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Measurement and calibration of temporal and spatial temperature differences of 100 K

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Abstract

We present experimental procedure to measure large and rapid temperature gradients of 200 K/mm and 100 K/s, traceable to National Institute of Standards.

1. Introduction

Temporal and position temperature measurements are performed with an IR camera with 30 frames per second and pixel resolution projected on the object space of 1 mm. .

2. Experimental setup

Three experimental setups are required to measure the temporal profiles of several adjacent pixels upon heating with high power IR laser beam: measurement of the incident laser power density on the pixel(s), shown in Fig.1; the irradiation of pixels and measurement of their temperature as a function of space and time, indicated in Fig. 2; and the calibration of the infrared camera using a black-body simulator, indicated in Fig. 3.

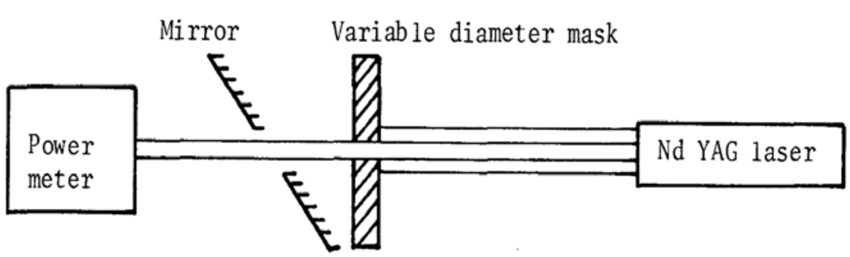

Fig. 1. Experimental setup to measure the laser power density incident on the target surface.

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Camera incorporates a cooled, single-element mercury-cadmium-telluride (HgCdTe) detector sensitive in 8 m to 14 μm wavelength interval. It measures scene temperature upon scanning. The nominally 100-W Nd:YAG laser has been described previously.[1] The Barnes Engineering 11-200T blackbody simulator operates at 200 C to 1000 C.[2]

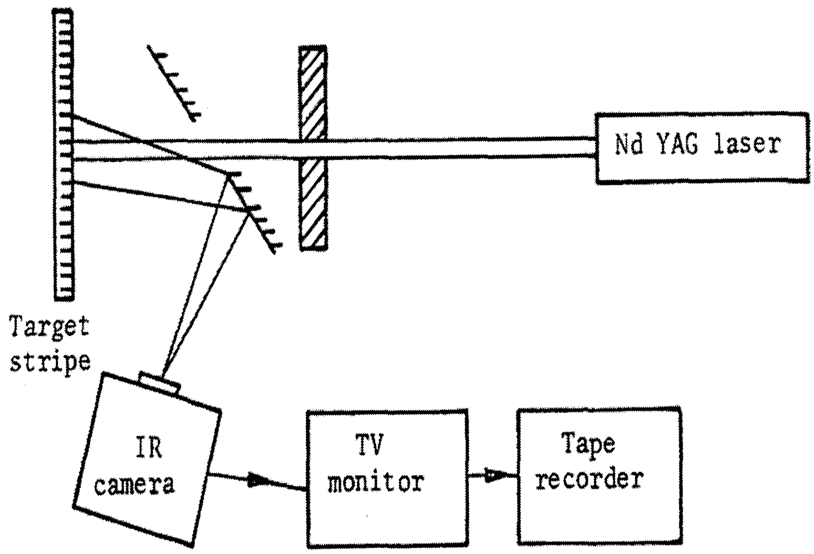

Fig. 2. Experimental setup to irradiate target pixels and measure their temperature as a function of space and time.

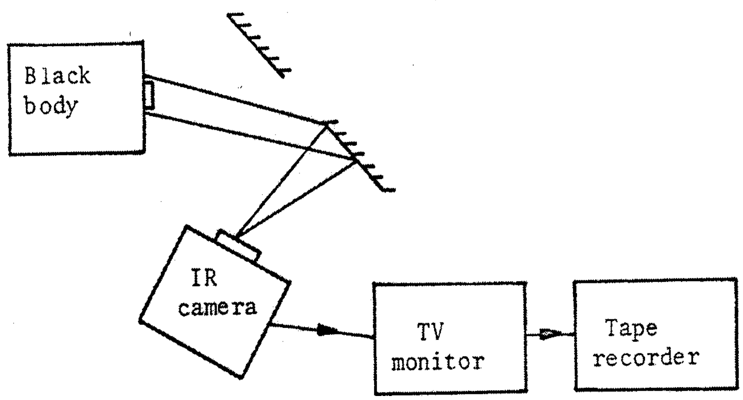

Fig. 3. Experimental setup to calibrate the infrared camera using a black-body simulator.

