LASER RADIATION ATTENUATION AS AN APPROACH FOR ESTIMATING HUMIDITY AND POLLUTION

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Abstract: Humidity is considered as one of the factors causing high absorption for several laser radiation wavelengths, namely the 10.6μm. The aforementioned wavelength is produced by carbon dioxide laser. Humidity was found to have great influence on this wavelength. In this reported research project, a compact system for measuring humidity, pollution and Laser transmission was constructed on Laboratory Scale. It consists of a wooden box, which have two holes as inlet and outlet for laser beam. A third hole for water vapor flow was made on the wooden box. Furthermore, the box contains two thermometers for measuring temperature. By using Beer-Lambert law, $I(x) = I_0 \exp(-\alpha x)$, the laser transmission was measured to be 86% at 10% humidity and 4% at 90% humidity. This suggests the great influence of humidity and similarly pollution (e.g. dust) on reducing the laser radiation transmission. We found the possibility of using the experimentally obtained laser transmission results as an accurate indication to estimate humidity and pollution.

1. Introduction

Laser is considered as an essential reason for making use of the optical frequency band in several communication systems. This is due to the fact that working in the optical band makes it possible to achieve high accuracy in directing the beam and in having highly intensified electromagnetic radiation in the free space. This can be referred to its 'high energy'. Another advantage is the compactness of laser systems in comparison to other conventional techniques. Due to the broad band of the optical frequency, it can contain a large number of frequency channels. Furthermore, the high frequency of this electromagnetic radiation satisfies high accuracy in measuring Doppler shift even for low velocity objects. Due to the laser characteristics, it found several applications to industry, medicine, communication, range finding, civil aviation safety, and laser radars and for remotely senses the distribution of wind velocity and pollution.

It is important to consider the atmosphere's transmission for the used laser wavelength. This is differently influenced by the attenuation and according to the atmospheric absorbing molecules. As is shown in Fig. (1), the atmospheric transmission for the infrared radiation regions can be distinguished. The first is from 3-5μm. One of the approaches to reduce the aforementioned high degree of attenuation suffered by the infrared region is a frequency doubling technique to obtain shorter laser wavelength. The range between target and laser transmitter directly influences laser radiation attenuation, however, it is much more significantly influenced by the inverse of the height angle with respect to the target. The main atmospheric attenuation cause for the CO_2 laser radiation is the absorption by the water vapor.

2. The Experimental results

The setup, which is shown in Fig. (2), was used to study the coherent detection technique. An RF-wave guide 4W CO_2 laser was used. Furthermore, acousto optic modulator, Mercury cadmium Telluride (M.C.T.) detector and expanding and collimating telescopes were used. Three pieces of germanium with 5-7.5cm diameters were used as shown in Fig. (2).

The CO_2 laser was replaced in some experiments with a semi conductor laser (λ= 810 nm) and Si detector.

The effect on the coherent detection was studied through designing a compact system for measuring humidity and measuring the transmitted laser intensity through the humidity system. The humidity system was a (30 cm x 30 cm x 30 cm) wooden box. It contains two holes as the inlet and the outlet of the laser beam. It also contains another hole for pumping water vapor. Two thermometers were installed inside the box for measuring temperature. One of them was watered with water. Beer–Lambert law was used to calculate the attenuation factor.

3. Discussions

Several parameters affecting the coherent detection were investigated in this research study. Of particular interest was the atmospheric attenuation due to humidity. It was found of significantly large effect on the CO_2 laser beam propagation.

This approach was successfully used to study the effect of polluting particles. The relative transmission for a wide range of humidity values was measured as shown in Fig. (3). The increase in humidity proved to significantly decrease the laser beam transmission.

The coherent detection proved to be much more efficient than direct detection when humidity is increased. At 98% humidity the signal gain was 6dB using the coherent detection. Interestingly, this number was found to decrease to1 dB with direct detection. Another parameter, affecting signal amplitude was the target or object reflectivity. It was studied intensively. The effect of distance on detection efficiency was also investigated. This was justified as caused by the laser beam divergence mainly (see Fig. 4 and 6). It suggests the necessity of using a beam expander to have constant expansion with the distance increase. Using a telescope proved to improve detection efficiency.

4. Conclusions

1. Humidity proved to be the most important parameter attenuating the laser beam.
2. The coherent optical radar can be used as an environment sensor for dust and humidity.
3. It is necessary to use an efficient optical system (telescope and beam expander) in laser radar. It was found to improve the detection range three times.
4. Using the coherent detection, the vibrations of several moving objects were detected. It was proved that these vibrations can be used as finger prints for identifying different targets according to their different frequencies.

References

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Appendix

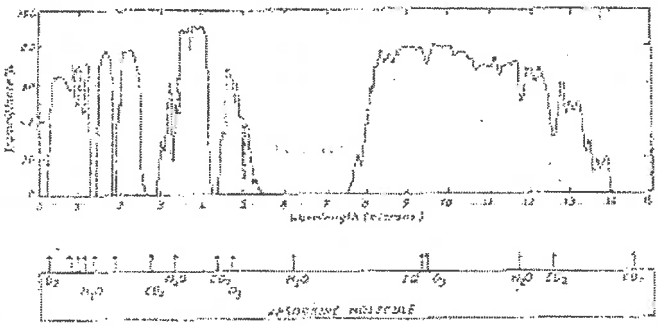

Fig. 1: The atmospheric windows for laser at the infrared and visible region.

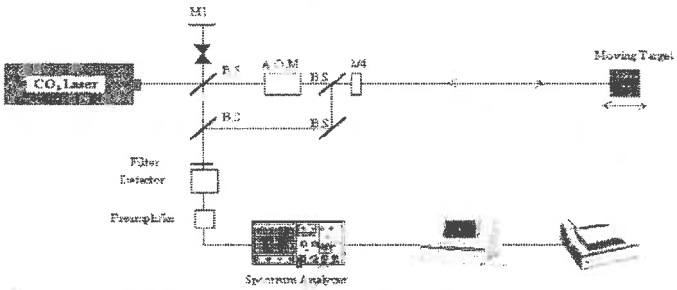

Fig. 2: The set-up, which was used to study the coherent detection technique.