JASMAC
Conference of the Japan Society of Microgravity Appllication

P09

微小重力ソーレ係数測定実験における位相解析法の改善

Improvement of Phase Analysis Method in Microgravity Soret Coefficient Measurement

○小田嶋俊宏 [1], 折笠勇 [1], 富永晃司 [1], 鈴木進補 [1], 稲富裕光 [2,3]
○Toshihiro ODAJIMA[1], Isamu ORIKASA[1], Kouji TOMINAGA[1], Shinsuke SUZUKI[1], and Yuko INATOMI[2,3]
1　早稲田大学, Waseda University.
2　宇宙航空研究開発機構, Japan Aerospace Exploration Agency.
3　総合研究大学院大学, The Graduate University for Advanced Studies.

1. Introduction

The Soret effect is a phenomenon in which a concentration gradient is graduated by a temperature gradient. To elucidate the Soret effect, our research group conducted Soret coefficient measurement as a Soret-Facet Mission in the International Space Station (ISS)[1)]. Interference fringes were obtained by in situ observation using a Mach-Zehnder interferometer[2)]. The temperature and concentration gradients can be calculated backwards by calculating the phase change of the interference fringes. In the conventional method[3)] of phase analysis, the time variation of intensity at each analysis point is directly converted into phase. Since the interference fringes can be regarded as a sine wave of phase, the maximum and minimum values of the sine wave are taken as the maximum and minimum values of intensity at each analysis point. However, the center and amplitude of the sine wave of intensity varies with time and location of analysis point. So, if the maximum and minimum values of intensity are set to a constant value, errors will occur. For the proposed method, the spatial intensity change converts into phase for each image. The proposed method can eliminate influence of sine wave changes in the time direction. In addition, the influence of spatial sine wave changes can be reduced by converting intensity into phase for each local area between adjacent peaks of intensity. The objective of this study is to show that the proposed method improves accuracy of the phase change compared to the conventional method.

2. Analytical Method

Artificial interference fringes were created by using the chirp signal. The frequency was changed from 2 to 1 in 10 seconds and the amplitude was 5. It was prepared for 1000 pixels and set the time to 1 second for 100 pixels. The size of the image of the interference fringe was set to 750 pixels. This was shifted by 250 pixels by 1 pixel for the time direction. Therefore, the phase change of each analysis point X is given by $\Delta\phi = -0.005X + 9.38$ [π^{-1}]. The noise was determined by adding the normally distributed random number to each image in the time direction. In the conventional method, in each analysis point, the maximum and minimum value was I_{max} and I_{min}, and the phase was calculated by following Eq. (1) applying to the whole time. For all analysis points, the phases were calculated in the same way.

$$\phi = sin^{-1}\frac{2I - I_{max} - I_{min}}{I_{max} - I_{min}} \tag{1}$$

In the proposed method, the spatial distribution of intensity was obtained at each analysis time. The N-th local maximum was set to $I_{\max(2N)}$, and the adjacent local minimums were set to $I_{\min(2N-1)}$ and $I_{\min(2N+1)}$. In the phase conversion, the phase at the all positions with local maximum were set to $\pi/2$ and positions with the local minimums were set to $-\pi/2$. The local region between $I_{\max(2N)}$ and $I_{\min(2N-1)}$ (or $I_{\min(2N+1)}$) were calculated using Eq. (1) with these values as I_{max} and I_{min}. In each method, the phase change $\Delta\phi$ at each point was obtained by unwrapping the time variation of phase.

3. Results

The spatial distribution of the phase change calculated for the artificial interference fringes by both methods is shown in **Fig. 1**. The standard deviation of $\Delta\phi \cdot \pi^{-1}$ from the set value is 0.204 for the conventional method, whereas the proposed method is 0.081. The spatial distribution of the phase change calculated for the Soret-Facet Mission interference fringes by both methods is shown in **Fig. 2**. Compared with the conventional method, the dispersion of the proposed method is reduced as well as the simulation, and the coefficient of determination R^2 of the phase change is 0.868 for the conventional method, 0.982 for the proposed method.

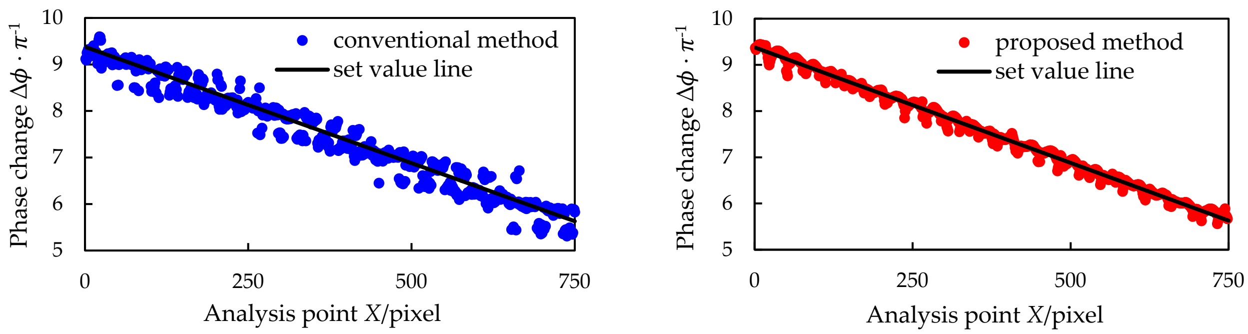

Fig.1 Spatial distribution of the phase change $\Delta\phi$ calculated for the artificial interference fringes.

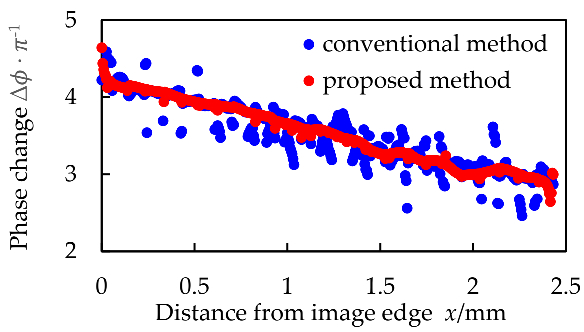

Fig.2 Spatial distribution of the phase change $\Delta\phi$ calculated for the Soret-Facet Mission interference fringes.

4 Discussion

From **Fig.1**, it can be said that the proposed method is closer to the set value compared to the conventional method. In **Fig. 2**, where points that the phase change of the conventional method differs significantly from the proposed method, there was excess or deficiency of peaks in the time variation of the phase compared to the proposed method. In the proposed method, peaks could be detected correctly by adding a peak detection range because the peak passes around $\pi/2$. Therefore, it can be said that the proposed method is more accurate in phase unwrapping and improves the accuracy of obtaining the phase change than the conventional method.

5 Conclusion

We can obtain highly accurate time variation of the phases by the proposed method, which convert the intensity of interference fringes into phases in a localized region in space. As a result, the accuracy of the phase change is improved compared to the conventional method.

References

1) T. Osada, Y. Hashimoto, M. Tomaru, S. Suzuki, Y. Inatomi, Y. Ito and T. Shimaoka: Int. J. Microgravity Sci. Appl., **33** (2016) 330407.

2) K. Tsukamoto: Int. J. Microgravity Sci. Appl., **31** (2014) 3.

3) I. Orikasa, T. Osada, M. Tomaru, S. Suzuki and Y. Inatomi: Int. J. Microgravity Sci. Appl., **36** (2019) 360306.