Replacing Optical Lenses by Silicon Structures

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Abstract

Since the start of photography, image optics, recording and display has been analog. In the forties, analog image display has been partially replaced by digital displays: through the line based CRT screen. In the early eighties, also image recording has been digitized thanks to solid state silicon imagers. We are now at the edge of digitizing the last analog part in the image handling flow: the optics. By making opto-mechanical structures in silicon matching the size of the wave length of light, the large, heavy, fragile and costly optical lenses can be replaced by cheap mass produced silicon, often integrated together with the imager and/or processing logic in a heterogeneous stack.

This presentation first describes the opportunities silicon processing offers to replace lenses, as well as the requirements that have to be met to make such a replacement successful. Examples are given of a few applications domains that benefit from silicon lenses. Next, one application area is presented in more detail, namely fast and cheap hyperspectral imaging. The adoption of hyperspectral cameras by industry has so far been limited due to their limited speed, limited compactness and their high cost, all caused by the need for many high quality optical lenses. Silicon structures allow to counter all these drawbacks. A novel hyperspectral sensor is detailed with the following key innovations: a Fabry-Pérot wedge filter monolithically integrated on top of a standard CMOS sensor; processed with minimal cavity sizes and integrated with the needed software to improve image quality. The result is a compact 2 megapixel sensor with a spectral range between 550 and 1000 nm and a spectral resolution lower than 10 nm. The speed is 340 fps at illumination levels as used in machine vision. Developing such a breakthrough solution required intense cross-disciplinary collaboration between process technologists, circuit designers, optical experts, camera and system designers, image enhancement specialists, image classification specialists and application experts. The design approach followed will be explained, as well as the need to develop special software tools to emulate the complete system, including lighting, lens aberrations, process technology variability, mechanical variability, optical distortions and software correction algorithms.