Design and Development of a Beam Expander

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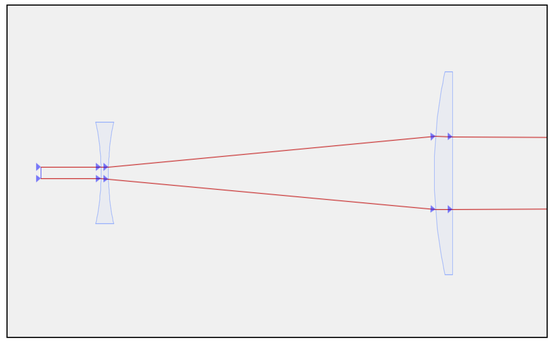
Abstract

Rotating Precision Mechanisms, Inc. (RPM) requested that TCU Engineering update their current Laser Position Accuracy Test Set, which utilizes a laser to calibrate rotating pedestals. RPM positions this test system at a range of distances from a rotating mirror, passes a laser beam through an optical system to the rotating mirror, and measures the offset of the reflected laser dot in order to test the pointing accuracy and repeatability of their positioners. RPM requested that the redesigned test set deliver a reflected laser dot size within 0.125 inches when the test system is any distance between 10 and 100 feet from the rotating mirror. The prototype for the redesigned Laser Position Accuracy Test Set relies on an optical component called a beam expander to cleanly extend the laser beam at the desired dot size over the specified range of distances. In order to design and manufacture this beam expander, TCU Engineering researched optical collimators, beam expanders, and lenses in addition to using an Optical Ray Tracing software to model potential beam expander designs. After constructing and testing a working prototype, several iterations were completed in order to improve the resulting laser dot size. Finally, TCU Engineering's beam expander design was compared to an Edmund Optics research grade beam expander to further quantify the success of the design.

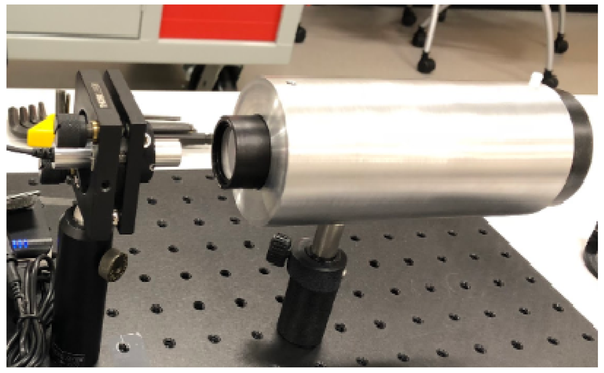
Approach

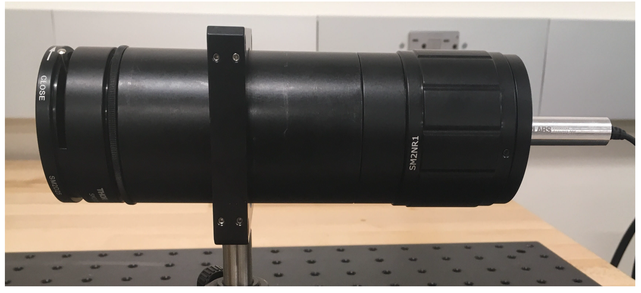
After researching beam expander lens configurations, the Galilean beam expander model was found to be the appropriate choice for this application. A variety of biconcave and plano-convex lenses were tested to figure out which combination yielded the most desirable dot size for the range of distances. Next, the housing of the beam expander was designed. The first prototype used standard lens tubes based on the range of distances between the lenses recorded during initial lens testing, as well as a shop manufactured aluminum lens tube connecter. Before testing the initial prototype, the final lens combination was modeled in the Optical Ray Tracer Software to hypothesize the distance between lenses that would yield the smallest dot size at each distance in the range of 10 to 100 feet. The initial prototype was then tested using an optical breadboard and optical posts to hold the beam expander and laser in alignment. During this test, the dot size and distance between the lenses were recorded at each 10 foot increment over the range of 10 to 100 feet from a target. After initial testing, the prototype was refined by implementing coated lenses to reduce aberrations, zoom housing to condense the beam expander and improve ease of use, and an exit lens iris to eliminate interference caused by the laser. Finally, the refined prototype was tested for dot size to compare it to a research grade beam expander.

