論文の内容の要旨

論文題目 Highly Sensitive and Point-Measurement Laser Spectroscopy of High Enthalpy Flow

(高エンタルピー気流の高感度および点計測レーザー分光計測)

氏　　名　野村　哲史

Mechanism of aerodynamic heating at reentry to the Earth atmosphere has been investigated experimentally and numerically. In the experimental investigation, reentry conditions have been reproduced on the ground by using high enthalpy flow generator. For detailed understanding of heating mechanism, diagnosis of the high enthalpy flow is of importance. Although new ground test facilities are being developed for in-space missions to other planets, diagnostics of translational temperature is not established yet. For translational temperature measurements in the plasma wind tunnel, the high wavelength-resolution, high sensitivity and point-measurement are required. Objectives of this thesis are 1) to measure the absorption of atomic oxygen in the arc heated air plasma flow, 2) to extend the applicability of LIF to optically thick plasma in combination with LAS and 3) to develop a novel technique to access to translational temperature in the shock layer.

Currently there is no successful work of LAS measurement in an arc heated air plasma flow. This is because absorbance between two excitation states is quite small because of its low electronic excitation. Cavity enhanced absorption spectroscopy (CEAS) was applied to an arc heated plasma wind tunnel at

Japanese Space Exploration Agency (JAXA). The undesired signal induced by the mechanical vibration was eliminated in the data processing. The reflectivity of the cavity was 0.9935 and sensitivity of LAS was enhanced by two orders of magnitude. As a result the absorption of atomic oxygen was observed as shown in Figure 1. The minimum detectable absorbance of this measurement system is 3.0×10^{-4}. To our best knowledge this is the first demonstration of the absorption measurement in the arc-heated air plasma flow.

In optically thick plasma measurements, the absorption of laser and re-absorption (or self-absorption) of fluorescence distort a fluorescence profile and make it difficult to deduce Doppler broadening from the observed fluorescence profile. Furthermore, when the probe laser intensity is high enough to induce saturation effect, saturation broadening makes the profile wider than the true profile. Correction methods for these effects were proposed and applied to the arc heated argon plasma. Observed LIF broadening and corresponding translational temperature without correction were, respectively, 2.20±0.05 GHz and 2510±100 K and corrected broadening and temperature were, respectively, 1.96±0.07 GHz and 1990±150 K. The profiles of corrected LIF signal is shown in Figure 2. The temperature of corrected profiles are shown in Table 1. The result showed a good agreement with the result of LAS with Abel inversion. This technique is valid only for measurement on the center axis of the plasma flow, however this technique can be a power tool to obtain a 1-D distribution of temperature along the center axis.

It is difficult to apply LAS to shock layer measurement. Although DLIF combined with LAS enables point measurement even in optically thick plasma, the absorption of probe laser is not the same as re-absorption of fluorescence in shock laser and the correction method can’t be used. In this thesis a novel technique which is termed as cross-beam saturated absorption spectroscopy (XBSAS) is developed to measure translational temperature in the shock layer. This technique can be applied to an arbitrary distribution. First XBSAS was applied to free stream measurement as shown in Figure 3. The result showed a good agreement with the result of LAS. Next, XBSAS was applied to the shock layer measurement. The 1-D temperature distribution in front of the probe, which is shown in Figure 4, was obtained successfully.

LAS has developed for point measurement and sensitive measurement of translational temperature. Although it is difficult to figure out the plasma condition in detail only by one measurement technique, the combination of these measurements, or proper application of these techniques depending on the plasma condition, help us to understand the plasma in detail.

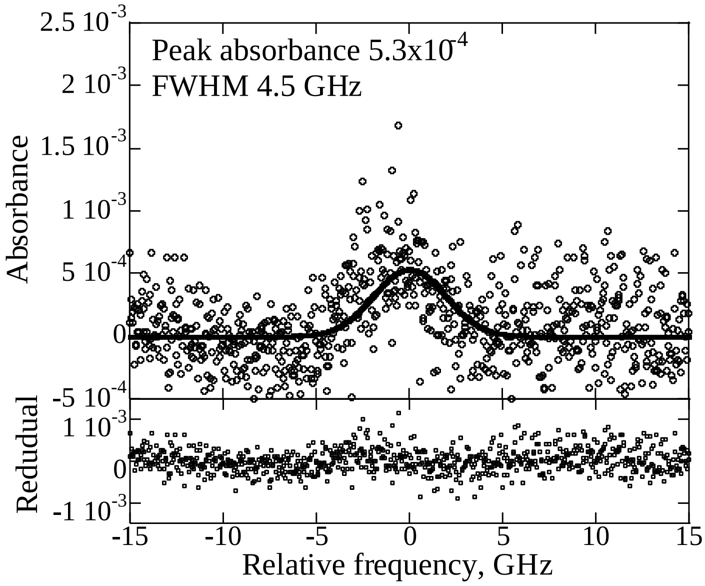

Figure 1 Absorbance profile of CEAS.

