Lenses for Micro-machining with Fiber Lasers

by Lynore M Abbott and Kevin Christensen, CVI Laser, LLC

Micro-machining applications require beam quality approaching diffraction limits for best performance which is why fiber lasers are becoming a popular choice in this space. Optics become critically important in order to realize all the benefits a fiber laser can provide.

Surface Quality

10-5 MIL-PRF-13830B is the best surface quality available at reasonable prices and quick deliveries. 10-5 relates to the size and frequency of scratches and digs in the polished surfaces. The lower the number the more pristine is the surface. Scratches and digs cause scatter which decreases the laser intensity at the desired focal point. Scratches and digs can also create hot-spots which can lead to a catastrophic laser damage of the component.

For demanding laser material processing applications, 10-5 is considered the required minimum specification.

Transmitted Wavefront Distortion

For micro-machining, minimizing all sources of wavefront distortion is critical for best performance. The three sources of wavefront distortion are astigmatism, coma, and spherical aberrations.

Coma — this off-axis non-symmetric wavefront distortion increases linearly with field angle or distance from the principal axis. See Figure 1.

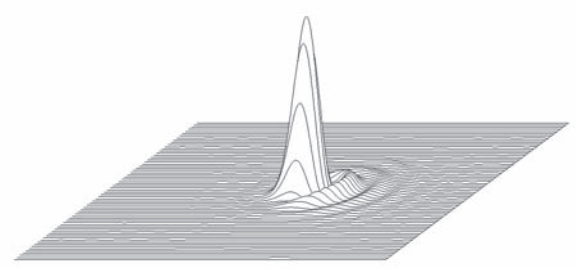

Figure 1. Uncorrected coma leads to irregularly shaped focus spots or a change in magnification with field angle. This illustration of the point-spread function of a lens with coma shows clearly non-symmetric wavefront distortion.

Spherical Aberrations — this axially symmetric distortion occurs when collimated rays passing through the outer zones of the lens focus at a different distance from the lens than rays passing through the central zone. See Figure 2.

Figure 2. Uncorrected spherical aberrations lead to blurry focal spots. This illustration shows the point-spread function of a lens with spherical aberration at marginal focus.

Astigmatism — this aberration results in the tangential and sagittal image planes being separated axially. This is characterized by a saddle, or "pringle", wavefront. This will appear as two distinct focal points. This is not typically an issue for on-axis applications

Good quality lenses correct for astigmatism. Bestform singlet lenses minimize coma and spherical aberrations. Further system improvements can be realized through the use of aplanatic multi-element lenses which more completely correct coma and spherical aberrations.

The graph below (Figure 3) depicts high quality (10-5, λ/10 TWD) Plano-Convex (PLCX) and Bestform (BFPL) singlets plotted against an equally high quality aplanat at 1090nm. The benefits to system performance by using a Bestform positive lens or an aplanat are remarkable in comparison to the Plano-Convex singlet lens.

For micro-machining applications, industry leaders rely on bestform or aplanatic lenses to maintain the excellent beam quality of the fiber lasers. For superior performance, the aplanat is the best choice for smallest spot and highest energy at the work surface.

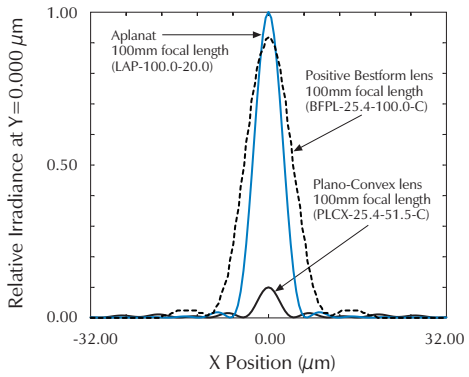

Figure 3. The graph depicts high quality (10-5, λ/10 TWD) Plano-Convex (PLCX) and Bestform (BFPL) singlets plotted against an equally high quality aplanat (LAP) at 1090nm.

continued

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Recommended Components from CVI

PLCX Singlet Lenses

BK7 or Fused Silica Spherical Plano-convex lenses, 1" or 25 mm in diameter with an AR V-coat or broadband AR coat will work for many micro-machining applications. CVI offers literally dozens of these lenses in these diameters with radii of curvatures ranging from 75 mm to 10,000 mm. For higher damage threshold performance, choose V-coat anti-reflection coatings and/or Fused Silica substrates.