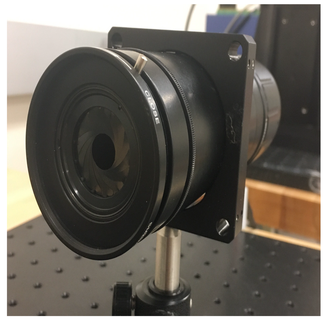
Results

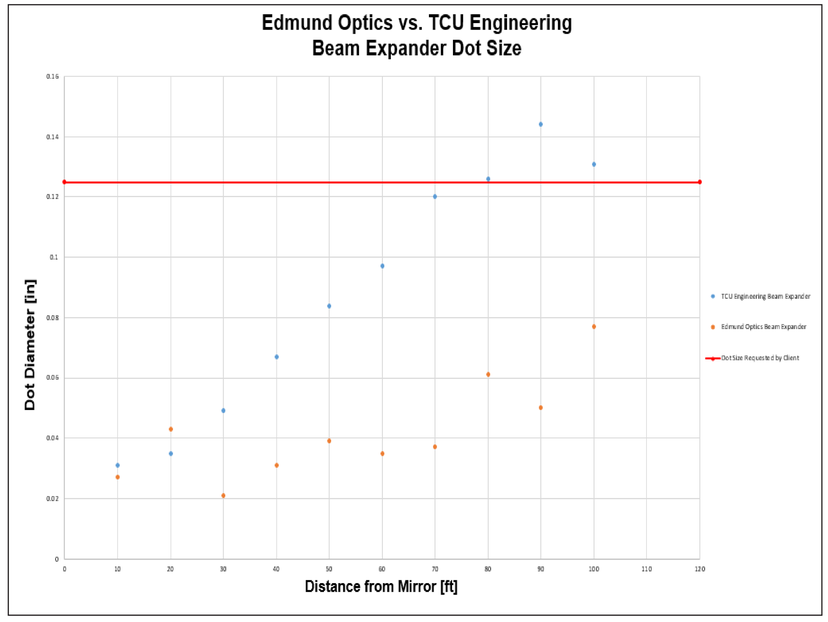


TCU Engineering Beam Expander Lens Parameters		
	Biconcave Entrance Lens	Plano Convex Exit Lens
Diameter [in]	1	2
Radius of Curvature [in]	1.56	3
Edge Thickness [in]	0.28	0.12
Index of Refraction	1.778	1.515









Discussion

TCU Engineering tested the beam expander prototype for dot size and repeatability. The dot size of this prototype was compared to the research grade Edmund Optics beam expander. TCU Engineering's beam expander yielded a smallest diameter of 0.03 inches at 10 feet from the target and a largest diameter of 0.145 inches at 90 feet from the target. All of the Edmund Optics beam expander dot diameters were within 0.125 inches, with a low diameter of 0.021 inches at 20 feet from the target and a high of 0.078 inches at 100 feet from the target. The TCU Engineering beam expander's dot size was within the desired diameter for 70% of tested distances from the target. This beam expander consistently yielded a circular dot with minimal aberrations, which allows the client to easily measure the dot.

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The goal of this project was to design and develop a beam expander that would expand the beam of a laser while keeping a dot size on the target no larger than 0.125 inches throughout a range of distances from 10 to 100 feet. The beam expander is a combination of two lenses, one biconcave and one plano convex that work as a telescope to expand the laser beam. These lenses sit in a zoom housing unit to provide ease of use to the user. Additionally, an iris was implemented to yield a clear, circular dot.