Amplifier-assisted cavity ring-down spectroscopy using optical waveguide

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(光アンプアシスト法による光導波路型キャビティリングダウン分光法に関する研究)

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論　文　内　容　の　要　旨

Thesis Summary

Population aging problem has become one of the significant social problem. Because of this problem, the demand of daily and easy health-check system for elder people is considered to be important. Especially home-based health monitor is desired. Breath sensing is available for the daily and easy health check because exhaled breath contains a lot kinds of disease markers. People only need breathing-out toward the sensor. The density of each disease marker in breath is analyzed at the time.

For home-use, breath sensor based on infrared absorption spectroscopy has the possibility to sense several kinds of gases at the same time. This is because each gas has its own eigen absorption peak in wavelength. For sensing ppm-order gas component in breath by using infrared absorption, an extremely long optical sensing path of several km is needed for sufficient light absorption (typically 3 dB). To achieve the effectively long length sensing path (corresponding km order) within a cavity, CRDS (cavity ring-down spectroscopy) has been proposed. One issue of the CRDS system as home-use sensor is its large size.

We have proposed breath sensor utilizing optical waveguide as the optical path for infrared absorption based on CRDS. This is because waveguide is capable for integrating several meter optical paths in a compact area (1 cm2). One problem is the waveguide propagation loss. Huge amount of loss decreases the sensing light intensity. As most of the sensing light intensity is reduced due to the propagation loss, ppm-order breath sensing becomes hard to be realized. As a solution, we have proposed amplifier-assisted CRDS to compensate the propagation loss. For hand-held breath sensor, SOA (semiconductor optical amplifier) is a candidate due to its capability of integration. To verify the effectiveness of the amplifier-assisted CRDS, we use an EDFA (Erbium-doped fiber amplifier) instead of the SOA inside CRDS system in this work. When EDFA is at a high pumping condition, ASE (amplified spontaneous emission) loops inside CRDS system and be amplified in the EDFA. Then, it starts self-lasing at a wavelength different from sensing light. Once self-lasing happens, sensing light looses the gain from EDFA. This is because most of the gain is attributed to lasing wavelength. We have proposed polarization direction control scheme to suspend self-lasing by weakening the coherency condition. The coherency is a fundamental requirement of making oscillation in cavity (namely, ring-cavity here) in general. The result showed that the self-lasing intensity was suspended, and the gain was improved to 24 dB from 14 dB at the sensing light wavelength.

Whereas the self-lasing issue has been improved, there is still an important issue in the amplifier-assisted CRDS system. The amplifier noise which exists at sensing light wavelength is hardly eliminated. In ppm-order gas sensing, the amplifier noise loops inside the system with sensing light for more than 1,000 times. The

significant accumulated noise intensity may surpass the sensing light intensity and prevent ppm-order breath sensing. Hence, the accumulated noise intensity influences the sensing ability of amplifier-assisted CRDS system directly. In this work, to evaluate the lowest gas sensing concentration of amplifier-assisted waveguide CRDS, we calculated the accumulated amplifier noise intensity at ppm-order gas sensing condition. Then we estimated the necessary injection light intensity for ppm-order gas sensing under the influence of the amplifier noise. The estimated results showed several kinds of ppm-order gases (CO_2, CH_4, NH_3, and CH_3COCH_3) are sensing-available by using the injection light intensity below 10 mW when the criteria level is set as 0.9. Meanwhile, the actual 3% CO_2 sensing was also demonstrated experimentally to confirm the effectiveness of this proposal shown in this thesis.