6 Future Polarizational Cameras

6.1 Polarization-Sensitive Chips

The polarimeters described in Chapters 2-5 utilize optical imaging systems that are external to the detectors. Compactness of design and speed of generating polarization images can be enhanced greatly by incorporating an array of microscopic polarization filtering optics directly onto a photosensitive chip. Wolff and Andreou (1995) started to develop a next generation of polarizational cameras. They designed a prototype of a polarization-sensitive chip with three photosensitive scanlines. Each scanlines consist of 128 pixels and are coated with one of 0^o, 45^o or 90^o orientations of linearly polarizing material deposited directly onto each column of sensing elements. Three horizontally adjacent pixels with, respectively, 0^o, 45^o and 90^o orientations produce one measurement of partial linear polarization. The controller of the chip is interfaced with a computer-guided scanning digitiser. The three columns of polarization component data are digitised, and are converted, using the composite (hue-saturation-brightness) visualization scheme, into a pixel column of false-coloured image. This one-dimensional polarization-sensitive chip is a precursor of two-dimensional polarizational camera chip arrays, which are currently under development.

6.2 Polarizational Cameras

A common design for colour cameras is to use a non-polarizing beam-splitter that directs equal amounts of incoming light onto three separate CCD sensors for the red, green and blue spectral ranges. If a linearly polarizing filter is placed over every CCD, each filter having a unique direction of its transmission axis, a so-called "polarizational camera" using a non-polarizing beam-splitter can be built that operates in white light or in a given part of the spectrum, if a colour filter is added in front of the lens system of the camera. This design was suggested by Wolff (1993) and first realized by Hanlon et al. (1999).

Wolff and collaborators are in the process of developing self-contained VLSI versions of polarizational cameras that sense complete states of partial linear polarization on-chip, compute state of linear polarization, and compute visualization or physical information related to sensed polarization. VLSI offers very high computational throughput so that VLSI polarizational cameras enable operations at very high speeds.

Kalayjian et al. (1996) designed a one-dimensional polarization contrast retina that can be used as polarimetric scanning sensor for real-time, automated vision tasks. The retina employs two parallel linear arrays of 29 photodiodes as sensing elements. Polarizing material is placed directly over the photodiodes so that each diode array receives totally linearly polarized light. The transmission axis of the polarizer on the first row of diodes is perpendicular to that on the second row. An on-chip analog circuit computes the polarization contrast with comparing the output signals of the two diode rows. In order to enhance the spatial resolution and to extend the one-dimensional array to high-density two-dimensional polarization contrast sensors, the commercially fabricated macroscopical linear polarizer should be replaced by a two-dimensional array of microscopical, pixel-sized areas of linear polarizers with lithographic techniques used in CMOS circuit fabrication.

A polarizational camera is a generalization of the conventional intensity camera. If necessary, the former can function as the latter. Adding colour-sensing capability to a polarizational camera makes it possible to sense the complete set of electromagnetic parameters of light incident on the camera. Polarizational cameras have more general capabilities than standard intensity cameras, and can be applied for different purposes (see Chapter 2).