Rapid, accurate, and high-resolution metrology of aspheric optics — can we "have it all"?

Gregory W. Forbes forbes@qedmrf.com
QED Technologies, Rochester, NY 14607

Performance requirements for optical metrology systems are strongly application dependent. In fact, since the advent of deterministic finishing, metrology is integrated even more tightly into optics fabrication. Two types of recurring questions now drive some of these requirements: (i) With this metrology, can I be confident in determining whether a part meets the stated spec? and (ii) Can I reasonably expect to improve the part by using this metrology as input for an additional cycle of finishing? The latter question has the added requirement that quantified maps of figure error must have an explicit correspondence between points in the map and all points on the test surface. Increasingly, the former proceeds by reference to the power spectrum density (PSD) of the surface's deviation from its desired nominal shape. This spectrum spans from figure/form through waviness/mid-spatial frequency and down to roughness (although roughness is generally treated separately). As optical tolerances tighten in high-end applications, and as designs require stronger aspheres, metrology often ends up on the critical path in terms of meeting specifications and schedules. This puts an increasingly heavy emphasis on characterizing metrology performance and understanding the real requirements. These tasks are by no means trivial. Nevertheless, the question posed in the title can be addressed in general terms.

In terms of accuracy, resolution, and speed/versatility, interferometric systems have uniquely met the requirements for the metrology of spherical optics. Speed is the chief sense in which these systems are not consistently stretched by current engineering requirements; these systems are oftentimes inadequate in terms of their aperture capabilities (both clear aperture and numerical aperture) and especially in their ability to deal with aspheres. While aspheres can be addressed by using dedicated nulls or coordinate measuring machines, such approaches come at the cost of one or more of speed/versatility, resolution, or accuracy. A natural option for trying to have it all is to supplement the existing workhorses with significant new capabilities.

Every decade or two, we are handed a factor of a thousand in terms of added computing power: gigaflop processors coupled with gigabytes of RAM and hard disks holding hundreds of gigabytes are now everyday. By coupling this new power to high-precision computer-controlled machines, it would be surprising if we could not greatly amplify the capabilities of a variety of optical metrology systems that gather megapixels of data at each shot. Further, since speed is typically not a key limitation, it should be workable to gather a variety of complementary data sets and fuse them via a range of possible numerical processes. In particular, we present new ideas and results to demonstrate that the old notion of data stitching is ripe for exploiting these new capabilities. In fact, stitching can simultaneously improve the performance of metrology systems in each and every metric mentioned above. It is only in that sense that we can hope to fleetingly have it all. The good news for those who relish a challenge is that, for the foreseeable future, at least the goal posts for accuracy and aspheric departure are sure to keep moving beyond whatever is delivered.

Key words: asphere metrology, stitching interferometry