Liquid crystal devices in the mid-infrared using graphene electrodes


Dept of Electrical Engineering, Cambridge University, Cambridge, United Kingdom, CB3 0FA

The mid-infrared (MWIR) wavelength band stretches for 2 to 6 μm and is a relatively unexplored region of the optical spectrum for liquid crystal technology. The MWIR band has many applications in both the military and civil avionics industry, as it is possible to image high temperature and intensity heat signatures such as jet engines at these wavelengths. There are now optical sources becoming available at these wavelengths, hence there is an increasing need to be able to modulate and control the light. Liquid crystals have the capability to operate at these wavelengths, however there are several problems with trying to create effective devices both in terms of materials and cell construction.

One of the biggest problems in the MWIR is the choice of electrode structure as indium tin oxide (ITO) transmission drops rapidly to zero at 5 μm as shown in Fig 1a. One solution to this is to use silicon or germanium substrates which are both transmissive in the MWIR as well as conductive, however device fabrication is quite difficult and the ability to create a pixellated structure is further limited. Another alternative is to use CaF₂, which is transmissive across the visible and MWIR, but it is not conductive, hence an alternative electrode structure to ITO is required. Recent work at Manchester on graphene indicates that it is a very suitable alternative to ITO[1] and the spectrum in Fig 1b shows that it is almost totally transparent out beyond 10 μm, whilst remaining conductive enough to address a liquid crystal cell.

![Graphene and CaF2 comparison](image)

Figure 1 a) Transmission spectrum of a 20 mm thick glass/ITO liquid crystal cell showing the roll off of the substrate. b) Transmission spectra of a CaF2 and a CaF2 + graphene substrate. The loss of the graphene is less than 2%.

The next challenge is then to find a suitable liquid crystal material for the MWIR. Previous work has shown that cyano based materials have characteristic absorptions at 4.1 μm[2]. Modern active matrix display materials such as TL216 have been synthesised with no cyano based groups and hence do not have this problem. This material is also desirable in the MWIR as it retains a birefringence of 0.18[3] at 4 μm making it suitable for optical modulation. The spectrum shown in Fig 1a contains 20 μm of TL216. Devices based on both Si and CaF₂ have been fabricated using graphene electrodes and show strong modulation across the entire MWIR range.

References:

* presenting author; E-mail: tdw13@cam.ac.uk