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Focal Length Measurements for the National Ignition Facility Large Lenses

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Abstract: The focal length of the spatial filter and final focus lenses for the National Ignition Facility are measured to < ± 0.01% using a combination of master lenses and production-oriented techniques for relative focal length.

OCIS codes: (140.0140) Lasers and laser optics; (220.0220) Optical design and fabrication

Introduction

The National Ignition Facility is a very large, 192-beam laser system being built at the Lawrence Livermore National Laboratory. Its research missions require light to be transported through two large spatial filters (24m and 60m long) and finally to be focused onto a small target about 700' away along the beam path. The corresponding wavefront budget requires the focal length of each lens be measured to approximately ±0.01%. Each beam line has two 12 m focal length lenses in a cavity special filter (CSF), two 30 m lenses in the transport special filter (TSF) and a heavily-wedged 7.7 m final focus lens (FFL). Each lens is approximately 43 cm square. These nearly 1000 large lenses are being fabricated at Tinsley Laboratories, Inc. An accurate, production-oriented measurement strategy was devised to meet the needed accuracy at relatively high throughput.

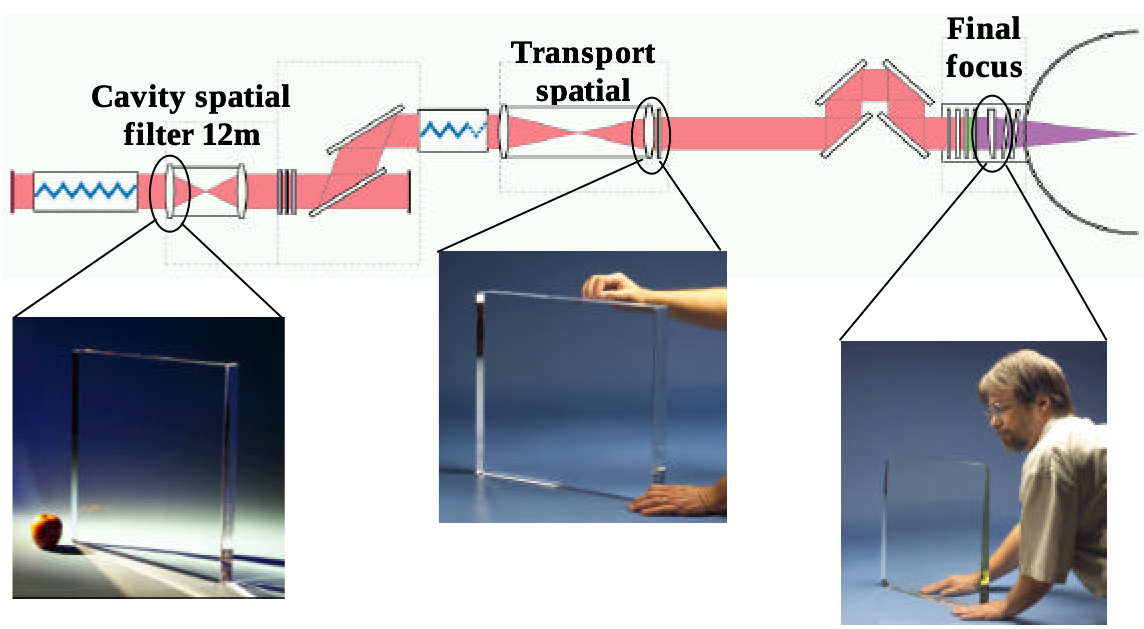

Figure 1. Optical layout of one of the 192 beam lines on NIF showing location of the five large lenses.

Three types of measurements were made to ensure the absolute accuracy of the focal lengths of the three types of NIF lenses.

1. Precision survey measurements of master lenses at full focal length (7.7, 12 and 30 m).
2. Benchtop interferometric measurements based on change in focus of a well-known lens in combination with a master lens.
3. Measurement of production optics relative to the master lenses using a specially designed test system that incorporated a full aperture interferometer and retrospheres.

Precision Survey LUPI Measurement System

This strategy consisted of three steps:

- Location of the center of focus for a master lens was determined using a Long Un-equal Path Inteferometer (LUPI), the master lens and a return flat in a self-collimating configuration.
- Focal length was determined by measuring physical distance between the LUPI pinhole and the lens at focus using conventional precision survey.
- Corrections were made for ambient temperature, pressure and wavefront error in the return flat.

This process was repeated for two master lenses for each type of lens (CSF, TSF, FFL).

Bench top interferometric test

The survey measurement accuracy is limited by vibration and turbulence affects over the path. Consequently, a sub-aperture benchtop test was developed to provide a fully independent measurement of the BFL of the NIF master lenses. This technique used a 12" phase-shifting interferometer in combination with a distance measuring interferometer to carefully characterize the focal length of a relatively short focal length reference lens. The long-focal length NIF master lenses were then characterized by measuring the change in focal length when they were inserted into the optical path as shown in Figure 2.

