Green laser light probes metals for hidden damage

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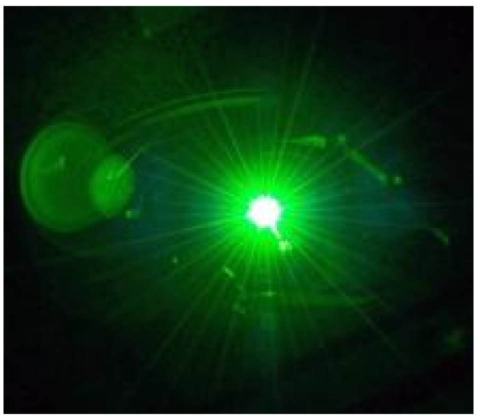

Credit: ORNL

Imagine being able to check the structural integrity of an airplane, ship or bridge, without having to dismantle it or remove any material for testing, which could further compromise the structure. That's the promise of a new laser-based technique that chemists are developing to reveal hidden damage in metals.

The researchers will present their work today at the 253rd National Meeting & Exposition of the American Chemical Society (ACS).

"Metals are often subjected to mechanical stress or fatigue that can weaken them structurally, but you can't tell that just by looking at them," James E. Patterson, Ph.D., says.

One real-world example is a U.S. Air Force plane that was unintentionally turned upside down in flight, a feat it wasn't designed for. The maneuver exceeded the specifications for the plane's stress tolerance, Patterson says, but there was no way to know if the inversion had actually damaged components enough to cause the plane to crash during a future flight. So the entire multimillion-dollar plane had to be scrapped.

"That's where nondestructive testing comes in," says Patterson, who is at Brigham Young University. NDT, as it's known, is already a billion-dollar industry, he notes. Current techniques for inspecting materials without harming them include X-ray imaging, which can detect microscopic cracks in metals. But the method is expensive, requires shielding from the X-rays and is hard to adapt for use in the field. Other NDT techniques give equivocal results and require highly trained technicians, he says.

His team is instead relying on a spectroscopic method known as second harmonic generation (SHG), which alters the wavelength of light. One of Patterson's graduate students, Shawn Averett, realized that the technique could be adapted to look for signs of internal damage in metals. Averett and undergraduates Scott D. Smith and Alex Farnsworth are working with Patterson on the project.

They begin by shining green laser light onto a metal sample. Through SHG, the metal converts some of the incoming light into ultraviolet light, which bounces back from the metal along with the remaining green light. "The amount of conversion depends on the properties of the metal, and if those properties have been changed by some form of stress, we can detect that in the converted light," Patterson explains. Tests to date indicate the technique could distinguish between metal parts that are still intact and those that have been irreversibly damaged and require replacing. The researchers say their method is more sensitive than existing NDT techniques and could thus give earlier warning of danger.

With some further refinements, the method could have applications in the aerospace industry, where plane parts are routinely replaced after a certain amount of use to avoid catastrophic failure, Patterson says. The replacement schedule is based on the average performance of several of the same components, rather than the actual condition of that individual component. The SHG method could be used to check whether a particular component is really worn out or still has useful life, leading to savings in time, money and material.

Patterson's team is also exploring applications with the U.S. Navy. The aluminum/magnesium alloy used in Navy vessels can undergo invisible corrosion with serious consequences. "There are stories of someone walking along a metal deck and stepping in the wrong spot, and a big chunk falling through to the deck below," he says. "Cracks also form in walls. And once visible cracks form, it's often too late to reverse the damage."

The researchers hope to develop their technique into a portable system that would indicate whether a scanned object is in good shape. "In principle, you could go around with a wand and some fiber optics and scan large areas of a ship for hidden damage," Patterson says. Other potential structures that could be evaluated with the technology include oil pipelines, building components and bridges.

More information: Nondestructive testing with second harmonic generation, the 253rd National Meeting & Exposition of the American Chemical Society (ACS), 2017.

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