

Champagne E B. Nonparaxial imaging, magnification, and aberration properties in holography. *J. Opt. Soc. Amer.* 57:51-5, 1967.
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The imaging properties of the diffractive optical elements characteristic to off-axis holography are developed. The image reconstruction angle is found to be that described by classical diffraction from a grating and is a function of the incident angle, the reconstruction wavelength, and the grating pitch. Critical reconstruction angles are explained. The influence of photographic magnification is explained and mathematical forms for the basic Seidel aberrations of astigmatism, coma, and spherical aberration are presented. [The *SCI*[®] indicates that this paper has been cited in over 110 publications since 1967.]

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"In the early 1960s many people found themselves in newly formed government laboratories which had just been split off from an Air Force product development division. The motivation for the split was the establishment and maintenance of a broader technology base than was probable under the constraints of product deadlines (we now find ourselves being incorporated back into a product division to facilitate technology transfer). Part of the newfound freedom was an encouragement (at least not a discouragement) to form in-house research projects. This fit quite well with a number of us in the laser based activities who were searching for thesis and dissertation topics. This 'thing' called holography had just been serendipitously rediscovered by Leith. It was a fascinating thing, perhaps even a savior for the laser. We, along with what appeared to be the world, bought Spectra-Physics 125 lasers, collections of optical components, granite tables, and Kodak 649F spectrographic plates. We began to make holograms.

"In my case, I began by making holograms of point sources. They were simple, allowed

me to learn some photographic processes, and produced nice spectra. These point-source holograms produced fascinating, delicate, and, at the same time, complex real images when reconstructed with the laser. Could these patterns be quantified? I found some of the patterns were similar to the classical Seidel aberration patterns called coma and astigmatism. I was familiar with the analytical work of Leith's group at the University of Michigan and obtained a preprint of Meier's paper.¹ These works explained what I was seeing in a qualitative manner, but failed a first-order quantitative analysis. In particular, critical or limiting reconstruction angles were not explained. This cutoff was quite noticeable when the reconstruction wavelength was longer than the recording wavelength (one condition Gabor proposed for magnification).

"The reconciliation lay in distance expansions about the ray to the point of interest. The first and probably the most important thing which fell out was an image reconstruction angle, which is a function of the reconstruction wave front angle, the wavelength, and the period of recorded interference pattern. This is basic grating theory. Expressions for fringe pattern magnification, wavelength change, and classical third-order aberrations followed rapidly and were published in the subject paper. Experimental verification of the aberration expressions and the influence of wavelength change continued. The total package, along with a chapter on two-dimensional imaging, is published in my dissertation.² The results appeared, and still appear, applicable to any diffractive element operating at any wavelength, i.e., acoustical interference patterns photographically sealed, and images reconstructed using visible light. I felt good, and still feel good, about the product.

"I feel the paper is highly cited because it is basic to computer based holographic optical element design programs, as has been pointed out by Sweatt.³ The diffraction equation and not Snell's law (as in optical design programs) determines the amount the incident ray direction is altered. A thesis by Peng⁴ recently came across my desk. It appears to be a rather complete modern summary and contains the results of experimental verifications."

1. Meier R W. Magnification and third-order aberrations in holography. *J. Opt. Soc. Amer.* 55:987-92, 1965. (Cited 215 times.)
2. Champagne E B. *A qualitative and quantitative study of holographic imaging*. PhD thesis. Columbus, OH: Ohio State University, 1967. 139 p.
3. Sweatt W C. Mathematical equivalence between a holographic optical element and an ultra-high index lens. *J. Opt. Soc. Amer.* 69:486-7, 1979.
4. Peng K. *Imaging by curved holographic optical elements*. Pijnacker, the Netherlands: Dutch Efficiency Bureau, 1983.