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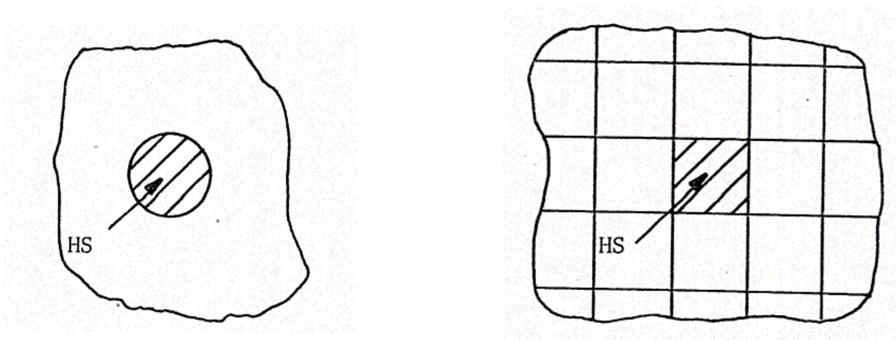
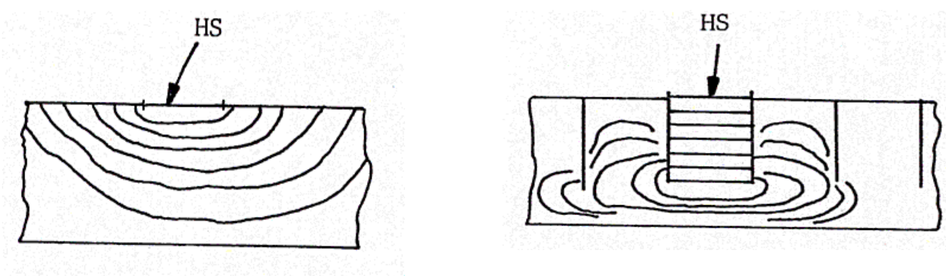
3. Pixel size

We consider target surface divided into small, 1 mm by 1 mm pixel elements, due to historical reasons.[3, 4]



(a) Bird's view of a 1 mm heated pixel.



(b) Lateral view of heat propagation within a small slab

Fig. 4. Thermal pixel element is relatively easy to define when groves are cut into the surface to decrease heat flow laterally.

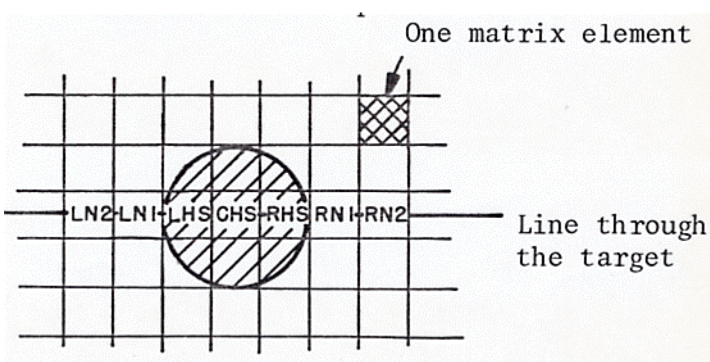


Fig. 5. Definition of pixels on the surface of the target.

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Until a suitably-low heat conductor was used, it was deemed necessary to cut groves into surface to decrease transverse heat diffusion. Figure 4 illustrates that the thermal pixel element is relatively easy to define when groves are cut into the surface to decrease heat flow laterally.

Then we consider a 3 mm heated spot as consisting of 3 heated pixels (Left Hot Spot, Central Hot Spot, Right Hot Spot) as illustrated in Figure 4. The first pixel to the right is Right Neighbor 1, followed by Right Neighbor 2. A three-pixel hot spot is illustrated in Figure 5, indicating the pixels by their position.

4. Experimental results

A thin, black plate with a smaller hole decreases the effective cavity opening, nominally 12.5 mm diameter. Its temperature range of operation has been extended below 200 C, by using a thermocouple and an independent voltage source in this interval.[2]

Object-pixel heating rate of over 100 K/s is demonstrated for 3 heated pixels on a glassy carbon slab in Figure 6. Figure 7 demonstrates that high temperature gradients of over 200 K/mm are maintained between heated pixels and their neighbors. Figure 8 illustrates the high heating rate of the irradiated spot as a function of heating power during the first two seconds.

