Laser ultrasound flexible system for non-contact inspection of medium size and complex shaped composite structures made of carbon fiber reinforced polymer.

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Laser ultrasonics is an interesting technique for the inspection of composite structures with complex shapes. The wider use of composite materials in the aerospace industries induces intensive research on adapted nondestructive inspection techniques. Ultrasonics is widely used in industry but requires either direct contact with the part inspected or to work at distance in water tank. Compared to classical UT, Laser UT (LUT) offers the advantage that no contact or couplant is needed and difficult to access points can be accessed by laser beams at distance. LUT usually combines two principles: the first one is the generation of an ultrasound wave at distance by a laser, the second is the detection of ultrasound at distance by an interferometric system. For the generation, a pulsed laser beam insulates briefly the material on its surface which generates the ultrasound through thermoelastic nondestructive effect or through the destructive ablative effect. For industrial application on composites, the second one has to be avoided and the laser and its parameters must be correctly chosen to work in thermoelastic regime. The second principle is the detection of ultrasound at distance by an interferometric system with a large optical etendue allowing working with potentially scattering surfaces. Various principles have been presented in literature. In any cases, a laser beam is sent on the surface to be probed and the ultrasound wave travelling to the surface will perturb the phase of the laser probe beam. These variations can be measured through a passive interferometer, like the confocal Fabry Perot (FP), or through adaptive interferometers based on the two-wave mixing (TWM) in photorefractive crystals.

Our works aim at developing a robotized system addressing medium size composite parts provided by aerospace industries. These parts have generally a square meter size and complex shapes. Industrial companies which are part of this project produce curved or assembled parts fully made of carbon fiber reinforced polymers (CFRP). Economic interest of LUT has been demonstrated for high end military aircraft composite parts and the question obviously arises in the civilian industries. Application cases have to be distinguished into medium or large parts, respectively smaller or larger than the square meter. Large parts could be scanned at high speed with high repetition rate laser (a few kHz), but this requires huge efforts in laser developments for both the generation and detection systems.

We recently developed a medium cost industrial LUT system which can address medium size complex shaped CFRP parts. The idea is to have a flexible lightweight optical head which couples both the generation and detection laser beams. This optical head is interfaced on the flange of a 6-axis robot system that can be programmed to follow paths on complex structures. An obvious way to have flexibility is to work with laser beams transported by optical fibers, with all laser and detection equipment located at a remote location, a few meters away from the inspection working area. While a detection system fully fiber-coupled already exist, and is considered in our system, we show the use of a fiber-coupled solution for the generation, through a pulsed YAG Q-switch laser at 532 nm. This solution is for the first time to our knowledge studied and compared to more classical approaches with other generation lasers. A new OPO laser for generating ultrasound in the mid-IR range has been recently incorporated in the system and is expected to provide even better results.

In this paper, we will describe the development of the fiber-coupled LUT system. Also we will review the study of parameters of interest governing the performance of the technique. In particular we compare our generation wavelength with the more classical solution using a TEA CO_2 laser. At last, we will provide results of inspection of a curved shaped CFRP structure.