Mastering liquid crystal phase technologies for terahertz communication

Terahertz radiation is very useful in a number of fields, including communications and biological imaging, but it has historically been difficult to control for such applications. Dr Masahito Oh-e at the National Tsing Hua University in Taiwan has been exploring how liquid crystal-based technologies might be used to make new devices to harness the power of terahertz radiation. In recent work, he has demonstrated how liquid crystals that switch their orientation in response to an applied voltage can shape terahertz radiation with rapid response times.

Any digital technologies, from televisions to communication, rely on the idea of control – where it is possible to change the properties of a material or the device by changing an external factor, such as a voltage or current. One of the most promising future technologies for wireless communication is the use of terahertz radiation because it offers an excellent way of performing high-bandwidth communication.

As we share more and more information digitally, networks and communications technologies have to become faster with more bandwidth to cope. Any technologies have to become faster digitally, networks and communications will want a large bandwidth to ensure the game or movie runs smoothly. For the visible or infrared light that is more commonly found in fibre optic cables, there are many devices that can be used to encode signals like the radiation, but this is not so common for terahertz radiation. Dr Oh-e’s novel type of liquid crystal switching for controlling terahertz radiation fundamentally changes the way that the device is therefore an important step in helping make terahertz radiation a more viable option for more efficient communications.

Dr Oh-e and his collaborators have successfully demonstrated the basic principles of a novel type of switching liquid crystals for THz phase modulation. Generally, phase shifters could be used to apply different phases to the terahertz radiation, which is a way of encoding information into the wave that could then be transmitted and used for applications such as telecommunications. One of the significant challenges of exploiting the potential of terahertz in communications is developing new devices that can control terahertz radiation and be used to manipulate properties like the phase.

Through this research on liquid crystal devices, Dr Oh-e aimed to develop terahertz modulation devices, including GREATER CONTROL.

Dr Oh-e has extensive experience in the field of liquid crystal displays and, in particular, controlling their switching for applications. Probably the most common place you will encounter liquid crystals is in display technologies. LCD (liquid crystal display) screens are often found in devices like computer monitors, digital cameras, and smartphones, and used to be a popular technology for televisions. Some of Dr Oh-e’s liquid crystal technologies have enabled the development of ultra-broad angle LCD screens, which are now an industry standard and used in portable devices such as iPhones.

While such technologies were known previously, a fundamental problem in making terahertz phase shifters to control the properties of the terahertz radiation was that the switching cells needed a thick cell gap, which caused a very slow liquid crystal response and made fast switching unfeasible.

By realising that combining in-plane with out-of-plane switching of liquid crystals could maximise the orientation range of liquid crystals, Dr Oh-e and his collaborators have found a novel way to control the terahertz radiation. Adopting both in-plane and out-of-plane switching in a display was previously not thought possible because it degrades the viewing angle characteristics in a display. Dr Oh-e aimed to change the conventional way of thinking when challenging an application of liquid crystals to the new frequency domain. Further, Dr Oh-e’s team found a way to overcome the issue of slow switching times with previous terahertz liquid crystal technologies by making special electrodes to allow for faster switching between three distinctive orientation states when an electric field was reversibly applied to the liquid crystal.

Dr Oh-e and his collaborators have successfully demonstrated the basic principles of a novel type of switching liquid crystals for THz phase modulation. A phase shifter. Electromagnetic waves, like terahertz radiation, have a ‘phase’ – a measure of how the wave has ‘shifted’ from a given reference point. For example, if you send a wave down a rope and measure the heights of the wave at different points along the rope, the displacement of the rope will be different in different sections, which is what the phase of a wave measures.

The phase of a wave is crucial. If the wave interacts with another wave, the relative phases of the two waves will determine whether the waves constructively interfere to amplify a signal or destructively interfere and cancel out, destroying the signal.
behaviour of the liquid crystals was not just dependent on the liquid crystal material itself but incredibly sensitive to the overall electrode geometries.

Dr Oh-e found that varying the electrode dimensions influences a number of parameters, such as the phase shift and response time of liquid crystal switching. From this finding, he proposed a novel type of liquid crystal switching, which enables reversible switching between the three orientation states of liquid crystals: two in-plane states and one out-of-plane state, just by changing the electrode layouts and geometries.

Now, Dr Oh-e has virtually demonstrated this idea in principle with liquid crystals capable of switching between the three states with a rapid response. This is part of the developments which have enabled the creation of more sophisticated terahertz phase shifters or modulators, however, addressing more challenges, including compatibility of tunability with rapid responses, low voltage operation, and broadening the phase range, is indispensable in addition to conducting feasibility studies.

Looking Ahead

Dr Oh-e’s current attempts to develop new phase shifters and modulators involve looking at some of the fundamentals of liquid crystal science and whether a rapid response is possible with a thick cell gap that is indispensable for terahertz modulation. If this attempt is successful, liquid crystal technology can be applied to terahertz modulation technology, which will be significant as an application beyond displays as well. Dr Oh-e believes properly unravelling the switching behaviour actually has a very strong influence, Dr Oh-e has not only been able to reveal more about exactly how the switching mechanisms of liquid crystals work but also provided suggestions of how electrodes might be tailored to achieve optimal designs. 6G testing is estimated for commercial release in 2030. Dr Oh-e’s developments might mean that 6G technologies end up being based on terahertz radiation, which has great potential for transferring vast amounts of data. The quest for liquid crystal-based terahertz devices continues.

Dr Oh-e’s developments may enable a potentially wider range of phase shifts with rapid responses using liquid crystals.

Research Objectives

Dr Masahito Oh-e aims to address current technical challenges by exploring multidisciplinary photonics and materials science.

Bio

Professor Masahito Oh-e earned his master’s degree from the Tokyo Institute of Technology, after which he worked as a research scientist at the Hitachi Research Laboratory of Hitachi, Ltd. He went on to earn his Ph.D. from the Tokyo Institute of Technology while also working as a research assistant at Hitachi, Ltd. He then became a visiting research fellow at the University of California, Berkeley. After several positions in industry and academia, Dr Oh-e began working as a professor at the Institute of Photonics Technologies, Department of Electrical Engineering, National Tsing Hua University, Taiwan. As one of the inventors of in-plane switching (IPS) liquid crystal displays (LCDs), Dr Oh-e made many frameworks for IPS electro-optical effects, and successfully developed ultra-broad viewing angle LCDs (recognised as IPS LCDs), which are now used in numerous common devices such as LCD TVs, tablets, and smartphones, including iPhones.

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Personal Response

What is a difficulty with this type of device and how can you solve the problem?

Although we have demonstrated the basic principles of a new type of switching liquid crystals in a thick cell gap, recent studies have revealed that tunability may not be compatible in principle with rapid responses. Unlike displays, however, there is no need to control liquid crystal switching for each pixel, and switching occurs uniformly on a screen. Therefore, it may be better to stack thin, fast-responsive liquid crystal layers and switch each layer differently. In other words, replacing a two-dimensional pixel array like a display with a one-dimensional stack of liquid crystal layers may enable tunability that is compatible with rapid responses.