An Overview of Raman: Interview with Kevin Repasky

In this interview, Wavelength Electronics Inc. joins Kevin Repasky, Ph.D., Assistant Professor at Montana State University, a previous researcher of Raman scattering. Currently, his research group is focusing on atmospheric LiDAR and DIAL.

RAMAN RESEARCH

Wavelength Electronics Inc.: What is your background in Raman?

Kevin Repasky: If I go way back to my thesis work, I did a lot of work with Raman scattering and developed Raman lasers. We looked at Raman scattering in diatomic hydrogen. Currently my research is focused on LiDAR and DIAL development, and that entails a lot of work with photonics development types of things.

WEI: Can you give us a brief rundown of how Raman spectroscopy works?

KR: There is a lot of remote sensing right now based on Raman scattering. Basically, what happens is I have a molecule that has a vibrational and rotational set of energy levels. I come in with some laser light. That light is absorbed and then re-emitted. The light that is absorbed, a little bit of that energy stays in the molecule causing it to vibrate or rotate. So the light scattered then has a characteristic wavelength shift, and that wavelength shift then lets me identify the molecule. Then I can determine how much there is by how much of the light is scattered if I know the Raman scattering cross-section of the molecule. So it's a way to identify a molecule and how much of a molecule is in a particular volume.

CRITICAL PARAMETERS

WEI: What are the most critical parameters in Raman Spectroscopy?

KR: The two most critical are going to be the scattering cross-section and the frequency shift of the scattered light. So the cross-section is going to tell you how much light is scattered – the potential for how much light is scattered from each molecule. The frequency shift is going to be specific to that molecule, so that lets you identify the molecule.

WEI: What about the detector?

KR: Typically in Raman spectroscopy, high power lasers are used because the Raman scattering is a non-linear process. So it requires a fair amount of input energy to see some scattered light come back. Higher power might mean different things in different situations – lab setting or a field setting.

WEI: Are there specific wavelengths that work better, or is the power more important?

KR: Depends on the application. If you are sending light into the atmosphere, typically they work with UV light because of the molecular scattering. 532 nm is a common wavelength because the YAG laser can emit at that wavelength and is a well developed laser. Then when you scatter the light, it's shifted. You're scattering hydrogen, dihydrogen, which gives you the biggest shift – you would go from 532 nm to 683 nm. So the scattered light is still in the visible range, and you can get very good sensitive detectors and do things like avalanche photodiode photon counting.

ELECTRONIC CONTROL

WEI: Can you tell me how the electronics affect the performance of Raman spectroscopy?

KR: You can imagine you have a frequency difference between the pump laser and the scattered light, and if you are looking for very low amounts of scattered light you need very narrow spectral filtering on the receiver side. If your laser wavelength is not stabilized, it can be very hard to keep the spectral properties you need to get the scattered light through the very narrow band spectral filtering on the receiver side.

WEI: Can you talk about the difference between optical noise and electrical noise?

KR: So optical noise can result from how much power your laser is putting out, how much background light your detector sees. Electrical noise would be the noise floor for your detector. If you have electrical noise in the current controller, that could result in affecting the performance of the laser. Electrical noise in the controller can result in optical noise, because they are tied together. Classically, you think of optical noise as power fluctuations, somewhere the photons are coming out. You have electrical noise in the detector where you can look at dark current, noise floors, those types of things. When you convert photons to electrons, essentially, at the detector, then you can see the electrical noise after the laser output.

WEI: How do you stabilize wavelength with different types of lasers?

KR: YAG lasers can use diode-based injection seeding systems, where the seed laser sets the frequency of the output of the pulsed laser. So you can lock that with a reference cell or a reference absorption line, and there are different techniques for doing that. Essentially you are locking the CW lasers to the reference cell using various techniques. If you have diode lasers, you are using the diode directly, so you stabilized the reference cell. If you are using a pulsed laser, you stabilize the CW seed laser and that stabilizes the pulsed laser.

COMPARING RAMAN

WEI: How does Raman compare to different types of spectroscopy such as Infrared (IR) absorption or Fourier Transform?

KR: With Raman, you can look at scattered signals. So you are looking for scattered signals at different wavelengths than your pump laser. The wavelength shift tells you the molecule. If you are using absorption types of systems, you send the laser through the medium, and you have to have a detector on the other side to measure how much transmission change is going through your medium. Then from there you have to tune to the absorption line that you are interested in, or tune across it to get an actual absorption. For Raman scattering, any pump wavelength can be used, and the frequency shift will tell you the molecule you have. That's a big advantage. If you are using absorption spectroscopy, you need to be at a very specific wavelength, and you can't always get lasers at the wavelength that you need. That can cause big problems. However, the non-linear Raman scattering has very small cross-sections. There has been some issues because you don't get a lot of scattered light. So you need higher powered lasers to see the scattered light.

In atmospheric LiDAR, solid-state lasers are used most commonly. If I look at spectroscopy in a lab setting, where I'm not trying to look at scattered light from kilometers away, I may be able to get away with a high power diode laser. But it will depend on the Raman scattering cross-section and the detector.

So the Raman spectroscopy lets you use well established lasers to do the pumping, and if you pick the right lasers and look at frequency shifts, then you can use well established photo detectors. With absorption spectroscopy, you're stuck with the absorption spectra of the molecule that you are interested in, making some experiments more difficult.

CONCLUSION

Raman spectroscopy can be a practical way to identify and quantify different types of molecules based on Raman scattering. Understanding the scattering cross-section and frequency shift of the appropriate molecules ensures experimental success. As previously shown, stable control of a laser diode, whether as the light source or pump laser, is crucial in establishing stable wavelength and reduced electrical and optical noise. With the wide variety of applications, Raman spectroscopy can provide molecular "fingerprints" based on vibrational or rotational modes of the molecule.

KEYWORDS

Raman, raman scattering, raman spectroscopy, spectroscopy, laser diode, optical noise, electrical noise, cross-section, frequency shift, wavelength stabilization, detector, pulsed laser, CW laser, seed laser, vibration, rotation

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