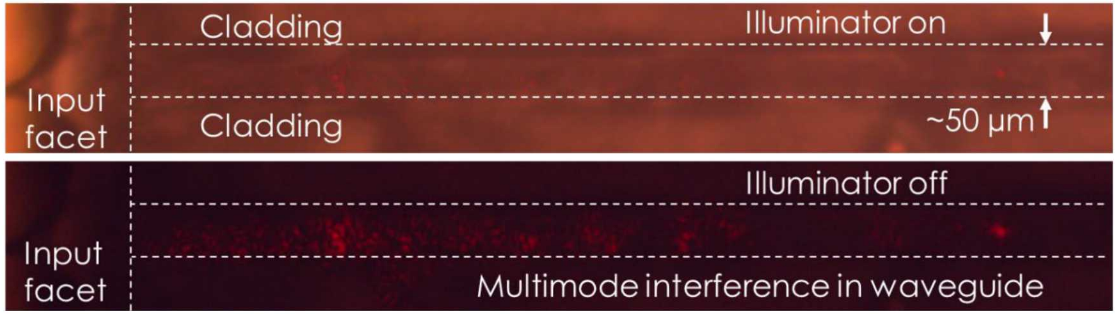
Microfabricated cell filled with LC and capped with a cover slip. The cells contains variety of waveguide lengths.

- Microfabricated cells on Si substrates with SiO_2 walls and Si_3N_4 guiding layer
- Si substrate heat conduction prevented laser orientation

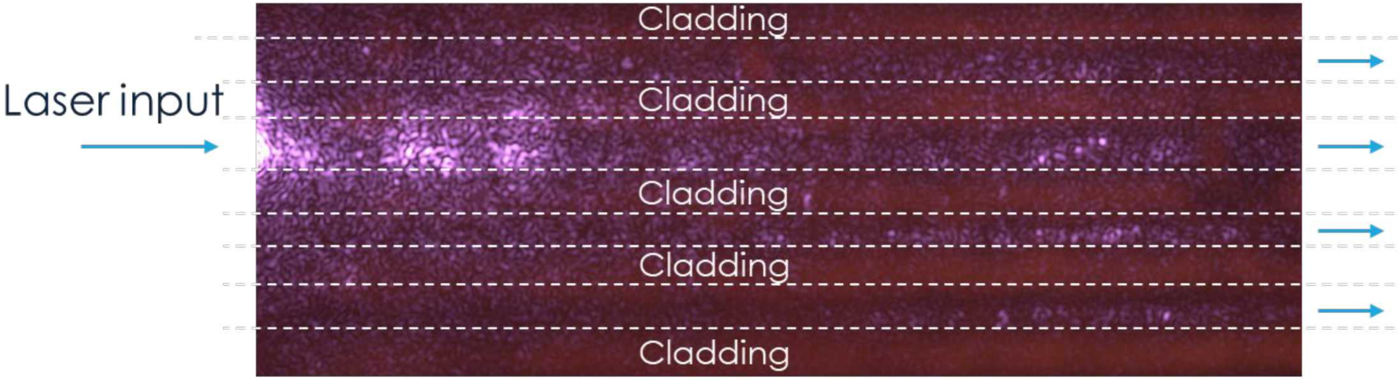
DACLC waveguides: Test

Direct write cladding around bulk aligned DACLC film on Si_3N_4



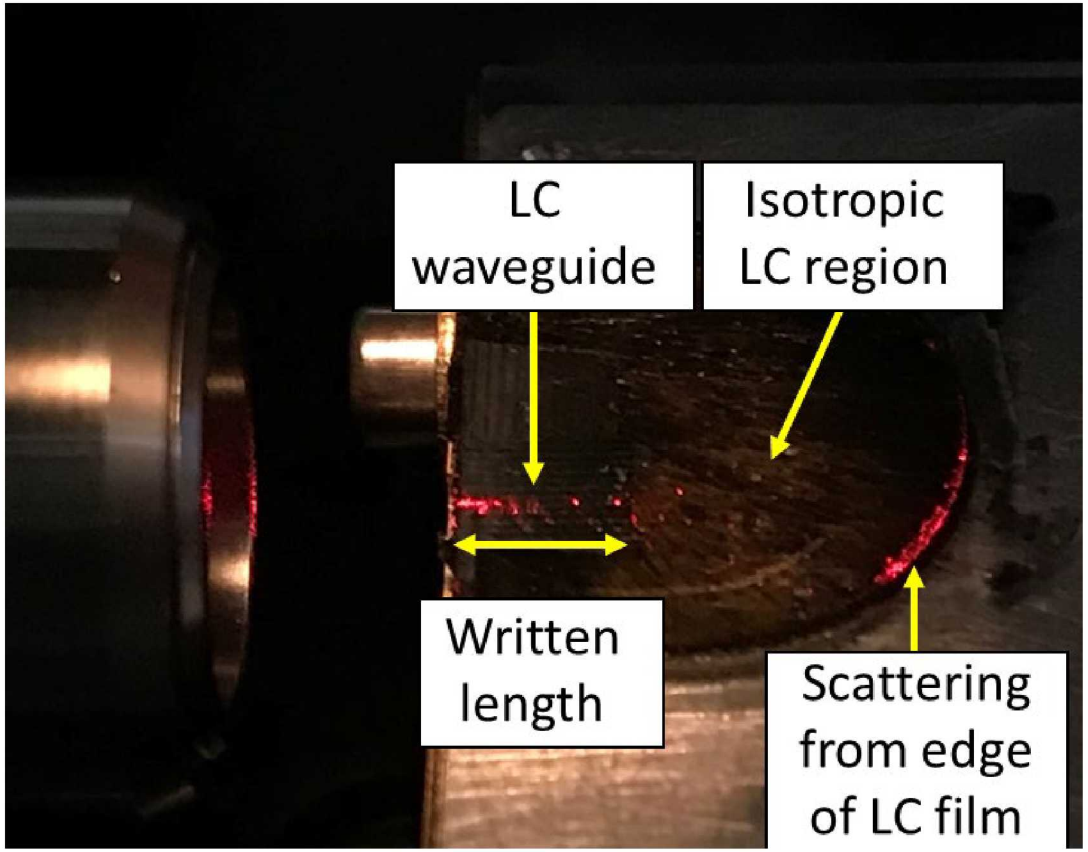


635 nm light coupled into an LC waveguide.



980 nm light coupled into an array of 50 μm wide LC waveguides

Conclusions



- Measured strong index contrast in polarized DACLC regions compared to amorphous
- Demonstrated writing and re-writing LC cells
- Evidence of waveguiding, but losses too high to be quantified
- Work needed on cell fabrication, direct-write process and material uniformity to be suitable for photonics

Acknowledgments

- Maddie Van Winkle (Denison, SNL, Berkeley)
- Hoke Wallace (Denison)
- Darwin Serkland (SNL)
- Michael Gallegos (SNL)
- Exploratory Express Laboratory Directed Research & Development (EE-LDRD)

Advanced Materials Laboratory, a part of Sandia National Labs since August, 1992