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Non selective thermal detector for low power measurements

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Abstract. This paper describes a non selective thermal detector intended for measuring the relative spectral responsivity of selective detectors at the exit slit of a monochromator. It is based on thin film technology. It uses a bolometer for measuring the temperature and an electrical substitution method for running the measurement under computer control operation. The expected characteristics are a spectral range from 200 nm to 2500 nm, a dynamic range from 1 µW to 100 µW, a signal to noise ratio of about 1000 at 1µW level and a time constant in the range of 1 second. The preliminary theoretical and practical studies have given the necessary information for starting the realization of the device.

Introduction

In the French National Metrology and Test Laboratory (LNE) the spectral responsivity measurement of detectors is carried out using a two steps method. In a first step the relative spectral responsivity is measured by comparison to a non selective thermal detector when both detectors are irradiated by the same flux coming out from a monochromator. In a second step the absolute spectral responsivity is determined at some laser wavelengths by direct or indirect comparison to a cryogenic radiometer. At present time the major limitations in the accuracy of the measurements come from the low responsivity of the thermal detector used and the low level of flux available at the exit slit of the monochromator. To overcome these difficulties, the development of a new thermal detector has been undertaken by the GREYC laboratory in the framework of a collaboration project with the LNE. The main characteristics of this detector should be : a spectral range from 200 nm to at least 2500 nm, an active area between 0.5 cm^2 and 1 cm^2, a dynamic range from 1 µW to 100 µW, a time constant of about 1 second and a signal to noise ratio of 1000 at the 1 µW level.

Description of the detector

The principle of the detector is described in figure 1. The sensor uses a thin film of Mylar coated with aluminium on both side, tight on a metallic support. The support, in copper, works as a heatsink at constant temperature and can be, if necessary, cool and temperature controlled. On the membrane, electrical resistors are etched using optical photolithography. Some of these resistors are used as thermometers and some others as heaters for applying the electrical substitution method. The upper part of the detector is coated with a black paint in order to absorb the radiation in the useful spectral range. An electronic device can control the temperature of the sensor and determine the radiant flux received by the sensor. [1, 2]

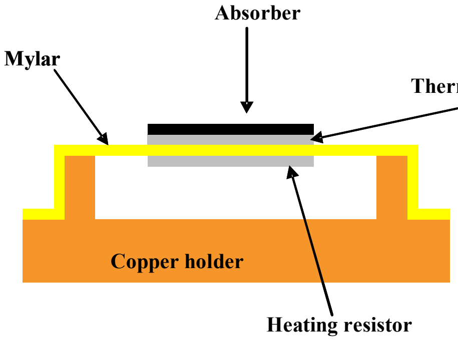

Figure 1. Schematic drawing of the detector (thickness of the various layers are not scaled).

Theoretical studies

In order to determine if a such device could be able to fulfil the requirement, a theoretical study has been carried out using computer simulations. Two cases have been considered, the first when the active part of the detector is in air and the second when it is in the vacuum. The results of these studies have shown that the responsivity of the detector is 10^{-3} K/µW when the detector is in air. When it is in the vacuum the responsivity is increased by a factor greater than 10 but nevertheless it is still a little below the requirement indicated at the beginning of this work. In order to increase the responsivity it has been decided to add a spherical mirror over the detector in order to reflect back the incident radiation reflected by the black coating and the radiation emitted by the detector itself (figure 2). With this mirror the device could be in the range of the requested responsivity.

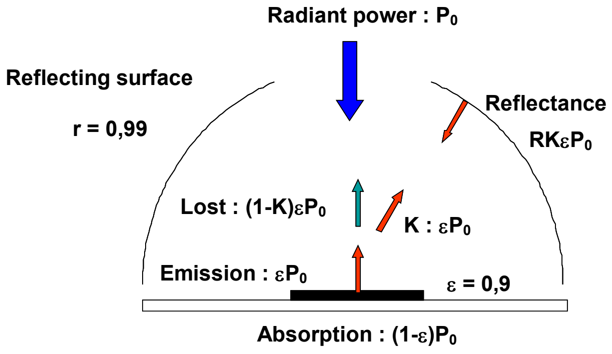

Figure 2. Power transfer between the detector and the mirror

The time constant of the detector has been also calculated and found in the range of approximately 1 to 2 seconds when the detector is in the vacuum. This value is perfectly acceptable.

