Research on VCSEL Interference Analysis and Elimination Method

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Abstract

Laser methane gas sensors have been increasingly accepted in coal mine safety monitoring. Most laser spectroscopic methane gas sensors are based in BFB lasers at around 1650nm. However, they suffer from high power consumption and high cost due to temperature control is required for laser diode operation at constant temperature. VCSEL lasers have offered low operation current and low power consumption when operating at non-TEC mode. However, it is found that the interference noise is critical for laser methane detection. This paper report typical results of the laser diode ripple characterization method and methods of noise reduction methods are discussed.

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Keywords: VCSEL，laser diode，gas detection，ripple，interference

1 INTRODUCTION

Laser methane modules are used in major industrial and mining enterprises due to their low power and high detection accuracy. When the laser methane module measures gas, there are interference problems due to the device problem or other factors used, the main stability data indicators such as ripple are unreliable, and the gas absorption peak image is slightly deformed, so it cannot be used when the gas content is small. Observing the absorption peak image through the software in time, affecting the measurement accuracy, and completely eliminating the interference is difficult to achieve, so the interference must be controlled within a small range.

The VCSEL laser is used in the laser methane module. The VCSEL laser is a vertical cavity surface emitting laser. It is different from LED and LD. It is based on InP semiconductor materials. The utility model has the advantages of small volume, circular spot output, single longitudinal mode output, small threshold current, low price and easy integration into a large area array. The laser methane module is applied to TDLAS technology, and VCSEL can be applied to the part with higher power consumption limit in TDLAS-based gas detection.

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In the experimental stage of the laser methane module, the connection test software observed its various stability data indicators, but the data showed that the ripple results were not very satisfactory. Therefore, the data is derived, the fitting calculation is performed, and the interference intensity is calculated. The maximum interference intensity was calculated to be four parts of ten thousandths by six-th polynomial fittings and two-order fittings. In the experimental analysis stage, the cause of the interference is first analyzed. Through experimental and mathematical methods, such as using the formula to calculate the cavity length generated by the interference, correspondingly find the position where the interference may occur and the device or other problems. Ripple elimination experiments were also performed as needed. In summary, the problem of ripple generation is detected experimentally and the ripple is minimized to improve the accuracy and reliability of the laser methane module during gas detection.

2 BASIC PRINCIPLE OF INTERFERENCE FORMATION

The laser methane module is mainly composed of a laser, a photodetector and the like. The light emitted by the laser passes through the mirror in the optical path and finally reaches the photodetector. During this period, stray light or reflection is generated to form multi-beam interference, and the partially reflected beam returns along the original path and encounters interference [1].

In the usual experiment we got:

1) When there is no methane concentration, the interference intensity is <0.4‰, but the curve after normalization is in a twisted state; 2) When 1.5% methane gas was introduced, the normalized curve clearly observed the baseline distortion; the interference curve and the normalized curve were significantly different when no methane gas was introduced. The interference curve is obtained by six fitting methods, and the normalized curve is obtained by a quadratic fitting method. The above differences occur because the fitting methods used are different. Because of the phenomenon of baseline distortion and other phenomena, the measurement accuracy is not high, and there may be a small amount of gas present at the baseline distortion.

3 related experiments to the problem of interference

In order to verify the possible problem of interference in the laser methane module optical path, suppose the problem point1) between the laser component and the PD component; 2) Inside the laser component:3) Reflection caused by the laser component/PD component. The distance between the laser component and the PD component is 68.94 mm, the distance from the laser component chip to the lens is 5 mm, the distance from the laser oblique window to the lens is 3.53 mm, and the distance from the PD component ball to the PD chip is 0.5 mm.

3.1 Experimental principle

The interference signal is related to the cavity length L. By measuring the change of the interference signal, the change of the cavity length L can be derived, corresponding to the module, thereby obtaining a problem point caused by the interference [4].

Calculate the basic formula for the length of the interference cavity from the interference pattern:

$$L = \frac{1}{2}\left(\frac{\lambda_1 \times \lambda_2}{\lambda_2 - \lambda_1}\right) \quad (1)$$

where λ1 andλ2 are the starting and the ending wavelength, and L is the interference cavity length.

3.2 Experimental content

The module link PC reads the original signal and the real-time curve, calculates the interference cavity length according to the wavelength information and curve information displayed by the module, and finds the problem caused by the interference according to the optical path diagram. The sixth-order polynomial fitting curve of the light source and the quadratic fitting signal of the probe were observed by software to see the interference fringes in the ripple. The ripple of the interference fringes is calculated by the raw data collected by the software at the starting wavelength λ1 of one of the interference periods and the ending wavelength λ2. Calculate the cavity length resulting from the interference.