BFPL Positive Bestform Lenses

BK7 or Fused Silica Positive Bestform lenses, 1" or 25 mm in diameter with an AR V-coat or broadband AR coat will work even better for many micro-machining applications. The CVI offering comprises more than a dozen lenses in the 1" diameter with focal lengths ranging from 50mm to 200mm. For higher damage threshold performance, choose V-coat anti-reflection coatings and Fused Silica substrates.

LAP and LAPQ Aplanats

As seen in Figure 3, for absolutely best performance the aplanatic lens is corrected for all of the major wavefront distortions providing the best beam quality, the smallest most perfectly focused spot, and the highest energy at the work surface. For critical micro-machining applications, the LAP will improve system performance the most compared to singlets. The focal length ranges for the LAP and LAPQ are from 5 mm to 500 mm. LAP is the product code for the SF11 version of this multi-element lens. For the highest laser damage threshold, we recommend the LAPQ Fused Silica Aplanat with a narrowband "V"-coat anti-reflection coating.

LAP/APM and LAPQ/APMQ Triplet Aplanats

To shorten the focal lengths while maintaining the best beam quality, CVI manufactures an LAP/APM Aplanatic Meniscus Lens assembly. The housing for the APM and APMQ are designed specifically to hold the APM Meniscus Lens at the proper stand-off distance from the matching LAP for best performance. The LAP/APM in SF11 and the LAPQ/APMQ in fused silica will provide an f number of 3.3 and maintain an optimized beam quality.

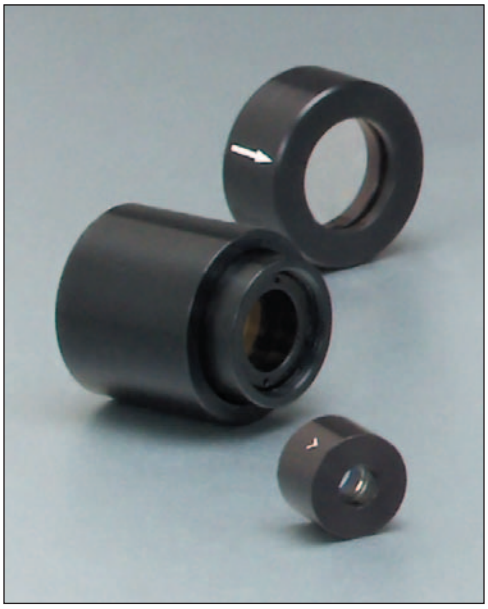

Figure 4. Pictured above are aplanat doublet and triplet assemblies. The large assembly in the middle comprises a LAPQ aplanat doublet combined with an APMQ aplanatic meniscus lens.

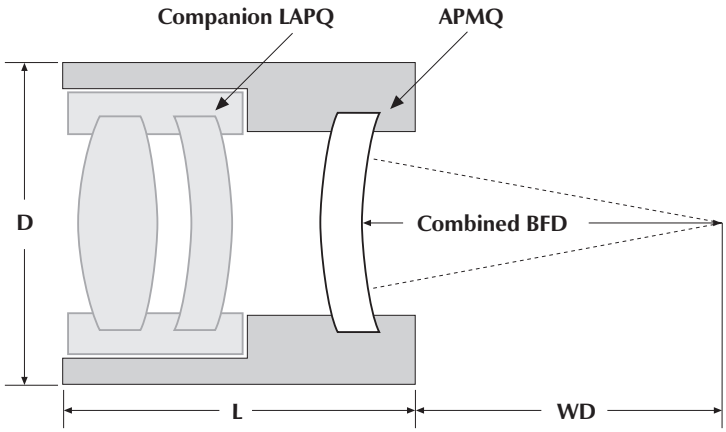

Figure 5. Schematic depicting an APMQ housing integrated with a LAPQ aplanat doublet assembly.

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