The thermal behaviour of the support when it is temperature controlled by a Peltier element put at its bottom has also been studied using the Quickfield software. The results have been found in agreement with the expected characteristics of the detector.

Practical studies

In order to realise the heaters and the thermometers the electrical parameters of the thin aluminium coating on the Mylar have been checked. The variation of the electrical resistance of the aluminium film with temperature has been studied and the measured temperature coefficient was 0.00190 K^{-1} at 300 K.

In order to realise thermometers and heaters, the thin aluminium layers on both side of the Mylar film are etched using optical photolithography. On one side of the membrane 3 thermometers are realised and on the other side 2 heaters are etched. The determination of the shape of the figures for realising these resistors have been done according to the following requirements : the pattern must be not too small in order to have an easy realisation, the resistance must be in the range of some ten to some hundred of ohms in order to keep the Johnson noise at a reasonable level. For the heaters the heating must be as homogenous as possible. The figure 3 gives the patterns used for the thermometers and the heaters on each side of the membrane. For the thermometer the width of the strips are 200 µm and space between strips is also 200 µm. For the heater the width of the strips is 100 µm and the space between strips is 200 µm. The diameter of the active part is 5 mm.

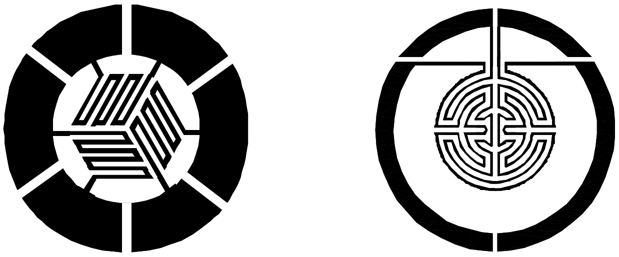

Figure 3. Left, Three resistors for temperature measurements, right, two resistors for heating the detector (two sides of the membrane).

The procedure for realizing these resistors has been studied and implemented. Several samples have been fabricated and checked. The mean values of the resistors are typically 195 ohms for the thermometers and 1040 ohms for the heaters.

For absorbing the radiation a black paint is used. It is a special paint developed for space applications by the Map-Coating society. A method for realizing a homogeneous thin layer has also been implemented and good layers with a thickness of 35 µm have been realized. This thickness could be adjusted to optimize the absorption and the time constant. Measurement of reflectance and transmittance of the layers has been done on the spectral range from 2 µm to 15 µm. With the checked samples the transmittance is always lower than 3.10^{-4} and the reflectance is less than $5\ 10^{-3}$ and increases very slowly with wavelength.

After these theoretical and practical studies the final design of the detector has been finalized. It is shown schematically in the figure 4.

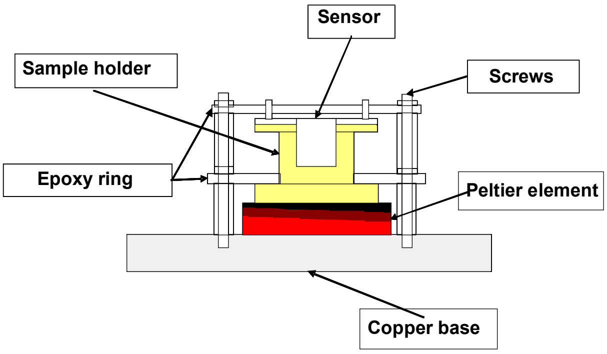

Figure 4. Schematic final design of the detector.

Conclusion

The thermal simulations carried out on various types have shown that it is possible to fulfil the requirements only if the detector is put in vacuum and a reflector is place in front of it. The determination and the method to realize the resistors used as thermometers and heaters have been implemented and the results are in agreement with what it is expected. The preliminary tests on the paint used to coat the detector for absorbing the radiation are also very encouraging. The next step will be the realization of a first prototype of the detector in order to check it in practical condition of use.

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References

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