Extended Depth of Field With the Logarithmic Asphere

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Conventional camera lenses record pictures that are sharply focused at a specific distance set by the photographer. There is a certain range around this distance, known as the depth of field, for which the picture is fairly clear. Outside of this range, the picture is badly blurred. With smaller f/#, the depth of field is smaller.[1]

Many investigators have sought to improve this situation, i.e., to obtain a greater depth of field at a given f/#. A noteworthy improvement is the cubic-phase mask reported by Dowski and Cathey, in which digital processing is used to improve a recorded picture that uses their novel lens and phase plate[2].

In our study of this basic problem, we sought a solution consisting of a circularly symmetric lens that has a radially varying focal length. This led us to a new class of lenses that we call "logarithmic aspheres."[3]

At any range there is an annular ring that provides a sharp image while the remainder of the lens records a blur. Digital processing is then used to remove the blur. Figure 1 shows the setup with an object at 950 mm. Since the steps are 50 mm each, the closest step is at 700 mm. We see that excellent recovery is obtained using an image-plane form of the Weiner-Helstrom filter (b,c). Even better contrast and less ringing are obtained by use of maximum entropy processing (d,e). The depth of field is increased about tenfold. Impressively, too, the impulse response is theoretically diffraction limited. Moreover, one can simply insert a logarithmic phase plate in an existing camera lens and obtain the same improvement.

Two modern machines are employed in fabrication. One is the Model SX50 computer-controlled grinding machine manufactured by OptiPro Systems, Inc. The polishing and fine figuring is obtained using QED Technologies magnetorheological finishing machine. The lens is fabricated in an optical grade of quartz to an overall accuracy on the order of one-tenth wavelength.

Applications can be foreseen for imaging conditions where depth of field is an important issue; they include the single use camera, the microscope, digital video and DVD pickup modules.

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