3.3 Experimental data collection

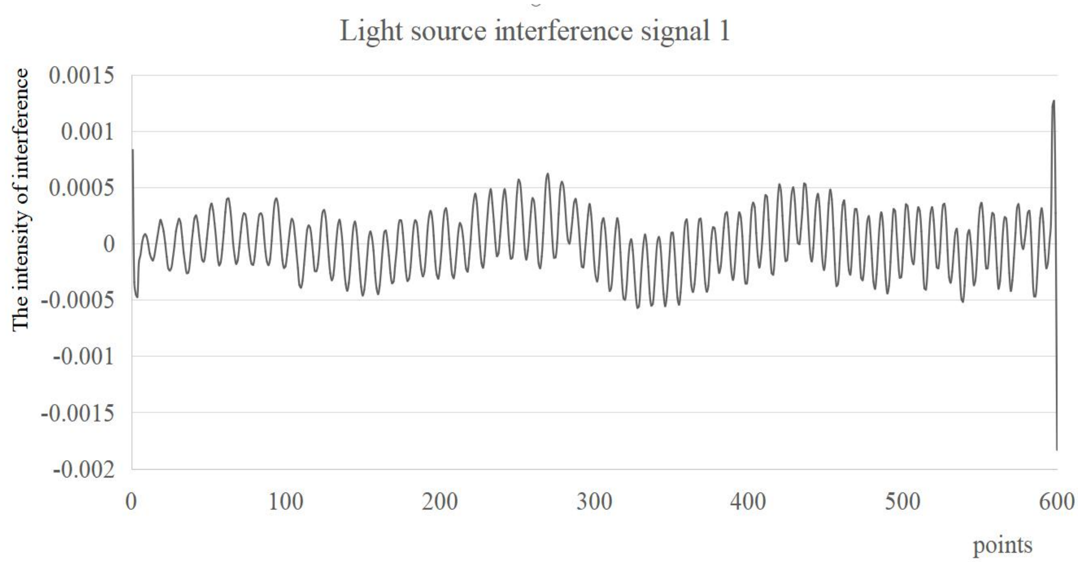

Figure 1 Light source interference signal

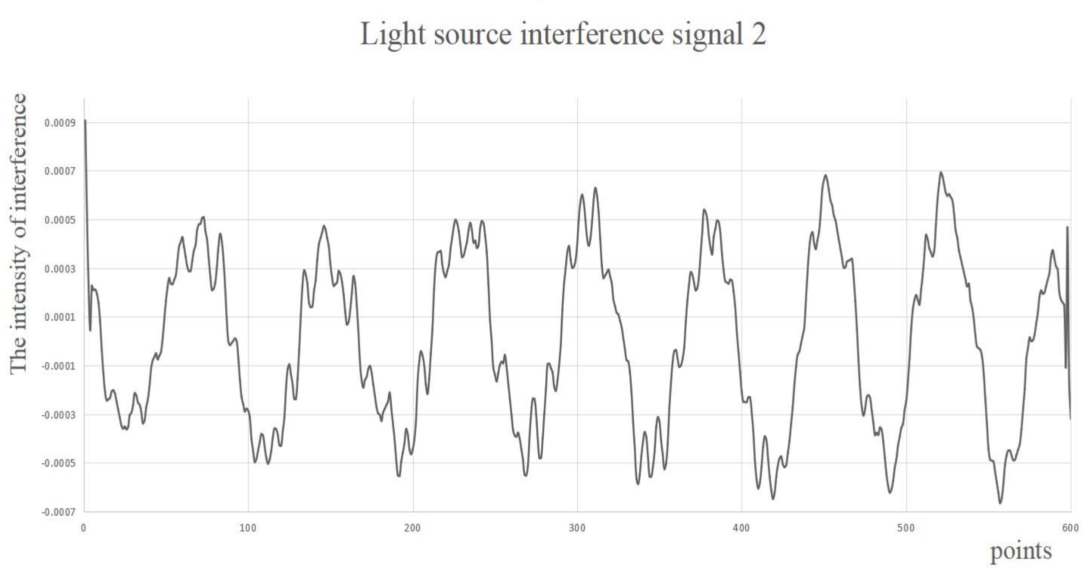

Figure 2 Light source interference signal 2

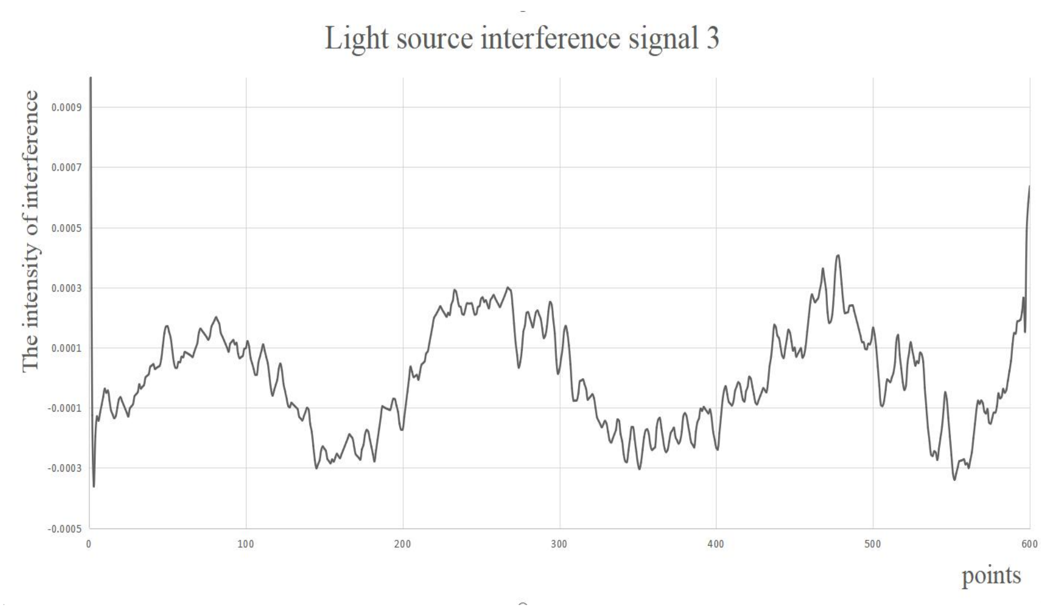

Figure 3 Light source interference signal 3

3.4Experimental data integration

Table 1 Source interference signal data integration

variable	Light source interference signal		
	1	2	3
Wavelength range（nm）	1.091	1.299	1.119
Starting wavelength（nm）	1647.606	1647.496	1647.583
Termination wavelength（nm）	1648.697	1648.795	1648.709
Scan points	600	600	600
Number of peaks	66	8	3
Center wavelength（nm）	1648.1515	1648.1455	1648.146
Wavelength range（min）	0.991	1.199	1.019
Wavelength range（max）	1.191	1.399	1.219
Wavelength stepping（nm/point）	0.001818333	0.002165	0.001865
Crest spacing（nm）	0.016530303	0.162375	0.373
Crest spacing（min）	0.015015152	0.149875	0.339666667
Crest spacing（max）	0.018045455	0.174875	0.406333333
Cavity length（L）	82.16435482	8.364537611	3.641267074
Cavity length（Lmax）	90.4554098	9.062163767	3.998604373
Cavity length（Lmin	75.26558447	7.766643572	3.342557716

The length of the cavity in the table is calculated according to the formula, and other data are sorted out by the collected data.

3.5 Experimental conclusions

By observing that the interference of three cycles is obvious, the interference cavity length is calculated.

1) Light source interference signal 1 - long distance interference: interference generated between the laser component and the PD component;

2) light source interference signal 2 - short distance interference: interference generated inside the laser assembly;

3) Light source interference signal 3 - Ultra short distance interference: interference generated inside the laser component / inside the PD.

4 Ripple elimination experiments

4.1 Experimental purposes and methods. In order to eliminate the ripple, the module with the ripple failure is blackened by the surface of the PD lens, mainly to attenuate the reflection intensity and eliminate the reflected light in the optical path, thereby reducing the ripple of the system [2].

4.2 Experimental content

