



Fig. 7. (a) Modal decomposition without physical lens and decomposition into modes without curvature. (b) Modal decomposition into modes that incorporate the wavefront curvature measured in Fig. 6 for a physical lens $f = 1000$ mm. The insets depict the corresponding mode intensities.

the wavefront reconstruction using a CGH is very beneficial for some reasons. One is the spatial resolution: whereas the Shack-Hartmann sensor is very limited in resolution by the number of microlenses, the resolution of the wavefront determined by the CGH has no theoretical limit. Since the directly measured values (modal powers and phases) are scalar numbers, the resolution from a practical point of view is given by the number of pixels per unit length with which the modal fields can be calculated. A second advantage is the extension of the measurement area of the wavefront. Regarding the Shack-Hartmann sensor it is immediately clear that the wavefront cannot be measured at points where there is little or no intensity, as for example at phase singularities. Of course this is also limiting for the minimization of the integral in Eq. (9). In contrast, the phase of the beam, as determined by the CGH, is defined everywhere, i.e., also in regions with no intensity. Another issue is represented by the measurable wavefront slope. The slope limit for the Shack-Hartmann sensor is given by the case where the focus of one microlens is shifted to the evaluation area of an adjacent lens. Concerning the reconstruction with the CGH there is no theoretical limit regarding the wavefront slope, e.g., phase jumps are easily detected.

11. Conclusion

In conclusion, we presented a new method to reconstruct wavefronts based on modal decomposition using computer-generated holograms. We have illustrated the power of the method by reconstructing wavefronts from both fiber and free space modes by a modal decomposition of the field. The versatility of the approach was demonstrated by studying arbitrary mode superpositions, complex polarization properties, vortex beams and aberrated Gaussian beams. Different reconstruction options were outlined, such as reconstructing the wavefront from the phase distribution for scalar beams without phase singularities and jumps, and reconstruction from the Poynting vector for the general case of inhomogeneously polarized beams. Our results were validated by comparison with Shack-Hartmann measurements. Pros and cons of wavefront reconstructions based on modal decomposition with respect to Shack-Hartmann measurements were discussed regarding applicability, measurement rate, spatial resolution, area of measurement, and measurable wavefront slope. The most striking advantages of our method is seen in spatial resolution, area of measurement, and measurable slope.

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