

Application Note

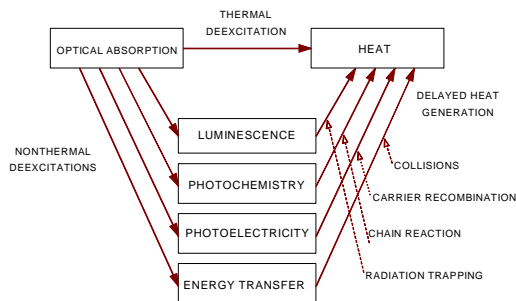
Non-destructive Testing

Introduction

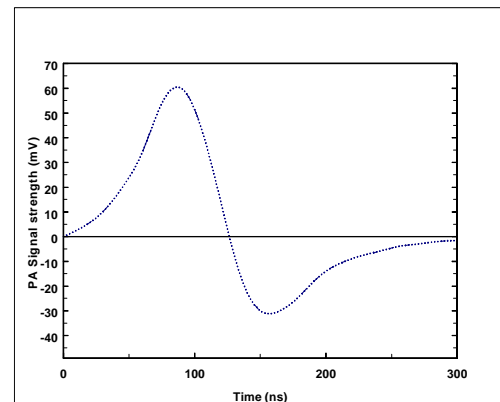
An interesting technique that has enjoyed a lot of attention in the last few years and has become a major application for pulsed CO₂ laser systems is the non-destructive testing of composite materials. Because the pulse width of transversely excited atmospheric (TEA) CO₂ lasers using pulse compressors is very short, typically 80ns, and the time jitter is very small (~10ns), the pulse can be used to generate an acoustic wave in composite materials that display large absorption coefficients at the wavelengths of TEA CO₂ lasers.

Photoacoustics

The term photo acoustics refers to the generation of acoustic or shock waves by optical radiation in gases, liquids, and solids, and is a form of de-excitation resulting due to photo thermal effects after the heating of a material by optical energy as illustrated by the schematic representation of the possible consequences of optical absorption given below.



Of these interactions, the most important branch with regards to the generation of photo acoustics signals is the thermal de-excitation branch. This branch leads to the generation of heat that causes an expansion of the irradiated volume. This expansion in turn produces shock or acoustic waves. The percentage energy absorbed depends on inherent characteristics of the material like the absorption coefficient, structural integrity, and the surface and substrate quality. If irradiation should alter any of these characteristics, the amount of absorption would change, affecting the typical photo acoustic waveform illustrated below that one would achieve with a TEA CO₂ laser



This illustration clearly shows the typical profile of a photo acoustic signal vis., the initial pressure wave followed by the subsequent rarefaction pulse that allows the sample to recover to its original state of equilibrium. A list of mechanisms that can generate photo acoustic signals are given

below with the efficiency of the process increasing from top to bottom.

- Electrostriction
- Thermal expansion
- Photochemical changes
- Boiling, ablation
- Plasma formation

The acoustic shockwaves generated by the processes listed above can be used to perform subsurface imaging of defects, irregularities, delamination, etc. The presence of any of these factors will alter the shape of the acoustic waveform given above and by monitoring the waveform a 3D image can be built up of the material being tested.

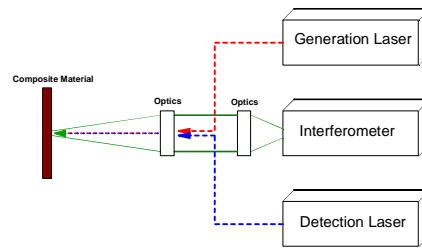
Non-destructive Testing Systems

Once the acoustic shockwave has been generated, the resulting expansion must be quantified to analyze the subsurface features of the material being tested. This is done conventional by monitoring the photoacoustic signal generated by either a piezoelectric transducer or a microphone. However, to image large and complex shapes such as the composite surfaces of aircraft interferometric measurements with a second beam is much more practical.



This technique requires the generation of the photoacoustic pulse by a short pulse length laser with a wavelength suited for the material being tested and the use of a coaxial measurement laser with a long pulse length. The ultrasonic vibrations generated on the surface of the material being tested can then be monitored by an interferometer that

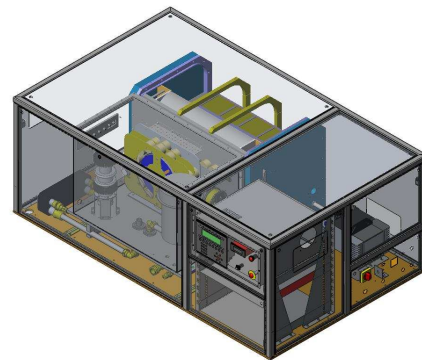
monitors the detection laser output. A schematic of the system in question is show below.



Using this method, one can determine the exact stress and damage points within the composite material. To date we have sold several TEA CO₂ laser systems to major European and American companies in the aerospace industry. These lasers were either incorporated in various non-destructive testing systems or used for research applications focusing on non-destructive testing.

SDI TEA CO₂ Lasers

SDI designs and manufactures a range of CO₂ lasers, both custom and off-the-shelf. We specialise in TEA, and miniature TEA (mini-TEA) lasers, with repetition rates of up to 1000 Hz. We also offer a range of high-pressure systems, with repetition rates of up to 300 Hz.



For further information on this topic, or on laser solutions to your problem, contact us at:

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