MA3 SMARTER SENSOR PIXELS THROUGH GEOMETRY CONTROL

K. Engelhardt, J. Kramer, D. Leipold, J.M. Raynor, P. Seitz
Paul Scherrer Institute Zurich, Badenerstrasse 569, CH-8048 Zurich, Switzerland

E. Tan
McMaster University, 1280 Main Street West,Hamilton, Ontario, Canada

Data acquisition in optical metrology is usually performed with linear or two-dimensional regular (rectangular) arrays of photosensitive sites (pixels), such as photodiode lines or CCD image sensors. The extremely regular spacing of the individual detector elements provided by the lithographic step in production allows very accurate localization of image structures on the sensor array with a precision of better than 1% of the pixel-to-pixel spacing [1]. In many problems of optical metrology, however, some *a priori* information about the image image structure of interest is known. In these cases, adaptation of the sensor geometry to the particular problem greatly simplifies image data acquisition and processing.

A first step in this direction was the "low cost smart camera" [2] which, under software control, allows to select pixels in an optimum order for rapid processing at video field rate (60/50 Hz).

Much more can be done if the sensor and pixel geometries are tailored to a specific problem. An example of this is active triangulation in the form of light sectioning for the acquisition of the three-dimensional (3-D) shape of objects, where the centroid of light stripes must be determined. If the image is sampled by a conventional image sensor the whole image has to be digitized, stored in memory, and processed. For a high-speed low-cost 3-D camera, a linear photodiode array was modified with a special chrome mask to obtain a linear array of triangularly shaped photodiodes [3]. The signals of two adjacent pixels of this array can rapidly be evaluated with simple lookup-table operations to obtain the center-of-gravity of the line image. Depth maps with 250v×125h pixels and an accuracy of about 3% of the depth range are generated at video rate (CCIR video signal with 50 fields per second)

Smart photodetectors which perform signal processing in the optical domain by their geometric shape can be realized with simple means and at high accuracy as so-called photo-ASICs using standard CMOS process [4]. Photodiodes fabricated with an inexpensive single-metal single-poly CMOS process (SACMOS 3, FASELEC Corp., Zurich) showed a high external quantum efficiency of up to 80% and a good uniformity of sensitivity over the light-sensitive area as documented by a non-linearity of PSDs (position-sensitive devices) of only 0.25%. Virtually all geometrical shapes of the light sensitive area can be realized. The only restriction is imposed by the smallest feature

size defined in the design rules of the semiconductor process. We have found, however, that e-beam produced masks with unusal, non-rectangular structures will in general be reproduced with a precision exceeding the smallest feature size.

This feature was exploited in the realization of an array of four sinusoidally shaped photodiodes performing a complex Fourier transform at a single spatial frequency. The application of the sensor is the high-speed detection of the relative phase of a grating image.

A specially shaped photodiode was designed and fabricated for the application in a single-chip planar triangulation range-finder. Due to its specific shape the detector will produce an output voltage which is linearly dependent on the measured range.

Geometry-controlled smartness of photodetectors can also be made dynamic. We have investigated special CCD image sensors fabricated with the CCD process available from Orbit Inc. (USA). By providing more clock lines in the horizontal and vertical direction, photogenerated charge can be summed over given areas by clocking the lines suitably. In this way the size and shape of the individual pixels can be determined purely electrically. Another CCD has been studied, the "optical lock-in" CCD image sensor, in which the photosensitive pixels are periodically "hidden" under an opaque light shield by applying appropriate clock signals.

In this work various novel photo detectors were realized and are currently under characterization. As shown by others, see for example [5], we are currently adding digital control logic (e.g. multiplexers) on the detector chip as well as circuits for signal processing like integrators, operational amplifiers and A/D converters. The combination of specially shaped photodetectors for optical pre-processing or temporally modulated photo detectors with dedicated analog and digital electronics on a single substrate will be a powerful tool for the realization of low-cost, robust and high precision systems in optical metrology.

References:

[1] P. Seitz, "Using CCD image sensors as high precision optical measurement instruments", Bull. Swiss Assoc. Sensor Technology, Vol. 05/1990-1, Nov. 1990, p.23.

[2] F. Buechli, E. Heeb and K. Knop, "Low cost smart camera", SPIE 595 (1985), 278.

[3] J. Kramer, P. Seitz, H. Baltes, "An inexpensive real-time 3-D camera with a smart optical sensor", Sensors and Actuators A (1992).

[4] J. Kramer, P. Seitz, H. Baltes, "Photo-ASICs: Integrated circuits for optical measurements using industrial CMOS technology", Proc. Transducers '91 (1991), 727.

[5] E.R. Fossum, "Architectures for focal plane image processing", Opt. Eng., Vol. 28 (1989), 865.