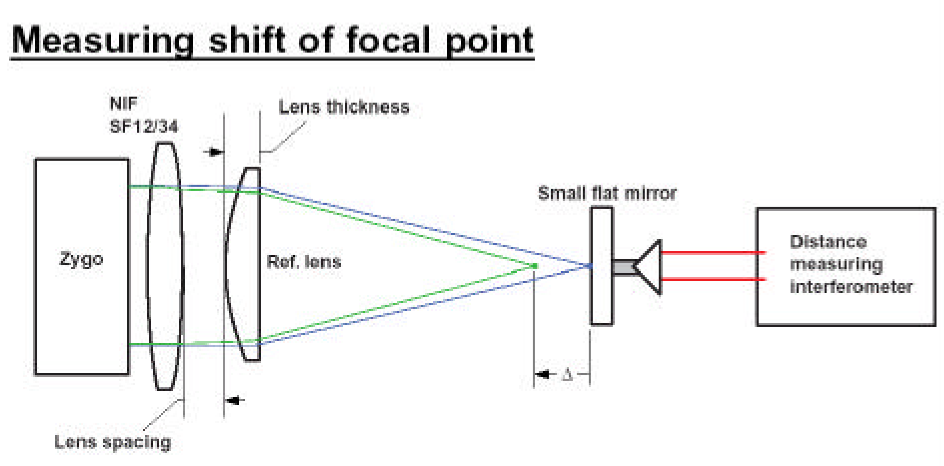

Figure 2. Benchtop test based on change in focal length when a NIF master lens is combined with a well-known reference lens.

LOTS Measurement System

Production lenses are measured relative to the NIF master lenses using a custom Lens Optical Test System (LOTS). This system (Figure 3) incorporates a Veeco/Wyko 24" Fizeau phase shifting interferometer, a lens mount to support the lens under test, and a turret holding three types of retrospheres as well as a reference flat. This configuration allows rapid and precise measurement of production lenses in a compact volume using a very short cavity. In addition to BFL, the LOTS also measures lens centration and the transmitted wavefront of production lenses.

Relative BFL is measured in a straightforward manner on the LOTS by first positioning a master lens in the lens mount, nulling all fringes relative to the retrosphere, swapping in a production lens, and finally translating the lens along the focal path by a carefully measured distance to re-null any fringes. This technique provided relative BFL measurements with a precision of <0.5mm.

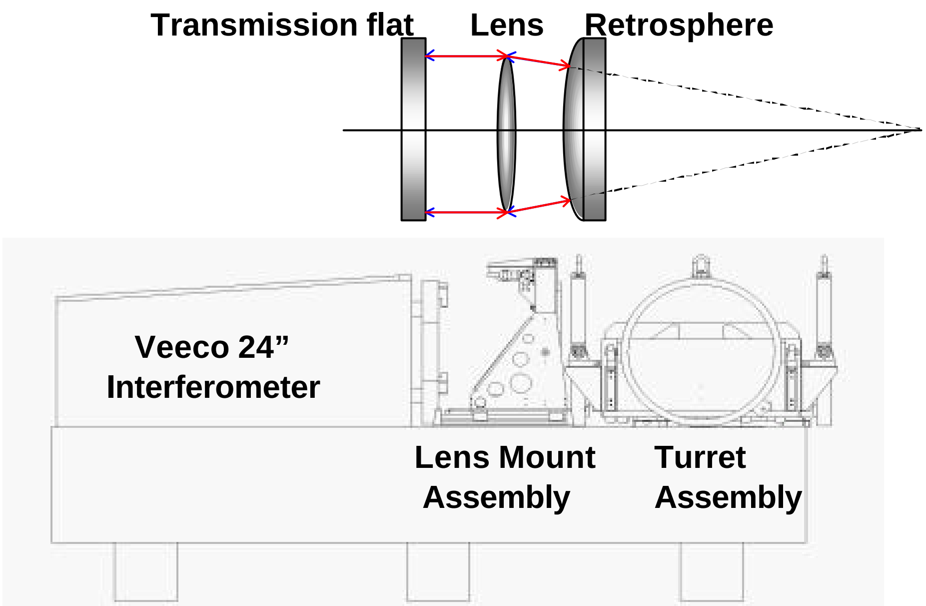

Figure 3. Physical and optical schematic of LOTS production lens measurement system with turret to support three types of NIF lenses and a reference flat.

Measurement Results

Agreement between the precision survey LUPI measurements and the bench top interferometric measurements of master lenses agreed to within the required error budget of $\pm$ 1 mm out of 12 m for the cavity spatial filter lenses and $\pm$ 4 mm out of 30 m for the transport spatial filter lenses. Comparison of the Δ BFL between two different master lenses measured on the Lens Optical Test System (LOTS) provided a third independent measurement of the precision of the measurements for each lens type. Measurements of the master final focus lenses met their target of $\pm$ 1 mm also. These well-characterized master lenses, in concert with the LOTS, have enabled rapid production measurements of the large NIF lenses while meeting the stringent goals for precision and accuracy.

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