

## Compact Breath Sensing using Amplifier Assisted CRDS (Cavity Ring-down Spectroscopy)

Li, Wenying

I-Eggs (Interdisciplinary Graduate School of Engineering Sciences), Kyushu University

Han, Yu

I-Eggs (Interdisciplinary Graduate School of Engineering Sciences), Kyushu University

Chen, Zanhui

I-Eggs (Interdisciplinary Graduate School of Engineering Sciences), Kyushu University

Jiang, Haisong

I-EggS (Interdisciplinary Graduate School of Engineering Sciences), Kyushu University

他

<https://doi.org/10.15017/2552953>

---

出版情報 : Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 5, pp.107-108, 2019-10-24. 九州大学大学院総合理工学府

バージョン :

権利関係 :



# Compact Breath Sensing using Amplifier Assisted CRDS (Cavity Ring-down Spectroscopy)

Wenying Li, Yu Han, Zanhui Chen, Haisong Jiang, and Kiichi Hamamoto

I-EggS (Interdisciplinary Graduate School of Engineering Sciences), Kyushu Univ.,  
Email: ri.uenin.271@s.kyushu-u.ac.jp

**Abstract:** Amplifier assisted CRDS (cavity ring-down spectroscopy) is proposed to realize ppm-order gas sensing using optical waveguide with telecom wavelength band. One issue of the amplifier assisted CRDS system is that the self-lasing may happen when optical amplifier is at high pumping condition. Self-lasing light takes away the gain of amplifier from the signal light, limits the sensing sensitivity. To stop the self-lasing, we proposed the polarization direction control scheme in this work. The experimental results show the light intensity of self-lasing light is suppressed down below -50 dBm, and the gain of signal light improved 24dB.

**Keywords:** Gas sensing; CRDS system; Waveguide.

## 1. INTRODUCTION

Breath sensing system based on CRDS (Cavity ring-down spectroscopy) method is attractive because human-breath contains various disease-markers, as well as its real time and high sensitivity sensing. Compact breath sensing system is desired for daily health care and optical waveguide gas-cell<sup>[1-2]</sup> has been proposed to realize such that compact system. The propagation loss of the waveguide, however, may prevent the low gas concentration sensing. We have proposed the optical amplifier assisted CRDS system scheme to compensate the waveguide propagation loss<sup>[3]</sup>. One issue is that when optical amplifier is at high pumping condition, self-lasing may happen. Self-lasing light takes away the gain of amplifier from the signal light, limits the sensing sensitivity. To stop the self-lasing, we proposed the polarization direction control scheme in this work. The experimental results show the light intensity of self-lasing light is suppressed down below -50 dBm, and the gain of signal light improved 24dB.

## 2. SELF-LASING ISSUE IN AMPLIFIED CRDS SYSTEM

The amplifier assisted CRDS system we use is shown in Fig. 1 (a). Two couplers and sensing-waveguide<sup>[3]</sup> form sensing “cavity”. Couplers work like mirrors to reflect signal light back into the cavity except a portion of monitor-light leak out via the coupler. In this system, we used an EDFA (Erbium-doped fiber amplifier) as an optical amplifier to compensate the propagation loss of the waveguide. An EDFA inside a closed ring loop, however, may form the structure of fiber ring laser<sup>[4-5]</sup>, when optical amplifier is at high pumping condition, self-lasing happens. Figure 1 (b) shows an example of this self-lasing. 1572 nm wavelength (Absorption wavelength of CO<sub>2</sub>) light is introduced into the CRDS system, however, another wavelength of 1564 nm starts lasing. The self-lasing light takes most of the gain from amplifier, signal light loses its gain, which limits the sensing sensitivity.

The ASE (Amplified spontaneous emission) that generated by EDFA works as the “first seed” and travelling inside the CRDS system. This travelling light

keeps the same phase, polarization and frequency, coherency is secured<sup>[6]</sup>, thus self-lasing happens. To stop the self-lasing, we propose the polarization direction control scheme. By changing the polarization of the travelling light, destroy the coherency condition, prevent the self-lasing.

## 3. RESULT AND DISCUSSION

The configuration of polarization direction control is shown in Fig. 2 (a). A polarization controller is set inside the CRDS system. The “first seed” of self-lasing, the ASE of EDFA is circular polarization light. When it propagates through the polarization controller, it is changed to linear polarization light, a portion of light intensity of this “first seed” is cut. As the polarization condition is changed from circular polarization to linear polarization, the coherency condition is weakened, thus the self-lasing is suspended. The spectrum of the amplifier assisted CRDS system after polarization direction control is shown in Fig. 2 (b). The self-lasing power is suppressed to be below -50 dBm. We estimate that the gain of signal improved 24dB.

Figure 3 shows the cavity ring-down waveform after the polarization direction control. As is shown in the figure, more than 200 pulses are achieved, which is available for ppm-order gas detection.

