Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2017

Improvement of the Raman signals of hydrogen gas by using the background noise signals

In Young Choi [a*], Sung Hoon Baik [a], Seung Kyu Park [a], Nak Gyu Park [a], Young Soo Choi [b]
[a]*Division of Quantum Optics, Korea Atomic Energy Research Institute, Daejeon 34057, Korea*
[b]*Division of Nuclear Convergence Technology Development, Korea Atomic Energy Research Institute, Daejeon 34057, Korea*
[*]*Corresponding author: iychoi8584@kaeri.re.kr*

1. Introduction

Hydrogen gas is the echo-friendly energy that has no emission of the pullutant materials during the combustion and oxidation. However, hydrogen gas is very dangerous because it has low combustion energy and it is explosive at the low concentration densities. Therefore, detecting and measuring technique of the hydrogen gas are very important to use safely.

Raman lidar system is one of the remote hydrogen gas detection techniques. Hydrogen gas has high Raman scattering effect and Raman lidar system is possible to measure the hydrogen gas concentration and range remotely.

This paper discusses the improvement method of the measurement accuracy in the Raman lidar system for measuring the hydrogen gas concentration. Raman scattering signals by the hydrogen gas are very weak and it include the background noise signal such as the pumping laser and laser-induced fluoresecens signals. To reduce measurement error of the hydrogen gas concentration by using the Raman lidar system, background noise signal eliminating methods are developed. To verify the effect of the eliminating method of a background noise signal from the hydrogen Raman scattering signal, hydrogen Raman scattering signal and background noise signals were measured respectively by the Raman lidar system along the changing the hydrogen gas concentrations.

As a result, the coefficient of the determination (R^2) of the calibrated hydrogen Raman signal distribution by using the background noise signals was improved. The measurement errors were decreased.

2. Raman lidar system

2.1 Raman lidar system

Fig. 1 shows schematic diagram of the Raman lidar system for measuring concentration of hydrogen gas. In order to measure the concentration of hydrogen gas, Raman scattering signal of the nitrogen gas and hydrogen gas in the air are simultaneously measured. Therefore, optical receiver of the Raman lidar system has two optical channels by using the beam splitter. Hydrogen gas concentration could be measured by comparing magnitudes of simultaneously measured nitrogen and hydrogen Raman scattering signals. If the wavelength of the illuminating laser beam is 355 nm, hydrogen Raman scattering signal has 416 nm wavelength and nitrogen Raman scattering signal has 387 nm wavelength. [1], [2]

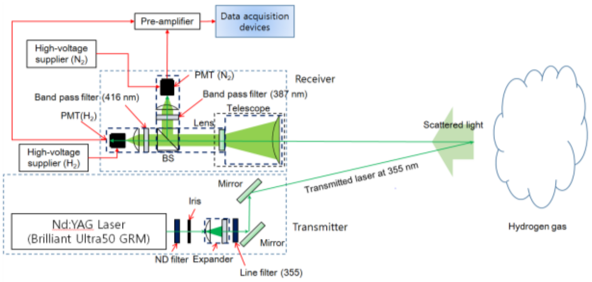

Fig. 1 Schematic diagram of the Raman lidar system for measuring the hydrogen gas concentration

2.2 Background noise signal

In case of the illuminating the pulse laser beam, hydrogen Raman scattering signals are mixed with other optical signals such as a pumping laser signal and laser-induced fluorescence signals, calling the background noise signal. To improve the measurement accuracy of the Raman lidar system, Raman lidar system uses various optical filters because the Raman scattering signal is weaker than other optical signal. [2] Therefore, Raman lidar system used the ultra-narrow band pass filter or notch filter for decreasing the effect of the laser and laser-induce fluorescence signals.

3. Experiment

Although an ultra-narrow band pass filter and a notch filter in the Raman lidar system are used for decreasing magnitude of the background noise, hydrogen Raman scattering signals will still include the background noise signal because all of the optical filters are impossible to perfectly block and transmit an optical signal. Fig. 2 shows the schematic diagram of the optical receiver to measure the hydrogen Raman signal and background noise signal. Hydrogen Raman signal and background noise signal are simultaneously measured by the Raman lidar system. From the two signals, background noise signals were eliminated from the hydrogen Raman signals. To verify the effect of the eliminating the background noise signal from the hydrogen Raman scattering signals, hydrogen Raman scattering signal and background noise signals were measured by using the Raman lidar system along the changing the hydrogen gas concentrations. To keep the hydrogen gas concentration and prevent the explosion of hydrogen gas, experiment carried out using a gas chamber. Table 1 shows the hydrogen gas concentration condition to measure the hydrogen Raman signal and background noise signal.

