Design of a WR-6 thermoelectric conversion power sensor

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***Abstract*—In this paper, the thermoelectric conversion power sensor, which is the key part in the WR-6 (110 GHz – 170 GHz) rectangular waveguide microcalorimeter, was designed and evaluated. The ANSYS simulation software was used to evaluate the quantitative relation between the THz power and DC power for the power sensor.**

I. INTRODUCTION

With the development of terahertz (THz) theoretical research in the past decade, the domain of terahertz applications is not only extending rapidly, but it has developed in a variety of directions, including imaging, communication, biomedical, and so on [1][2]. Unfortunately, the present measurement standards used in the THz region could not meet practical measurement requirements. The development of the THz power standard has the highest priority, as the power is one of the most important parameter in the area of radio frequency metrology. Microcalorimeters are used as the national primary standards for microwave power in many National Metrology Institutes (NMIs) [3-5]. A series of rectangular waveguide microcalorimeters, such as WR-28, WR-22, WR-15, WR-10, were developed by the National Institute of Metrology (NIM) of China, enhancing Chinese radio frequency power measurement capability up to 110 GHz [6]. The power sensor below 110 GHz, the key part of the microcalorimeter, is the commercial thermistor sensor. In this paper, a WR-6 (110 GHz to 170 GHz) thermoelectric conversion power sensor was designed and the quantitative relation between the THz power and DC power was evaluated.

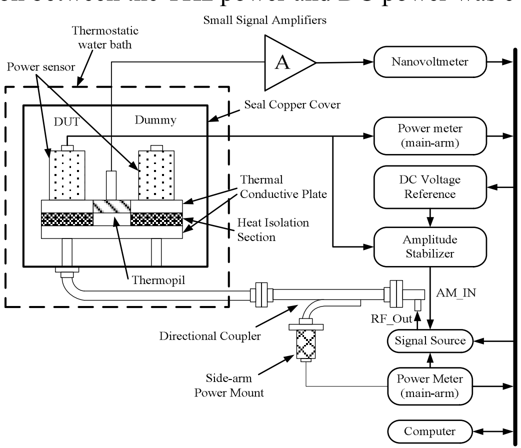

Fig. 1. Schematic diagram of the WR-6 microcalorimeter at NIM

II. DESIGN PRINCIPLE

The WR-6 thermoelectric conversion power sensor was manufactured base on matched load, as illustrated by Fig.2. The ultimate goal of the power sensor is to transform the THz power into the identifiable power, such as DC power. Therefore, the THz power could be traceable and metrological.

The THz power, through the flange and waveguide, could be absorbed by THz absorbing material. Then the absorbed power was converted into heat energy, and resistance of thermistor could change by thermal transmission. On the other hand, the heating resistor was applied by DC power. The heat could be transferred though the waveguide, and the resistance of thermistor similarly changed by thermal transmission. In the case of quantitative relation between the THz power and DC power, the thermoelectric conversion power sensor could be used as the core device in the primary standards for THz power.

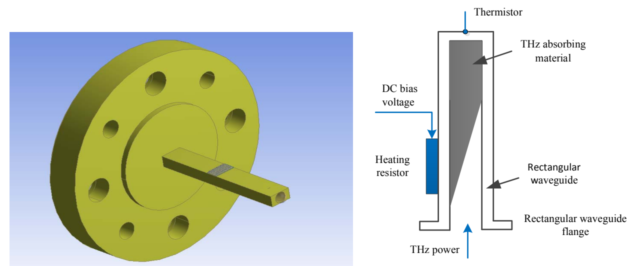

Fig. 2. External view and structure diagram of the WR-6 thermoelectric conversion power sensor

III. EXPERIMENTAL RESULT

In order to evaluate the quantitative relation between THz power and DC power, the electromagnetic and thermal field distribution on the power sensor were determined using large finite element analyzing software ANSYS. Firstly, the method of ANSYS electromagnetic analysis (thermal coupling module) was used to evaluate the temperature T of the thermistor, under different THz power level conditions.

