Liquid Crystal Sensors for Ultrasound Detection

The visualisation of ultrasonic wavefields is important for non-destructive testing (NDT) and structural health monitoring (SHM). It allows for detection and monitoring of defects in components or structures over their lifetimes, and can also be used to further the understanding of how waves interact with defects and changes in geometry.

Standard techniques for wavefield visualisation include vibrometry, interferometry, and the use of microphones and hydrophones. These methods all require point-by-point scanning to map the wavefield over an area, which can be time consuming. Instead, the unique optical properties of liquid crystals (LCs) can be exploited to create a low cost sensor that requires no scanning [1-3].

Acoustography is a commercial technique that uses a LCs as an acousto-optic sensor [1], however, the method operates in a water bath for a narrowband frequency range and requires polarisers to view the ultrasound, making it unsuitable for in-situ measurements. Polymer-dispersed liquid crystal (PDLC) films allow for fast and low cost visualisation of ultrasonic displacement without the need for polarisers or a water bath [2], appearing cloudy when no ultrasound is present and clearing when ultrasound is incident. However, they display a sharp on-off characteristic, meaning the area where the sensor has not fully cleared is small.

More detailed displacement information could be obtained using thermochromic liquid crystal (TLC) sensors. Heat is generated by the ultrasonic field in a TLC layer with the aid of a backing layer. Chiral nematic LC in the TLC contains layers that vary in separation with temperature, selectively reflecting different wavelengths of light. This results in a colour scale that varies with ultrasound displacement, since displacement depends on temperature [3]. Quantitative measurements for displacement in the form of a temperature map can then be obtained from photos of the sensor.

Initial work had been conducted on the use of the TLC sensor for measuring the displacement of various modes on a flexural transducer. Interferometry data is used for comparison. Figure 1 shows photos of several resonant modes visualised using the TLC sensor. Figure 2a and 2b show a photo of the mode at 320kHz and temperature map analysis of this photo respectively, with figure 2c showing comparison of average diameter lines. Future work will include exploration of NDT applications for the TLC sensors, such as defect detection and their use in thermosonics.

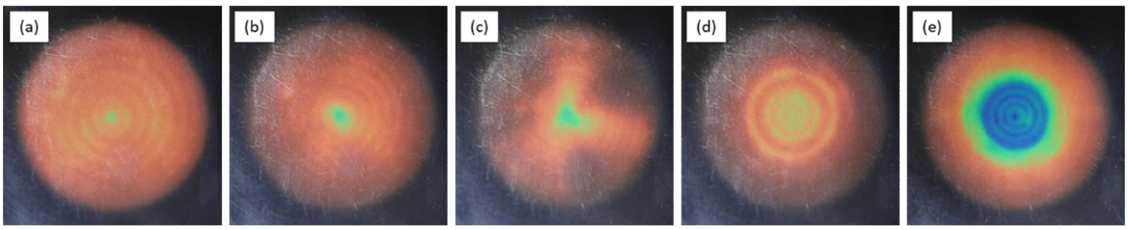

Figure 1. Visualisation of resonant modes of a flexural transducer using the TLC sensor at frequencies (a) 320kHz, (b) 420kHz, (c) 740kHz, (d) 4.7MHz, and (e) 6.77MHz.

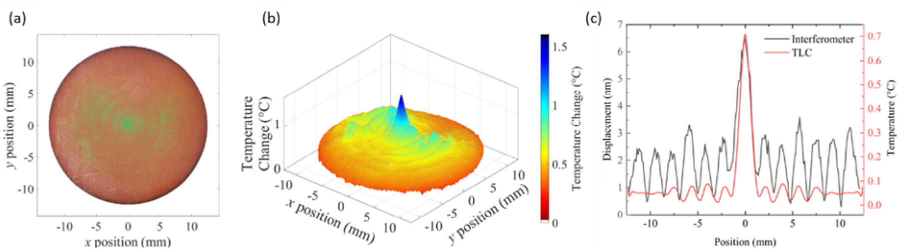

Figure 2. (a) Photo of the mode at 320kHz, (b) temperature map analysis of mode, and (c) comparison of average diameter lines from TLC and interferometer measurements.

[1] J. S. Sandhu, R.W Schoonover, et. al., Adv. Acoust. Vib., **2012** (2012).
[2] R.S. Edwards, J. Ward, et al., App. Phys. Lett., **116**(4), 044104, (2020).
[3] Y. Kagawa, T. Hatakeyama, et. al, J. Sound Vib, **36**(3), 407-IN6, (1974).