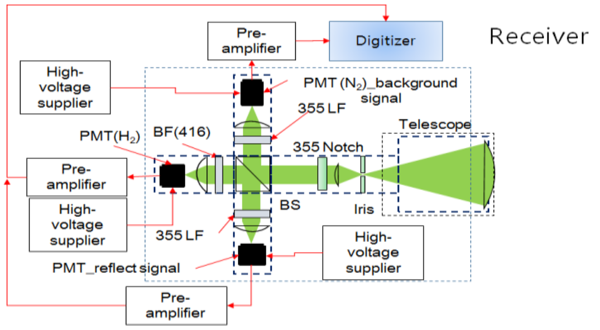

Fig. 2 Schematic diagram of the optical receiver in the Raman lidar system for measuring the hydrogen Raman signal and background noise signal

Table 1: Hydrogen gas concentration condition

Hydrogen gas concentration (Vol. %)	0.04	0.66	1.32
	3.29	6.45	13.16
	19.74	39.47	59.21
	78.95	100	

4. Experiment results

Fig. 3 shows the hydrogen Raman signal distribution according the hydrogen gas concentration. Hydrogen Raman signal has some voltages at 0.04 Vol. %, because hydrogen Raman signal still included background noise signals. Fig. 4 shows the background noise signal distribution according the hydrogen gas concentration. The background signal is nearly constant value regardless the hydrogen gas concentration values.

Fig. 5 shows the hydrogen Raman signal distribution eliminating the background noise signal according hydrogen gas concentration. Comparing Fig. 3 with Fig. 5, the coefficient of the determination (R^2) of the calibrated hydrogen Raman signal distribution by using the background noise signals was improved from 0.9983 to 0.9993. The measurement errors were decreased from 1.00 % to 0.70.

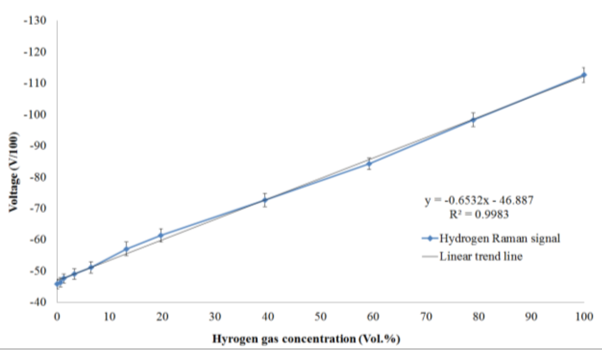

Fig. 3 Hydrogen Raman signal distribution according to hydrogen gas concentration.

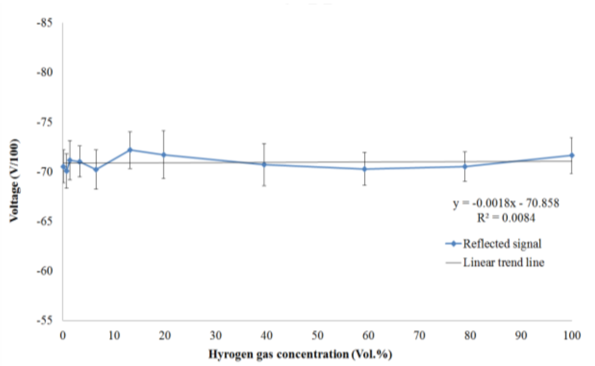

Fig. 4 Background noise signal distribution according to hydrogen gas concentration.

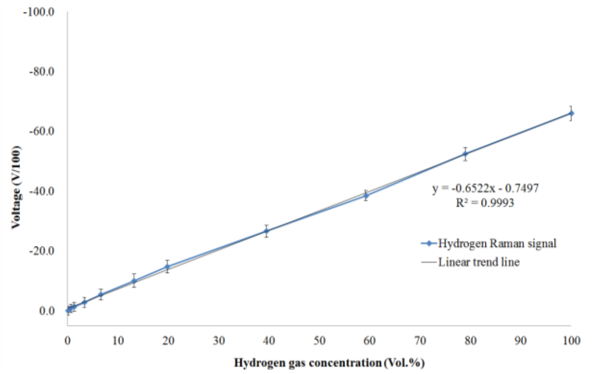

Fig. 5 Hydrogen Raman signal distribution eliminating the background noise signal according to hydrogen gas concentration.

5. Conclusion

This paper discusses the improvement method of the measurement accuracy about the Raman lidar system by using eliminated the background noise signal from the hydrogen Raman signal. To simultaneously measure the hydrogen Raman and background noise signal, optical receiver of the Raman lidar system was developed. Through the experiment, we proved that the coefficient of the determination (R^2) of the calibrated hydrogen Raman signal distribution by using the background noise signals was improved from 0.9983 to 0.9993 and the measurement errors were decreased from 1.00 % to 0.70.

ACKNOWLEDGMENT

This paper was supported by the Ministry of Science, ICT & Future Planning

REFERENCES

[1] H. Ninomiay, S. Yeashima, and K. Ichikawa, Raman lidar system for hydrogen gas detection, Optical Engineering, Vol. 46, No. 9, pp. 094301, 2007.

[2] E. I. Voronina, V. E. Privalov, and V. G. Shemanin, Probing Hydrogen Molecules with Laboratory Raman Lidar, Techincal Physics Latters, Vol. 30, No. 3, pp. 178 – 179, 2004.