In this paper, the Voltage Standing Wave Ratio (VSWR) was chosen to estimate the electromagnetic property of the power sensor, and the VSWR of the WR-6 power sensor had some fluctuation as shown in Fig.3. The WR-6 power sensor was used under small power condition, and the heat capacity of the whole power sensor was not small. Therefore, the temperature variation of the thermistor at different frequency point could be neglected. The verdict was also proved by the simulation results. In this paper, the simulation results was described at the center frequency 140GHz so as to simplify the analysis.

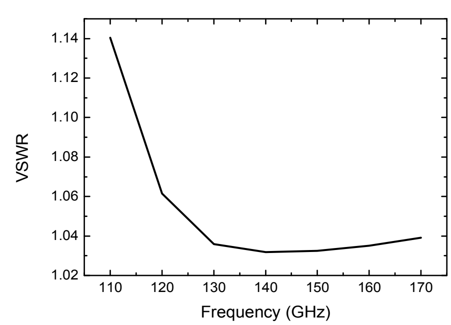

Fig. 3. The VSWR of the WR-6 thermoelectric conversion power sensor

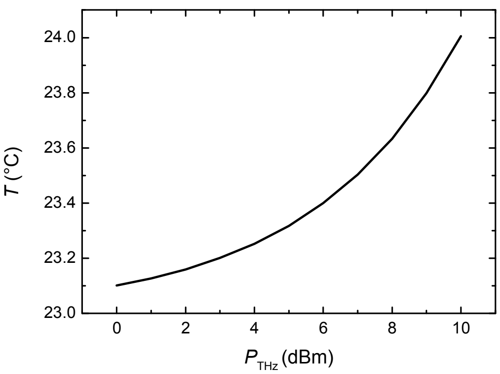

Fig. 4. The relationship between the THz power P_{THz} and the temperature of the thermistor T at the 140GHz.

Then, the Thermal-Electric coupling analysis was used to estimate the temperature of the identical thermistor for the WR-6 thermoelectric conversion power sensor by ANSYS.

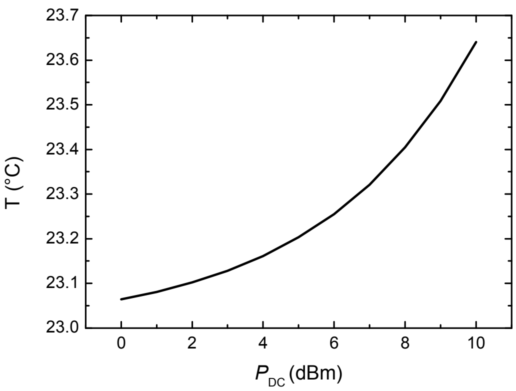

Fig. 5. The relationship between the DC power P_{DC} and the temperature of the thermistor T

Finally, the quantitative relation η could be achieved under the condition of the same temperature for thermistor.

$$\eta = \left.\frac{P_{\mathrm{DC}}}{P_{\mathrm{THz}}}\right|_{T=\mathrm{constant}} \tag{1}$$

Where η is the quantitative relation of the WR-6 thermoelectric conversion power sensor, P_{THz} and P_{DC} are the THz power and DC power applied to the power sensor, and T is the temperature of thermistor. The η is described as quantitative relation between the THz power and DC power, under the same conditions of temperature for thermistor.

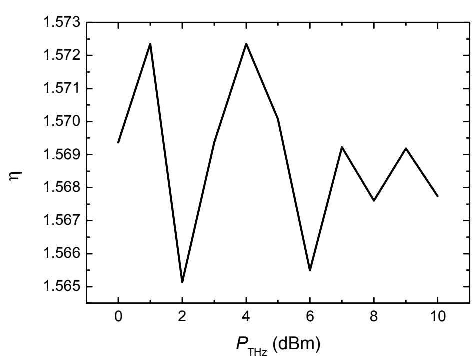

Fig. 6. Dependence of quantitative relation η on the THz power level at the 140GHz.

IV. Conclusion

In this paper, the WR-6 thermoelectric conversion power sensor was designed. And the performance of the power sensor was evaluated in Electromagnetic-Thermal coupling and Thermal-Electric coupling aspects by the ANSYS software. The quantitative relation between the THz power and DC power for the power sensor was obtained according to the experimental results. Meanwhile, the equivalence error of the DC substitution is currently underway.

Acknowledgment

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