Freeform optical elements will have a profound importance in the future of optical technology. Orthogonal polynomials added into conic sections and recently radial basis functions were investigated for optical freeform shape descriptions. The first part of this dissertation focuses upon describing freeform optical surfaces with polynomials and shows their limitations, such as the number of terms required as well as edge-ringing and ill-conditioning together with possible remedies. We show that an edge-clustered grid that effectively surpasses the edge-ringing and yields exponential approximation convergence rates. Provided different grid types, we furthermore compared the efficacy of using different types of polynomials, namely Zernike and gradient orthogonal Q-polynomials.

In the second part of this dissertation, we present an efficient, localized, and hybrid surface description method combining assets of radial basis functions and local polynomials. The method reduces the order of polynomials terms required for freeform surface description and applicable to general apertures due to its locality and stitching properties. Instead of thousands of terms including many higher orders, we show that the method makes use of low order 25 terms of Zernike polynomials in each subaperture to reach subnanometer accuracies.

Finally in this dissertation, the benefits of making an effective use of impressive computational power offered by multi-core platforms for the computation of polynomials are investigated. The polynomials, specifically Zernike and gradient orthogonal Q-polynomials, are implemented with a set of recurrence based parallel algorithms on Graphics Processing Units. The results show that more than an order of magnitude speedup is possible in the computation of polynomials over a sequential implementation.

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The public is welcome to attend.