Polarization imaging

APPLICATION NOTE

Introduction

Traditional cameras generate an image based on variation in intensity of the incident light. Polarization imaging is a technique whereby more information is extracted by also taking the polarization state of the light into consideration. By looking at the difference in images captured with light of different polarization, subtle variation in texture and form can be detected that is otherwise not easily seen. In the medical field this technique can for example be used to analyze superficial tissue for distinguish skin cancer from benign speckle patterns. In machine vision it is used for in-line inspection to detect the shape of single-colored or transparent objects, to read out detailed profiles such as a stamped code, and to investigate stress in materials. Polarization imaging can also be used to detect objects in poor lighting conditions such as fog or smoke.

Problem

There are several ways to realize a polarization imaging system. One simple way is to use a standard image sensor with a polarizer that can be rotated to only transmit light with a certain polarization axis. Several images are taken in a sequence with the polarization axis changed for each image. However, the technique relies on the mechanical motion of the polarizer which limits the speed of the image capture, the accuracy, as well as the durability of the system. Another way is to use a prism to split up the incident light into several beams. Each beam goes through an individual polarizer with a different polarization axis than the others and falls onto individual image sensors. In this way all the information is recorded simultaneously. But it requires more than one image sensor and a high quality prism, making it a quite advanced and expensive design. Yet another approach is to put small polarization filters directly on top of the individual pixels in the image sensor. For example alternating rows of pixels can have polarizers with different polarization direction. All information is recorded simultaneously, but a specially designed image sensor is required making it an expensive approach. Furthermore, the resolution is sacrificed as separate pixels needs to be dedicated for the different polarization directions. The three approaches described above are either limited in performance or rather expensive.

Solution

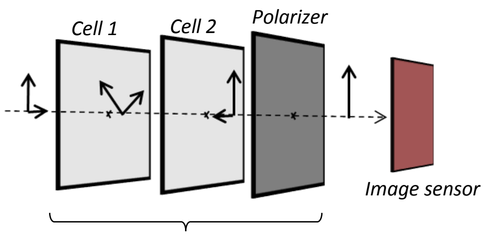
One way to realize a polarization imaging system without the need for multiple- or advanced sensors and without the problems with moving parts is to use a polarization modulator based on liquid crystal (LC) technology, such as the Fast Polarization Modulator (FPM) series from LC-Tec. The polarization modulator consists of a LC cell with an exit polarizer. Without any voltage applied to the LC cell the incident light experiences strong birefringence and the polarization direction is rotated.

When a sufficiently high voltage is applied the birefringence is removed and the polarization of light passing through the LC cell is unchanged. Only light with polarization direction parallel to the exit polarizer will be transmitted to the image sensor and contribute to the image. Polarization imaging is achieved through time-multiplexing by synchronizing the polarization switch with the image capture.

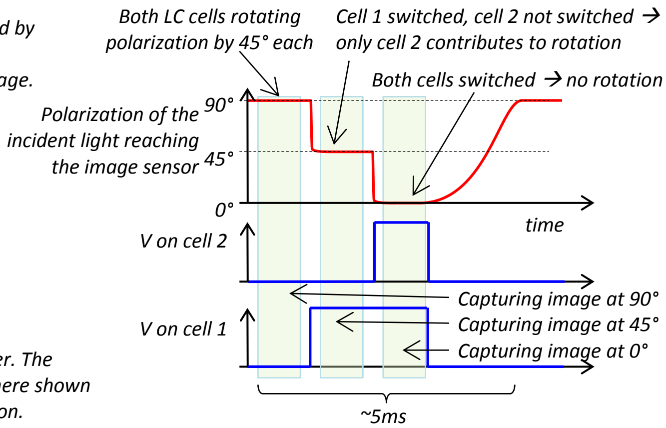
If more than two polarization directions are of interest (*e.g.* 0°, 45°, and 90°), the **X-FPM(3L)** model is highly suitable. This model consists of two stacked LC-cells, each rotating the polarization 0° or 45° depending on the applied voltage. Zero voltage applied to both cells gives 90° rotation, full voltage applied to only one cell gives 45° rotation, and full voltage applied to both cells gives 0°. The switching between each state can be achieved in 50µs when going from high to low angles, but 1.6ms for the opposite direction. The reason for this asymmetry in switching speed is that the former switch process is voltage driven, while the latter is a pure relaxation. The fast switching enables frame rates up to 3x200 FPS, and the fact that the systems contain no moving parts makes it very rugged and reliable. Furthermore, it only requires a single standard image sensor.

X-FPM(3L) principle of operation

The polarization components of the incident light are rotated by LC cells 1 and 2. Only light with polarization parallel to the polarizer transmission axis passes and contributes to the image.



The X-FPM(3L) consists of two stacked LC cells and a polarizer. The three parts are sandwiched together in the real device, but here shown as separate components to illustrate the principle of operation.



Advantages

- ✓ Only one image sensor required
- ✓ Can use a standard image sensor (no need for special design)
- ✓ No moving parts
- ✓ Large design freedom
- ✓ Fast switching
- ✓ Excellent optical quality
- ✓ Ruggedized
- ✓ Reliable

Main characteristics

	X-FPM(L)	*X-FPM(3L)*
Drive voltage	18V	18V
Transmitted polarizations	0° or 90°	0°, 45°, or 90°
Switching time, 90° → 45°, 45° → 0°, or 90° → 0°	≤50µs	≤50µs
Switching time, 0° → 45°, 45° → 90°, or 0° → 90°	≤1.6ms	≤1.6ms
Size	Custom designing up to 14 x 16 inches	

For more information, please contact us at: info@lc-tec.se.

