

ACS AMA: We're James Patterson and Shawn Averett from Brigham Young University. Ask us anything about using lasers for non-destructive testing of structures.

AmerChemSocietyAMA¹ and r/Science AMAs¹

¹Affiliation not available

April 17, 2023

Abstract

ACS AMA Hello, Reddit! I'm Prof. James E. Patterson of Brigham Young University. I completed my B.S. and M.S. degrees in chemistry at BYU, and my Ph.D. in physical chemistry at the University of Illinois at Urbana-Champaign. After a postdoctoral fellowship at the Institute for Shock Physics at Washington State University, I began my appointment at BYU in 2007. Most of my work has focused on the use of nonlinear optics (sum-frequency generation and second harmonic generation) to the molecular-level investigation of materials and interfaces. A common theme has been to understand the molecular response of materials, such as polymers and metals, to mechanical, thermal and chemical stress. Hi Reddit! My name is Shawn Averett, and I am finishing a Ph.D. in physical chemistry at BYU. As a graduate student I use sum frequency generation spectroscopy to investigate the surface response of materials to mechanical deformation. I am also working to better understand the nature and origin of nonresonant sum frequency generation. Prior to graduate school I taught high school science and engineering for four years. Our team recently presented research about a new laser-based technique we've developed to reveal hidden damage in metals at the 253rd American Chemical Society National Meeting & Exposition. Non-destructive testing (or NDT) offers the ability 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. Current NDT techniques include X-ray imaging, which can detect microscopic cracks in metals. This method is expensive, requires shielding from the X-rays, and is difficult to use in the field. Other NDT techniques give less precise results and require highly trained technicians. Our approach uses a spectroscopic method known as second harmonic generation (SHG), which alters the wavelength of the light. We start with 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. By measuring this conversion, we can detect if the metals have been changed by some form of stress. We've found this technique can distinguish between metal samples that are still sound and those that have been irreversibly damaged and require replacing. Our method can detect damage invisible to current NDT, and because SHG is extremely sensitive to material changes it may give earlier warning of danger for damage that current NDT can detect. You can learn more about this research in this video. Ask us anything about our new approach for non-destructive testing and its applications for detecting damage. We'll be back at 11am EDT (8am PDT, 3pm UTC) to answer your questions! -acs edit

[REDDIT](#)

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AMERCHEMSOCIETYAMA [R/SCIENCE](#)

[ACS AMA](#)

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Interesting work!

[WRITE A REVIEW](#)

My graduate studies focused on NDT for both metal and composites (my background is in aerospace).

CORRESPONDENCE:

DATE RECEIVED:

April 26, 2017

A few questions -

DOI:

1.) Is this a baseline-free technique? i.e do you need a measurement with a healthy structure in order

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to form a baseline to which you compare a damaged structure's response? The video made it seem like this was a baseline-free technique.

2.) Does this technique work for composite structures? These materials are becoming more prevalent in the aerospace industry, and Barely Visible Impact damage is a huge area of study. From the video, it seems like you're focused on UV light harmonics. In my previous work we had some difficulty using laser doppler vibrometers with certain composite structures due to the way they refracted the light. I'm unsure if UV light would be affected in the same way.

3.) Does this technique work with complex geometry structures? Many aerospace fuselage structures have curved surfaces which can be difficult to work with if the technique requires measurements at multiple points (at least, without some sort of jig structure to support the moving laser). Does this method use a single measurement point? Or some sort of surface mapping?

4.) Does this technique require paint to be removed for measurement? Many aerospace structures are painted to prevent corrosion.

[PSU Engineerd](#)

1) The tech works by detecting changes in the amount of UV light created, which means that you need either a baseline or reference. One area where you may not need a baseline would be batch testing parts. For example if 99 out of 100 parts produce the same amount of UV you may not want to use the 1 part that was different. 2) Some of our work with plastics and adhesives suggests that we may be able to detect damage in composites, but we haven't looked into it in much depth yet. 3) The excitation beam and UV collection can be done with fiber optics which can collect the UV very close to the material surface. This reduces the effect of curves and rough surfaces. The technique interrogates a specific spot, you just check that spot, or raster the instrument to map the part. 4) It can be done through paint, but it is easier without it.

What industry applications is this aimed towards? Who has the most to gain by using this as a test?

[vegetaman3113](#)

Currently we are working on detecting plastic deformation in aerospace grade aluminum and the formation of intergranular beta phase in naval grade aluminums. We haven't decided what to work on after we finish with those. Some of the possibilities are hydrogen embrittlement, plastic deformation in structural steel, fatigue, impact damage in composites, and damage from nuclear irradiation. We are interested in licensing and/or collaborative partners if you are aware of a potential application.

The amount of uses of this are huge! What's a real-world application that you or your team hopes gets priority?

[Shredder13](#)

To date we have focused on 2024 (aerospace grade) Al and its response to mechanical deformation and 5XXX (naval grade) Al and chemical modifications that happen over time. The main applications we foresee are noninvasive, nondestructive characterization of mechanical components to detect damage or weakness prior to catastrophic failure.

Why do you specifically use green laser light?

[TexasShouldSecede](#)

Simple answer: that's the laser we have. Longer answer: there are a wide variety of good sources at this wavelength, so it should help with miniaturizing a system. Fundamentally, there is nothing that says the light needs to be green.

