Prototype Ultrasonic Inspection System for Structural Damage

This project is constructing ultrasonic hardware that will generate images of damage to the surface of structures, such as optics with a set of multiple sensors applied to the outside surface and normal to the surface being inspected. The system will also be portable, enabling field-testing of optics or other structures such as weapons. A prototype will be built and demonstrated on glass optics with programmed defects and actual laser damage to assess detection and sizing capabilities.

Project Goals

Our goal is to detect and size actual laser damage on an optic with defects ranging in size from 100 μm to 10 mm or larger, by generating images of a laser-damaged optic that are easily interpreted by those less familiar with ultrasonics.

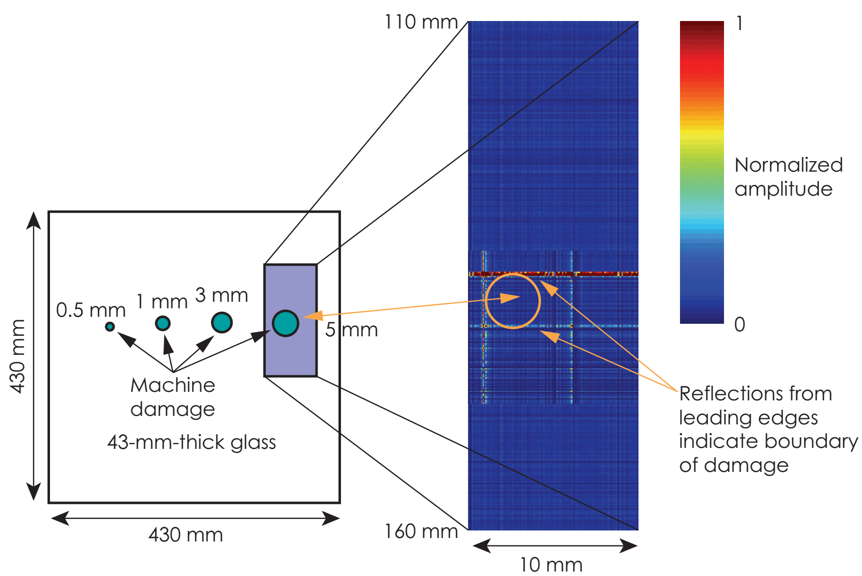

Figure 1. Image of a 50-mm-x-10-mm region showing a hemispherical machine damage site.

Relevance to LLNL Mission

This project will demonstrate a prototype system that could be subsequently deployed to inspect NIF optics on the target chamber or in the beamline. The technology is also applicable to generating 3-D images of weapons components or systems without scanning.

FY2005 Accomplishments and Results

We are investigating the application of two ultrasonic techniques, low-frequency longitudinal waves and high-frequency shear waves, to imaging surface damage in optics. To evaluate the techniques, we are using fused silica samples with programmed machined damage as well as a sample with actual laser-induced damage.

We performed experiments on an optic with programmed hemispherical defects machined into the surface. Defect sizes ranged in diameter from 0.5 mm to 5 mm. An array of 10-MHz shear wave sensors was placed on adjacent sides to collect high-frequency shear wave data. The data sets were merged by taking the product, to form an amplitude map of the reflection. The shear wave technique was able to accurately image and size all the machined defects.

The image in Fig. 1 shows the boundary of the defect. Accurate sizing is a significant advance, since previous acoustic methods failed to accurately size defects.

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Low-frequency longitudinal data was also taken using a 1-MHz array with omni-directional sensors. Tomographic techniques are currently being applied to the longitudinal data to generate images as well.

Initial experiments were also performed on an optic with laser damage induced under no vacuum loading conditions. A single 10-MHz shear-wave element was able to detect laser damage of sizes 0.5 mm to 8 mm in diameter (Figs. 2 and 3). A higher signal-to-noise ratio with virtually no effects of mode conversion or multiple echoes from the bottom surface was observed compared to previous 5-MHz longitudinal acoustic data.

Related Reference

Martin, P., D. Chambers, and G. Thomas, "Experimetal and Simulated Ultrasonic Characterization of Complex Damage in Fused Silica," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, **49**, 2, pp. 255-265, 2002.

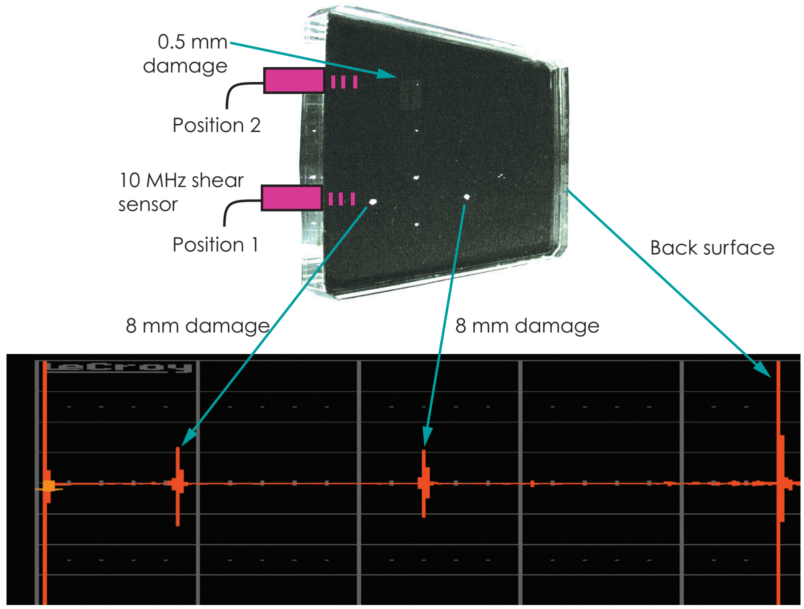

Figure 2. Sample experimental results. A 10-MHz shear wave sensor placed at Position 1 detects the echoes from two 8-mm laser damage sites on the surface of a 430-mm-x-430-mm-x-43-mm optic.

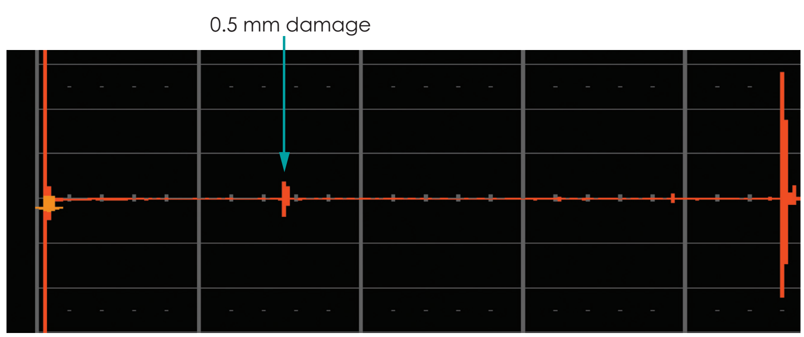

Figure 3. Sample experimental results. A 10-MHz shear-wave sensor placed at Position 2 on Fig. 2 detects the echoes from a 0.5-mm laser damage site.

FY2006 Proposed Work

In FY2006 algorithms and data collection will be optimized. Experiments will be performed on an optic with actual laser damage created while under a vacuum. Images of actual laser damage will be generated with the optimized techniques. Postprocessing techniques will also be done to make improvements. The final imaging capabilities of the low-frequency longitudinal tomography and high-frequency shear techniques will be compared.