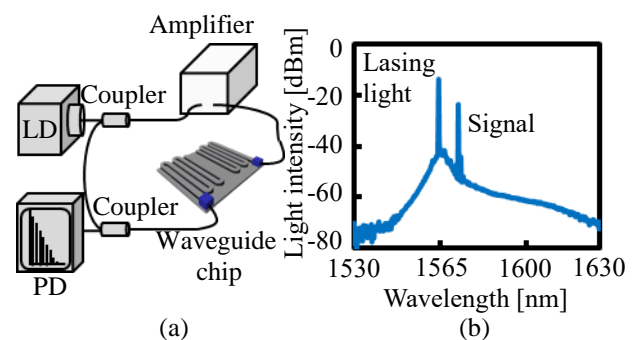


Fig. 1 (a) Amplifier assisted CRDS system configuration.  
(b) Spectrum of amplifier assisted CRDS system.

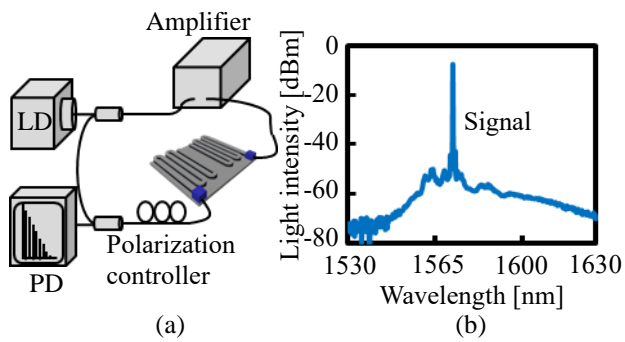


Fig. 2 (a) Configuration of polarization direction control in amplifier assisted CRDS system. (b) Spectrum of polarization direction controlled CRDS system.

#### 4. CONCLUSIONS

In amplifier assisted CRDS system, when optical amplifier is at high pumping condition, self-lasing may happen. The self-lasing light consumes most of the gain and the signal light hardly get gain from amplifier. We introduced the polarization direction control scheme to suspend the self-lasing, the experiment results show the light intensity of self-lasing light is suppressed down below -50 dBm, and the gain of signal light improved 24dB.

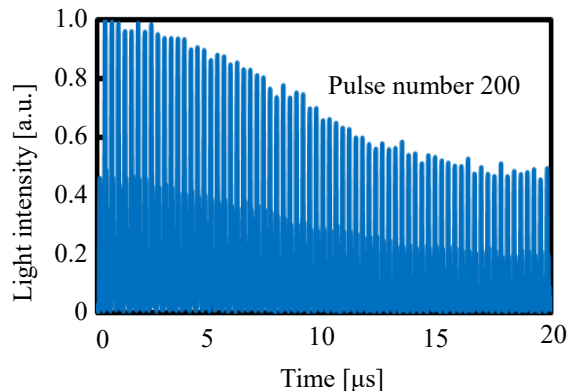


Fig. 3. Cavity ring-down waveform after polarization direction control.

#### 5. ACKNOWLEDGEMENT

This research was financially supported by SECOM Science and Technolygh Foundation.

#### 6. REFERENCE

- [1] A. Wilk, F. Swichter, S. Kim, E. Tutuncu, B. Mizaikoff, J.A. Vogt, U. Wachter, and P. Radermacher, Toward the quantification of the  $^{13}\text{CO}_2/^{12}\text{CO}_2$  ratio in exhaled mouse breath with midinfrared hollow waveguide gas sensors, *J. Analy. Bioanal. Chem.*, 402 (2012) 397-404.
- [2] W. Lai, S. Chakravarty, X. Wang, C. Lin, R. Chen, On-chip methane sensing by near-IR absorption signatures in a photonic crystal slot waveguide, *J. Opt. Lett.*, 36 (2011) 984-986.
- [3] H. Hokazono W. Li, S. Enami, H. Jiang, and K. Hamamoto, Gas sensing demonstration by using silica high-mesa waveguide with amplified cavity

ring down spectroscopy technique, *J. ELEX*, 12 (2015) 20150574.

- [4] C. Chang, and A. Amrullah, A steady-gain C-band EDFA for multi-wavelength fiber optical transport networks, *Int. J. of Optoelectron. Eng.* 3 (2013) 6-11.
- [5] X. Liu, Z. Li, S. Luo, Z. Gu, J. Liu, Y. Wang, and Q. Shen, Multiwavelength erbium-doped fiber laser based on a nonlinear amplifying loop mirror assisted by un-unpumped EDF, *J. Opt. express* 20 (2012) 7088-7094.
- [6] Ter-Mikirtychev, and Vartan, *Fundamentals of fiber lasers and fiber amplifiers*, Springer, Switzerland, 2014, pp. 79-98.