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Measurement of cryogenic thermal expansion coefficient and accuracy analysis

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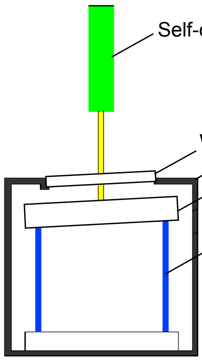

Framework of thermal coefficient measuring system.

Abstract: To improve the detection efficiency, the optical components of modern infrared detection system generally need to be cooled. The determination of the thermal expansion coefficient of the infrared material at low temperature can provide the theoretical basis for the study of infrared optical system. Some institutes from home and abroad had researched the thermal expansion coefficient of common solid material in the past. But few people explored the thermal expansion coefficient of infrared materials in low temperature environment. When the infrared material is in minus 250 degrees Celsius, the deformation of material is very small. If the accuracy of the device is not high enough, measurements would become very difficult. So the thermal expansion coefficient of the infrared material is lacking. In order to realize the high-precision measurement of the thermal expansion coefficient of the infrared material under the cryogenic vacuum environment, a measurement scheme of solid material is proposed. Based on the self-collimation principle, this scheme designs a microstructure. The scheme uses a sample column made of infrared material and two support columns to support a plane mirror, and the three cylindrical rods are placed in a triangular manner. A collimator is placed at the top of the plane mirror to measure the angle of the mirror. When the temperature changes, the length of the sample column will change. So the angle of the plane mirror will change. The coefficient of thermal expansion of the solid material is estimated by measuring the angle change of the plane mirror through the collimator. Then the article establishes the relationship between structural deformation and angle, and deduces the formula of thermal expansion coefficient measurement. As the measurement accuracy is relatively high, it is necessary to analyze each error source. In order to calculate the magnitude of the thermal expansion coefficient error, the article calculates the error sensitivity function for each factor and integrates all errors. So using the measurement formula, this article analyzes the error transfer formula theoretically, and also uses the error sensitivity function to analyze the design accuracy of the system. Calculation shows that the effect can be ignored when the squareness tolerance between sample column and the platform reaches 6 levels. Finally, the precision of the scheme is measured to be only 0.76% which satisfies the nanometer measurement requirement. The scheme can achieve not only measurement of thermal expansion coefficient in low-temperature vacuum and high-temperature environments, but also other high-precision nano-sized measurements of linear deformation.

Keywords: cryogenic thermal expansion coefficient measurement; micro deformation measurement; error transfer function; cryogenic optics

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