Compact Alignment for

AS the idiom says, necessity is the mother of invention, which is exactly what led Livermore physicist and optical engineer Mike Rushford to develop the laser beam centering and pointing system (LBCAPS). His inspiration was the Advanced Radiography Capability (ARC) System, a petawatt-class quad of laser beams used at the National Ignition Facility (NIF) to diagnose the compression and ignition of a target during a shot.

"Each of ARC's beams must be pointed parallel to a specific input axis and centrally focused to safely reach the target," says Rushford. Previous instruments to ensure this accuracy required two separate sensors, two cameras, and various pieces of equipment in between. "However, where ARC is located on NIF," says Rushford, "space doesn't exist for a conventional system. We needed something smaller, cheaper, and with fewer cameras because of ARC's proximity to the main chamber and the risk of damage that might require system replacement." The result is a 17.8-centimeter-long cylindrical tube with one bifocal lens that images both the centering and pointing information onto one camera, cutting the cost of beam alignment in half. Rushford received an R&D 100 Award for his invention.

Physicist and optical engineer Mike Rushford developed the laser beam centering and pointing system.

Aligning the Beams

Precisely aligning a laser beam involves adjusting the beam's position within the component apertures through which it passes, as well as sending the beam in the correct direction toward the target. Basic geometry tells us that two points make a line. To achieve alignment, therefore, the beam must intercept two fixed image points in space. The first point determines if the beam is centered in its path, while the second determines if the beam is pointed in the right direction. In conventional laser-beam alignment systems, a sensor is needed at each alignment point to relay that information to the beam control system. These two alignment sensors can be mounted separately, each with its own camera, or as a single optic system and camera, in which case a centering lens is exchanged for a pointing lens.

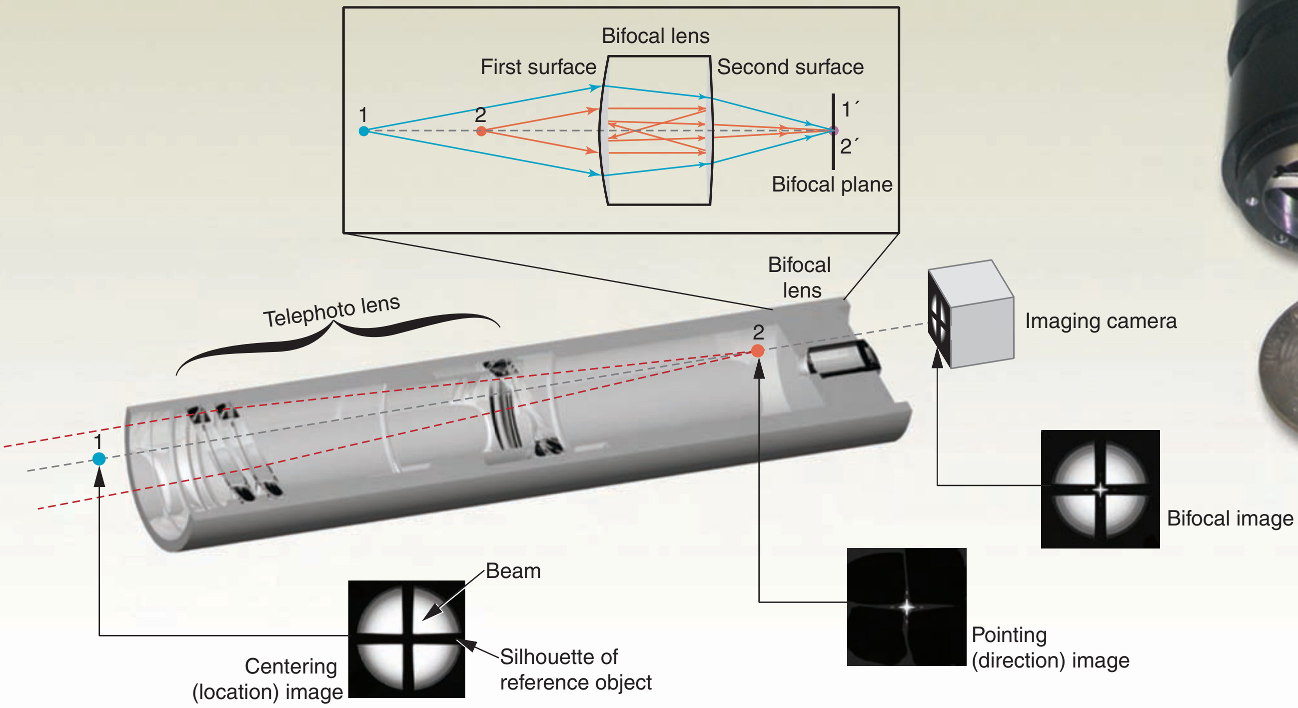
In one mechanically simple optic tube, LBCAPS performs the work of both sensors. It uses a single bifocal imaging lens to view both points simultaneously, combining and transmitting their images to one camera. The image contains both the centering and pointing data needed to align the beam. Because LBCAPS combines two alignment sensors in one, it cuts the cost of alignment components in half and saves precious space and computing resources. In addition, LBCAPS is monolithic, formed in a single piece, with no moving parts, which provides substantial advantages in stability and repeatability over conventional alignment systems that have two separate sensors mounted on an optics table.

How It Works

The rigidly mounted LBCAPS tube contains a three-element telephoto lens and a two-surface bifocal lens, whose two focal lengths allow it to produce images of both near and distant objects. The laser beam entering LBCAPS backlights a crosshairlike reference object near the first element of the telephoto lens, forming a silhouette. (See the figure on p. 19.) The telephoto lens and the bifocal lens together image the reference object and the beam onto the camera (see blue lines in the inset figure). The resulting combined image shows the beam's centering location relative to the reference object.

As the beam travels through the tube, the telephoto lens focuses the beam near the bifocal lens. Both surfaces of the bifocal lens have a 30 percent reflective coating, which refracts the light path at a different angle as it goes through the first surface, reflects it back at

Diagnostic Laser Beams



The laser beam centering and pointing system combines two laser beam alignment sensors—centering and pointing—into one. The dual-imaging bifocal lens images both the "centering" and "pointing" data onto the camera.

the second surface, reflects it again at the first surface, then finally refracts it once more at the second surface (see ray path 2 to 2´ in the inset figure). The position of the focus spot in the resulting image on the camera reveals the beam's pointing direction.

Setting the focal lengths and positions of the telephoto lens and adjusting the curvatures and thickness of the bifocal lens allows for optimal magnification of both the centering and pointing images for a particular application. Because beam centering and pointing can be monitored relative to the backlit fixed reference object, LBCAPS is self-referencing and does not depend on the location of the camera for beam alignment. Consequently, centering and pointing references are not lost if a camera has to be replaced.

Future Applications

This compact, reliable, and cost-effective system is being tested for the Laboratory's Mercury laser project and the Livermore-developed extreme x-ray system used in nuclear materials detection. In addition, incorporating a stable local reference for both centering and pointing could be beneficial in many industrial high-power laser applications, such as laser welding and cutting, and in scientific experiments to explore the nature of atoms and molecules. "LBCAPS is effective and provides huge advantages in stability and repeatability over conventional alignment systems," says Rushford.

—Cindy Cassady

Key Words: Advanced Radiography Capability (ARC), bifocal lens, imaging camera, laser beam alignment, laser beam centering and pointing system (LBCAPS), National Ignition Facility (NIF), R&D 100 Award.

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