Hi, thank you for taking time out of your day to answers questions. As a college student studying in the construction science major, how do you think this type of technology will change my life as a project manager, Superintendent, owner, Etc. in the following years of graduation?

[philmcdonald](#)

We would hope that it would become a standard technique to monitor structural integrity of various components. Right now, though, we are very much in the development stage, so it may be a while before you see a commercial system.

What implications could this have for medical research..could it replace certain blood tests, for example?

[rehtulx](#)

This does not seem to be a likely candidate for any blood work or tests on other fluids. It could, however, be used for minimally invasive monitoring of artificial joints to see how they are holding up.

Hello! Former BYU grad, current new medical Resident Physician.

I have a broad question if you have any insight. On rounds so I don't have time right now to elaborate. Any thoughts appreciated.

Question: any possible application in medical world, i.e. Bone or other survey?

[halflistic_](#)

Hello! Bone itself would likely be tricky. It's not the easiest thing to work with optically. Metal implants, like artificial joints however, do seem to be likely candidates.

Thank you for answering our questions today.

How much time does it take to run your analysis, per unit of area?

What is the smallest object that can be measured with your approach? E.g. a coin, a knife, an I-beam...

[egrek](#)

It depends. With our current laser it takes a few seconds to test a spot. A more expensive laser could do it in a tenth of a second or so. The area tested is a circle which can have a diameter ranging from microns to millimeters.

How similar is frequency generation spectroscopy(FGS) to LIDAR?

Can FGS penetrate water columns to give accurate readings about the lower parts of hulls, or does the ship need to be lifted?

How much of the chemical makeup, such as oxidation, can be measured with these methods? Is there a standardized scale for these results?

[crowcawer](#)

We are not that familiar with LIDAR, so it's hard to comment. Penetrating water would be tricky with our current system because of UV absorption in the water. As for changes chemical makeup, that's an area we want to do more in. We have done preliminary work on formation of beta phase in 5XXX series (naval grade) Al alloys, but there is clearly more to try. Every new material would require standardization work, so we would be interested in identifying licensing partners or other collaborators to broaden the scope of that work.

Possible electrical use: In 1980 electrician was sent to a commercial site because of breaker tripping. Clamp on amp meter showed load much less than breaker rating. Cleaned the 250 MCM AL wires and re-landed. Tripping problem continued. Amperage logging meter on conductors showed nothing abnormal that would cause the breaker to trip. Close inspection of the conductor insulation indicated it had been subjected to excessive heat. Cut back the conductors as far as possible that would still allow them to reach breaker. Problem solved. AL conductors that has been subjected to heat don't appear to conduct electricity as well as unheated conductors. AL \neq AL. NDT of conductors?

Unrelated to above: Is what you are doing related to creep?

[rcrracer](#)

Sounds like something to look into. Thanks for the tip. As for creep, we haven't looked at that directly, but it would also be of interest.

Do you have any plans to make this technique readily available in industry? (If so, what's the timeline?)

And for Shawn - what you say is the best way to get high schoolers interested in typically 'less interesting' fields like engineering and physics? I'm currently studying engineering in university but I'd like to teach after working in my field for a few years. Thanks!

[Piertotum Locomotor](#)

BYU's tech transfer office would be very happy to help make this tech available to industry. In my experience high school students are very interested in science and engineering, when they get to actually do science or engineering rather than hearing about science or engineering. Displaying your students work tends to help drive enrollment as well. I would strongly suggest a problem based learning curriculum like the ones put together by Project Lead the Way.

Ask you anything about using lasers for non-destructive testing of structures?

Okay.

How many lasers can you shoot at a structure without destroying it?

Serious question time, roughly how much money do you predict your new technology will save compared to older NDT techniques, and what materials in particular does it work on?

[BGummyBear](#)

We are careful to keep the laser power low enough to not cause damage to the material, otherwise it

wouldn't be non-destructive. It's hard to give firm numbers, but some NDT systems can cost hundreds of thousands of dollars. We envision portable or semi-portable systems for a few tens of thousands. Our preliminary work has been on metals, but other materials should also be possible. We are interested in partnering with others to help develop this IP.

Does this have any application to concrete or inspecting reinforcement in concrete?

Also if I may ask a second question, how far away is this research from being adopted in the field of construction, repair and inspection of bridges and buildings? Do you see it being commonly used in the next few years?

[mercury1491](#)

Concrete doesn't seem like a viable candidate for this technique. To date, we have focused our efforts on metals, although we have done some related work on polymers. Polymer composites seem like a possibility, but concrete seems like it would be very difficult to work with optically. As far as adoption, we have been mainly doing initial proof-of-concept work to date. We are interested in finding licensing partners that want to help us more fully develop this IP.

You mentioned being able to narrow the test area down to microns. Is it possible to use this method on PCBs, solder balls, other electronic components, etc?

[howitzeral](#)

SHG microscopy has been done, so that seems like a good possibility.

Are the lasers yet at a stage where they can be carried around, or can only be used in a lab or perhaps in a mobile lab?

[zycamzip](#)

For now, this is a bench top system. We are certainly interested in finding licensing partners to develop portable systems.

What does a day on the job look like?

[event3horizon](#)

Green. Or more seriously, most of my work is done on an optical bread board, kind of like the one Leonard uses in the Big Bang Theory tv show.