Proceedings of SPIE 1927, pp.686-708 (1993)

Vector aerial image with off-axis illumination

Eytan Barouch, Uwe Hollerbach, Steven A. Orszag
Program in Applied & Computational Mathematics
Princeton Univ., Princeton, NJ, USA

Daniel C. Cole
IBM Corp., Essex Junction, VT, USA

ABSTRACT

As the numerical aperture (NA) in optical projection systems increases, the vector nature of the projected electric and magnetic fields becomes more important. Recent advances in off-axis illumination, tilting condenser lenses, and applying spatial filters, as well as phase-shift masks, hold the potential of increased depth of focus. To simulate these techniques in the high-NA regime, we have developed new fast algorithms. The development reported here builds on our recent work [1] extending scalar aerial imaging. The systematic treatment of [1] has now been applied to account for the vector nature of light.

The optical projection system examined here involves an alpanatic lens system with high NA and finite magnification as applied to both i-line and deep-UV, 4x and 5x, steppers.

Our new algorithms owe their genesis to a variety of subtle mathematical properties of the scalar and vector aerial image formulae. These new algorithms are based on our high NA aerial image model juxtaposed with Yeung's [2] original ideas for the vector field image. This formulation, which involves non-uniform grid fast Fourier transform techniques, has resulted in a tremendous speedup of the aerial image simulation with uniform accuracy throughout a domain of 1000μ x 1000μ and beyond, with the potential to simulate an entire chip, thus providing a solution to the "grand challenge" of full-chip design.