

Laser Ultrasonic Testing: An EnLIGHTening Advancement in Nondestructive Evaluation

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EWI has significant experience with laser ultrasonic testing (LUT) and has identified it as a mature technology ready for new industry applications. For many years, a primary target for LUT has been aircraft and structural composites. It's no surprise that Lockheed Martin developed a system to inspect the Joint Strike Fighter (JSF); however, many other industries and material systems could also benefit from LUT. In the last five years, great strides have been made in the development of commercial LUT systems which can be installed in production or post-production settings.

Using Lasers for Ultrasonic Generation and Detection

High-powered, short-pulsed lasers have the ability to interact with the surface of a material in several ways, ranging from thermal expansion to more destructive material ablation. In LUT, a short-pulsed, high-energy laser irradiated onto a material's surface causes localized thermal expansion. This generates a thermoelastic wave in the material which can be detected by an optical interferometer (1) on the same side as its generation, (2) on the back-side of the material, or (3) at some angle in-between. Bulk, shear, and surface waves can be simultaneously generated in this photoacoustic event and detected with interferometry (Figure 1). The received signals can be used to determine the elastic and density properties of the material and can uncover discontinuities such as cracks and delaminations. Spatial resolution and sensitivity to specific feature sizes can also be optimized for a broad range of micro-scale and macro-scale applications.¹

In order to capture ultrasonic transmission in a material, most interferometers rely on the interference between a laser beam reflected from the surface of interest and a reference beam. Interference of these two beam paths varies with the path-length changes caused by bulk and surface vibrations.

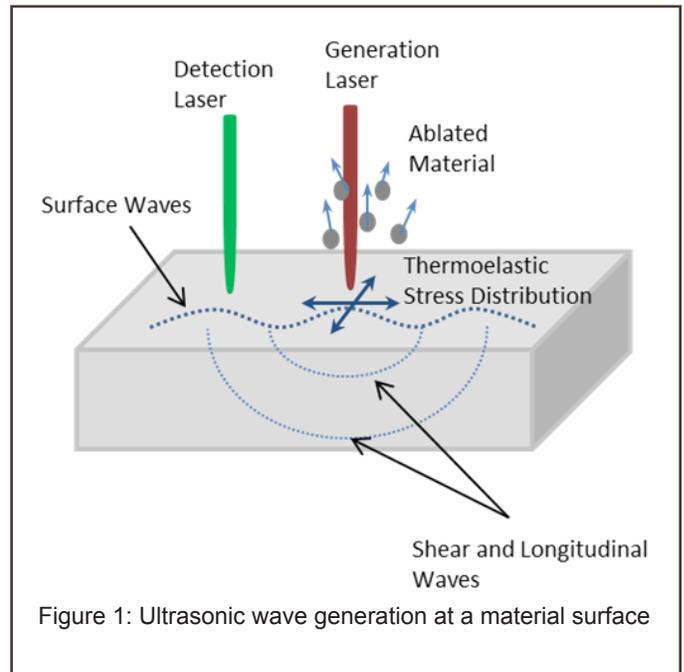


Figure 1: Ultrasonic wave generation at a material surface

The Advantages of Laser Ultrasonic Testing

LUT has a number of significant advantages compared to contact transducer ultrasonic inspection. As a non-contact technology that can be operated remotely, it is also well-suited to high-temperature, harsh, and dirty environments. Scan times are fast without the need for couplant, and the process is non-destructive for most applications. LUT is broadband (10kHz to 100MHz for existing commercial systems) with a flat frequency response that can be tuned to detect different discontinuity sizes. For example, depending on the detector, frequencies in the THz range can be used to evaluate thin films. Additionally, multiple vibration modes can be generated and detected simultaneously, including longitudinal, transverse, surface, and plate, eliminating the need for multiple transducers.

Commercially Available Systems

There are many standard interferometric techniques and each can be customized to account for rough surfaces and geometric surface complexities. One technique to improve reception of laser light from a less reflective or rough surface is to implement the confocal Fabry-Perot interferometer. The Fabry-Perot makes use of an etalon-style reflection cavity like those used in high-resolution spectrometers, assembled with confocal mirrors to direct light coming in at wide angles. The captured reflections from the examined material are modulated to be in phase with one another to generate a constructively interfering signal. Some commercially available systems have implemented this type of detection system and are able to account for the type of material and the inspection environment. Other techniques implemented to benefit industry applications include the use of a pulsed-laser source instead of a continuous source for inspection of thin films and composites, interferometers with delay line functionality (Figure 2), and the use of photorefractive crystals to enable two-wave mixing. These different configurations can enhance stability or resolution depending on the material inspected and the testing conditions. Further advantages can be realized by using laser wavelengths ranging from ultraviolet to infrared to adapt to different material types, or by installing a laser array for increased throughput.

Current Efforts at EWI

EWI is pursuing LUT techniques and applications using our variety of high-powered, short-pulsed lasers. Due to its maturity and affordability, LUT technology can now offer value across a wide range

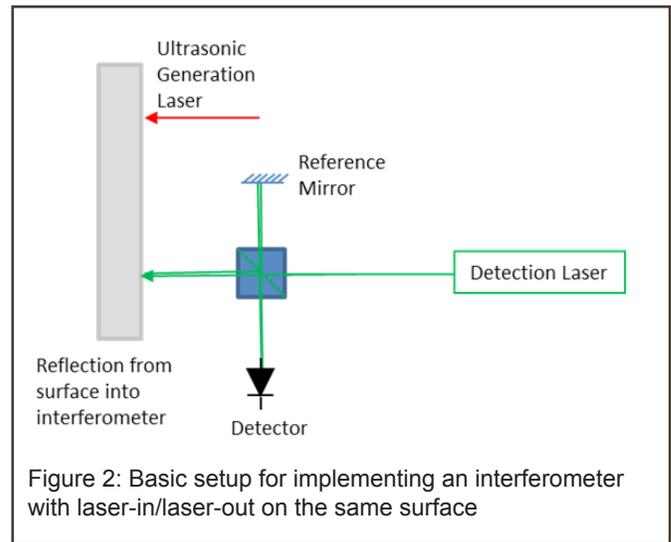


Figure 2: Basic setup for implementing an interferometer with laser-in/laser-out on the same surface

of applications on factory floors and in the field. It is at this stage of technology development that EWI can most effectively help educate industry and facilitate integration. We are currently focused on developing and procuring increased LUT capabilities, which will be available to our clients. These capabilities will include an array of laser wavelengths, powers, pulse widths, and pulse repetition frequencies, as well as one of the latest commercial laser ultrasonic detection systems. Research will be conducted on metals, plastics, composites, thin films, and additional materials based on the needs of our clients.

References

1. Scruby, C. B., and L. E. Drain, *Laser Ultrasonics Techniques and Applications*, Bristol: Adam Hilger, 1990.

Lindsey Lindamood is an Applications Engineer specializing in developing techniques for characterizing and monitoring materials using laser ultrasonics. Her specific material knowledge is in aluminum, graphite, and carbon fiber epoxy composites with an emphasis in non-contact ultrasonic evaluation of these materials. She is currently developing processes for monitoring ultrasonic metal welding, advancing capabilities of ultrasonic metal welding, and expanding applications of laser ultrasonics.