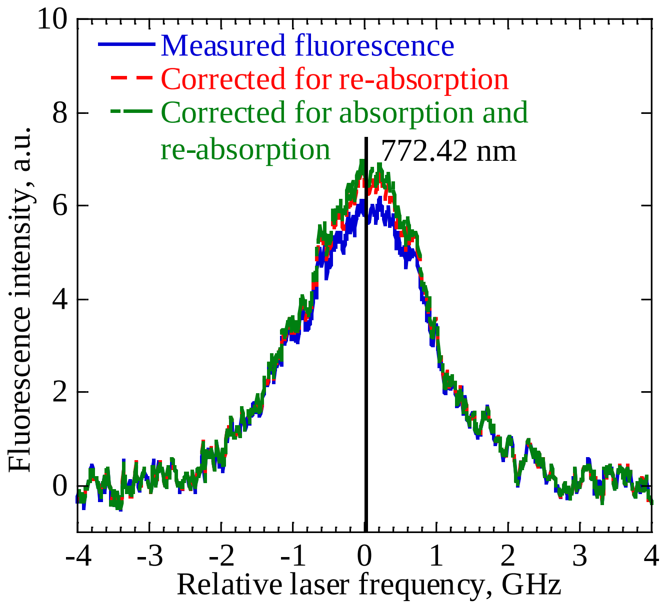

Figure 2 Measured and corrected fluorescence profiles of argon.

Table 1 Full width at half maximum (FWHM) and temperature of distorted profiles.

	FWHM, GHz	Temperature, K	Ratio of estimated temperature to true temperature
Profile distorted by re-absorption	2.04	2150	1.08
Profile distorted by absorption	1.98	2030	1.02
Profile distorted by saturation	2.11	2310	1.16
Observed profile	2.20	2510	1.26
True profile	1.96	1990	1

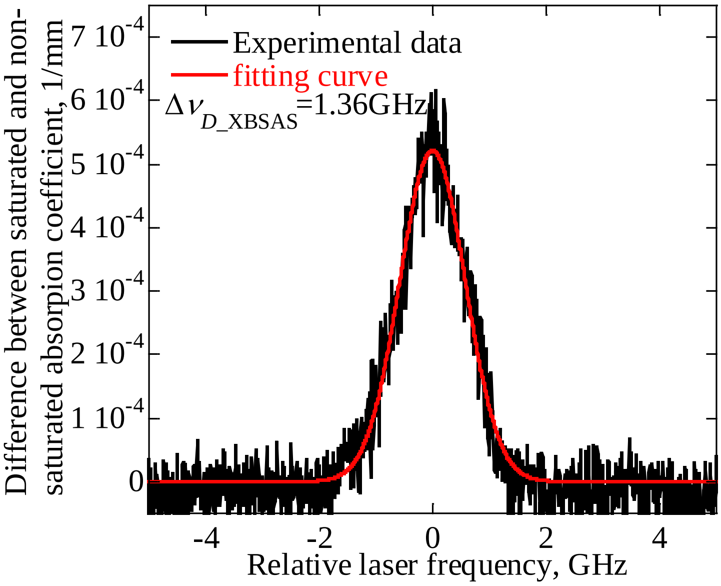

Figure 3 XBSAS profile with a fitting curve.

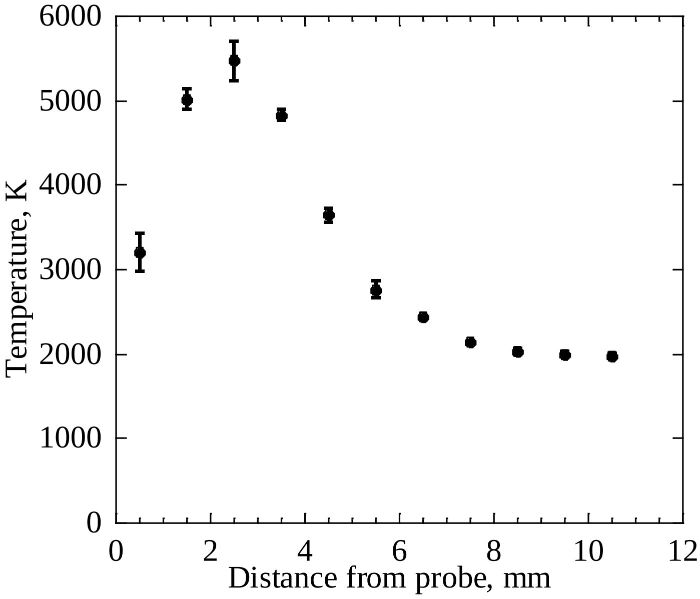

Figure 4 Temperature distribution in front of the spherical probe.