The GJGX100M intrinsically safe laser methane software (20180201) and Laser ripple test software V1.0 were used in the experiment. The data was obtained through these two software, and the data was exported. After six fittings, the system ripple was controlled within 0.5‰. At the same time, there will be no obvious periodic regular interference on the waveform. This is an expectation of the experiment.

In the packaged module, the laser sleeve has been fixed and cannot be manipulated, and the interference inside the PD cannot be interfered. Therefore, the most convenient operation is the interference between the laser lens and the PD lens, which can be blackened on the PD lens. This way weakens the reflected light, which in turn reduces the ripple of the system.

Black marks are used in turn and black 704 silica gel is used to black spots at different positions of the PD lens to see the effect of ripple removal.

4.3Experimental data

Table 2 Ripple elimination experimental data

Serial number	Before blacking		After blacking		Test the next day after blackening	
	Ripple	Gain	Ripple	Gain	Ripple	Gain
1	0.0008	130	0.0003	104	0.0004	106
2	0.0011	130	0.0005	142	0.0007	101
3	0.0004	4	0.0004	42	/	/
4	0.0013	9	0.0004	7	0.0006	7
5	0.0004	21	0.0003	35	/	/
6	0.0006	56	0.0008	78	/	/
7	0.0004	14	/	/		
8	0.0002	22	/	/		
9	0.0003	10	/	/		

4.4 Experimental conclusions

1) In the sample with the elimination effect, the position of the black spot is best applied to the center of the PD incident light spot.

2) The elimination effect is also related to the gain of the module (ie, the light intensity), and the module with low gain (light power) eliminates the effect.

5 Conclusion

The exiting light intensity of the laser causes interference, and the emitted light of the laser is reflected in the optical path, and then reflected back and then satisfies the interference condition together with the outgoing light of the laser to form interference, and finally the measurement accuracy is not high. Each device in the optical path forms interference at different distances. At present, the problem of interference is initially found through experimental methods. The next step is to eliminate interference by software method and further improve the measurement accuracy of the module.

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