Real-time Diagnosis of Plasma Molecular Temperature Based on Visible Image Regression Analysis

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The temperature parameter diagnosis of low-temperature plasma plays an important role in the study of its mechanism and applications in various fields. For example, efficient and accurate diagnosis of plasma molecular rotational and vibrational temperatures is crucial in numerous domains, such as plasma medical treatment, plasma spraying, and aerospace combustion technology.[1] As the most commonly used method of plasma temperature diagnosis, optical emission spectroscopy (OES) requires the collection of emission spectrums and manually fit them offline to obtain the rotational and vibrational temperatures of the plasma.[2] Consequently, the need for real-time and accurate parameter diagnosis has emerged as a focal point in contemporary plasma research. The rapid development of machine learning in recent years have provided new ideas to address this challenge.

In the previous research of our team, we studied and analyzed the temperature parameter characteristics and internal mechanism of gas discharge plasma under different experimental conditions.[3] In order to avoid the problem of low efficiency of manual comparison and fitting of spectral data, we employed the Elastic-net linear regression technology to analyze the plasma emission spectrum and achieved ideal performance.[4] Moreover, to avoid costly spectral acquisition equipment, we explored the use of visible image recognition technology to diagnose plasma molecular temperatures, using convolutional neural network (CNN) to predict the temperatures of five kinds of plasma discharge visible images.[5] However, this approach essentially treated the problem as an image classification task, and the small number of classes makes the model generalization ability very poor, and the predicted temperature range is limited and discretized.

To address these limitations, we expanded upon our previous research by establishing a wide temperature range visible image dataset for plasma discharge, and used deep learning image regression technology to train and analyze the data. A plasma molecular temperature intelligent diagnosis model based on visible image regression analysis was established, achieving continuous prediction of the rotational and vibrational temperatures of the plasma visible images. The specific experimental process is illustrated in Figure 1 and involves the following steps:

1) The emission spectrum data of needle plate gas discharge under various working conditions was collected and machine learning linear regression technology was utilized to quickly predict its rotational and vibrational temperatures to avoid the problem of low efficiency of manual comparison and fitting.

2) While collecting emission spectrum data, plasma visible images under the same working conditions were collected. A dataset was established based on the mapping relationship between visible images and molecular temperatures.

3) The chromaticity information in the plasma visible image or CNN image regression automatic feature extraction was used to perform regression analysis on its rotational temperature and vibrational temperature, so as to realize the continuous prediction and diagnosis of the molecular temperatures of the plasma visible images.

In conclusion, our research presents a novel approach to real-time diagnosis of plasma molecular temperatures using visible image regression analysis. This method offers a more efficient and accurate alternative to traditional techniques, paving the way for advancements in plasma research and its applications across various industries.

This work is supported by National Natural Science Foundation of China (Grant No. 52207158).

References

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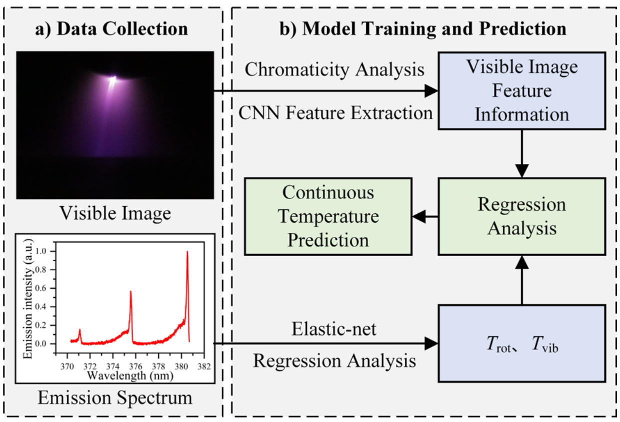

Figure 1. Specific experimental process for real-time diagnosis of plasma molecular temperatures based on visible image chromaticity analysis and CNN feature extraction regression analysis.