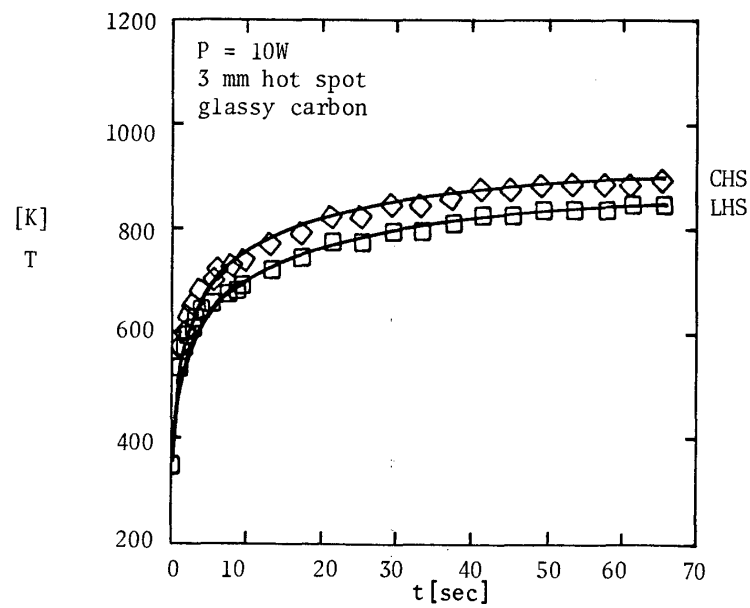

Fig. 6. Object-pixel heating rate of over 100 K/s is measured for 3 heated pixels on a glassy carbon slab.

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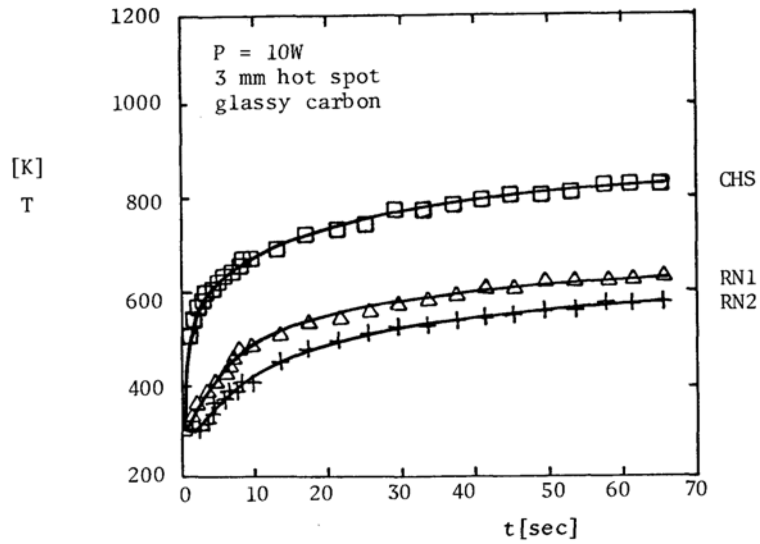

Fig. 7. High temperature gradients of over 200 K/mm are measured between heated pixels and their neighbors.

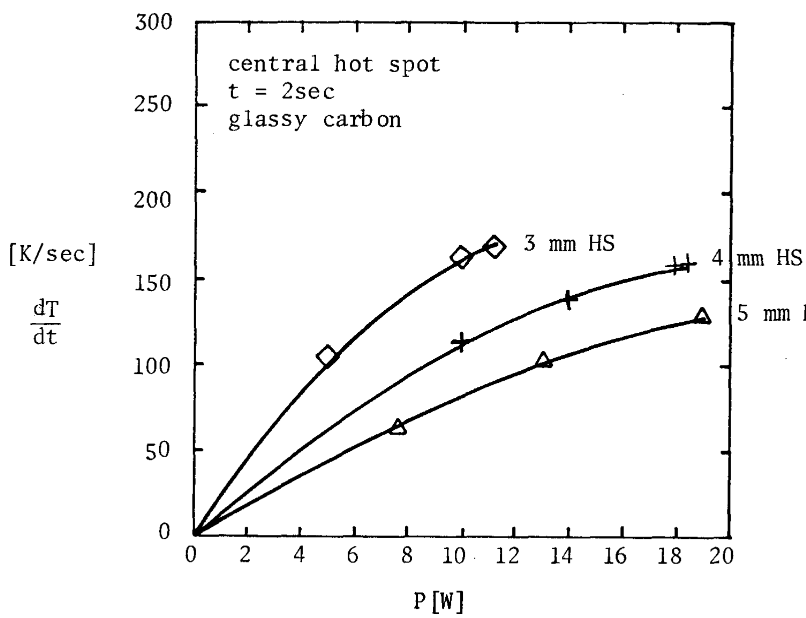

Fig. 8. Heating rate of the irradiated spot as a function of heating power during the first two seconds.

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5. Summary

We described experimental procedures to measure large and rapid temperature differences of 200 K/mm in space and 100 K/s in time. Upon incorporating components traceable to National Institute of Standards (U. S.) and following careful calibration procedures, very accurate results are achieved.

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