

Grinding and polishing of nontraditional optical shapes for military use requires moving beyond traditional fabrication techniques.

Advanced manufacturing generates conformal optics

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The military battlefield requires weapon guidance, threat detection and recognition, and targeting optical systems that operate in all conditions, day or night, in difficult and varied settings. To fulfill these needs, high-precision optics have become pervasive in the military—ranging from simple night-vision systems for infantrymen to far-more-complex systems such as laser rangefinders, target designators, missile seekers, threat detectors for aircraft, precision guided munitions, and cruise missiles. All projections for future military systems indicate that the trend toward higher-performance optical solutions will continue to accelerate.

As next-generation weapons systems evolve, military prime contractors must contend with the conflicting requirements of high optical-system performance, low aerodynamic drag, and low observability. Attempting to fulfill these requirements using traditional optical shapes—spherical lenses and flat windows—results in unacceptable compromises, making traditional optical shapes completely inadequate for many next-generation systems (see Fig. 1).

In addition, fabricating nontraditional optical shapes in hard, brittle optical materials to extremely accurate optical-system demands using traditional methods is very difficult, leaving no realistic manufacturing solution. The machining precision needed to meet the system-performance requirements for nontraditional military optics exceeds the capabilities of commercially available machine tools and processes by two to three orders of magnitude. Additionally, glass and infrared crystalline materials are several times harder than the hardest hardened steel or superalloys, with some of the preferred materials, such as chemical-vapor-deposition diamond, metal-matrix composites, and sapphire being among the hardest and most difficult-to-work materials known.

The combination of high-accuracy requirements and difficult materials pushes the sensor optics required for next-generation systems well beyond the range of current grinding



FIGURE 1. Conformal optics have aerodynamic and other advantages over conventional optics. Night Vision Pilotage System (NVPS) for a Comanche helicopter consists of a segmented window that can be replaced with a curved conformal window to reduce radar signature.

and polishing capabilities at any affordable cost. For this reason, the Center for Optics Manufacturing (COM) at the University of Rochester (Rochester, NY) and QED Technologies, LLC (Rochester, NY) are working to systematically identify and overcome the obstacles—both in manufacturing technology and cost—that prevent the use of nontraditional optical shapes and materials in next-generation optical sensors.

Deterministic microgrinding

The use of computer-controlled machining and the deterministic microgrinding process can be extended from the fabrication of traditional optical shapes to the making of aspheric and free-form optical surfaces that conform to the shape of the platform into which they are mounted. Two new machining and finishing centers being developed by COM under the US Defense Advanced Research Projects Agency Precision Conformal Optics Technology Consortium will soon demonstrate production feasibility. The centers will automate the production of a wide variety of refractive and reflective optics in nontraditional shapes.

A major milestone has been the completion of a new conformal deterministic microgrinder. The new microgrinder (Nanotech 500FG; Moore Nanotechnology Systems; Keene, NH) will provide the optics industry with next-generation conformal-optics-manufacturing capability. Conformal optical shapes include both axisymmetric and nonaxisymmetric optical components and can have a combination of aspheric, spherical, cylindrical, conical, diffractive, plano, or ogive (pointed) shapes. The computer numerically controlled, multi-axis, ultraprecision machining system is capable of generating arbitrary conformal optical surface shapes (including non-axisymmetric) within a 250 × 250 × 300-mm machining envelope. Grindable materials range from optical glass and infrared materials to nonferrous metals, crystals, polymers, and ceramics.

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