Development of Non-Intrusive and Micron-Resolution CARS Sensing for Gas Mixture Flow considering Reduction of Non-Resonant Background Noise

K. Kojima1, Y. Yamagata1, K. Yamamoto2, Y. Sato1
1: Dept. of System Design Engineering, Faculty of Science and Technology, Keio University, Japan
2: Dept. of Mechanical Engineering, Tokyo University of Science, Japan
* Correspondent author: kojima@fse.sd.keio.ac.jp

Keywords: CARS, Non-resonant background noise, Non-intrusive measurement, Gas mixture flow

HIGHLIGHTS
- CARS system with variable excitation beam diameter was developed.
- The non-resonant background noise from a glass slide was reduced by the expansion of excitation beams.
- Concentration measurement of a gas flow in a minichannel was carried out by the developed system.

ABSTRACT
CARS microscopy is useful for measurements of temperature and concentration due to its high signal intensity. However, the two high-powered pulsed excitation beams also generate the non-resonant background noise (NRB noise) and the noise makes the measurements in gas flows in mini- and microchannels difficult because the intensity of both the CARS signal (from the gas) and the NRB noise (from the channel wall) are quadratic functions of the number density of the molecule. In this study, a CARS system with variable excitation beam diameter was developed and the expansion of the excitation beams was conducted to reduce the NRB noise. Intensity of the NRB noise generated from a glass slide was measured with three different beam expansion conditions. As a result, the NRB noise was reduced as the beam diameters increased and as the distance between the glass slide and focal point of the excitation beams were widened. The NRB noise was hardly detected when the glass slide was approximately 0.3 mm away from the focal point in the case of the largest beam diameter condition. Moreover, the CARS signal to the NRB noise ratio was obtained for three conditions. It was found that the signal-to-noise ratio significantly improved for the largest beam diameters. With this condition, concentration distribution of CO2 in a CO2/N2 mixing flow in a Y-shaped minichannel was successfully measured through the channel walls made of borosilicate glass.

Table 1: Diameters of excitation beams and the generation region of the CARS signal.

<table>
<thead>
<tr>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>3.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Stokes</td>
<td>4.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Generation region [μm²]</td>
<td>2.55×2.55×22.2</td>
<td>2.24×2.24×20.7</td>
</tr>
</tbody>
</table>

Fig.1 Schematic of the developed CARS system.

Fig.2 NRB noise intensity from a glass slide.

Fig.3 Calibration curves for different beam diameters.

Fig. 4 (a) Measurement points in a Y-shaped channel and (b) CO2 concentration profiles.