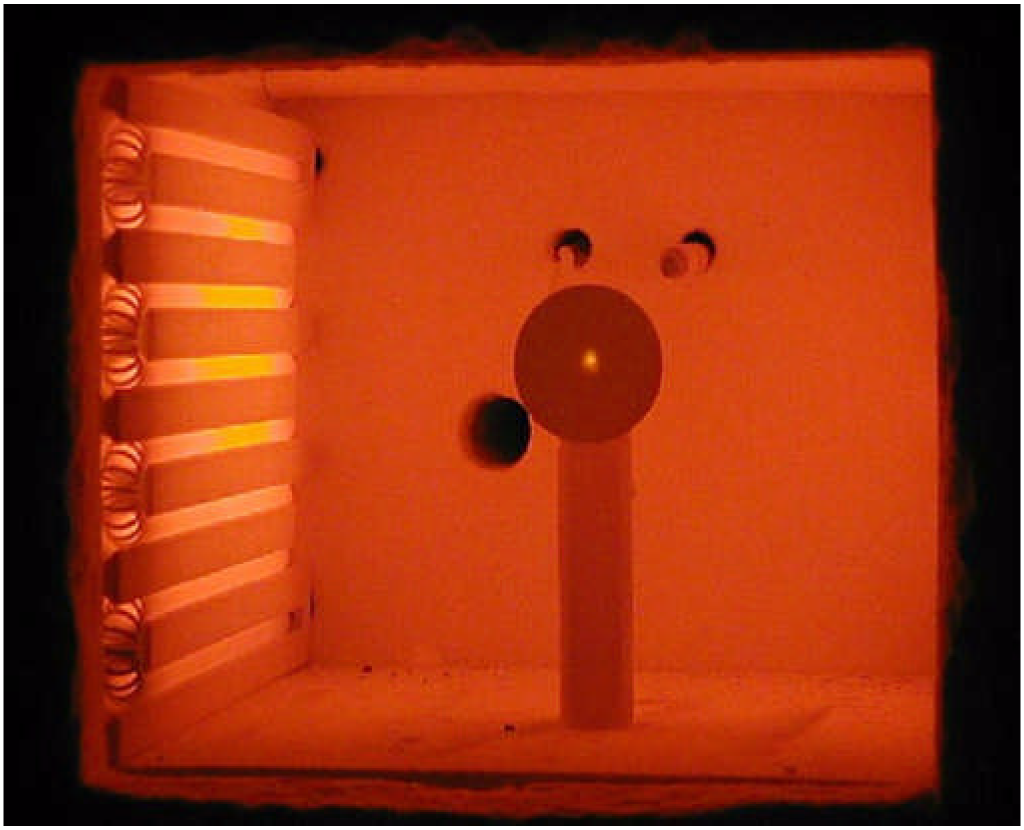
High-Temperature Sprayable Phosphor Coating Developed for Measuring Surface Temperatures

The use of phosphor thermography for noncontact temperature measurements in harsh environments has been proven over the last decade, but it has suffered from difficult application procedures such as vapor deposition or sputtering techniques. We have developed a high-temperature-sensitive paint that is easily applied with commercially available paint-spraying equipment and have successfully demonstrated it to temperatures up to 1500 °C. Selected phosphors have also shown measurable signals to 1700 °C, thus allowing a combination of phosphors to be used in high-temperature binders to make surface temperature measurements from ambient to over 1500 °C.

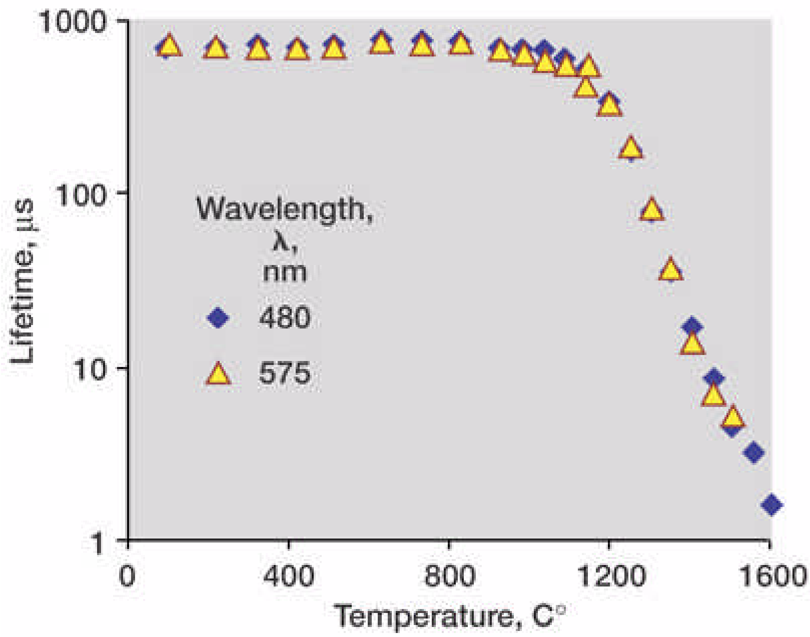
Phosphor thermography is an optical technique that measures the time response of fluorescence light, which is a function of the phosphor temperature. The phosphors are excited with short wavelength light (ultraviolet or blue), and they emit light at a longer wavelength. This technique has a benefit over other temperature measurements, such as thermocouples and infrared thermography, in difficult environments such as high blackbody backgrounds, vibration, flames, high electromagnetic noise, or where special windows may be needed. In addition, the sprayable phosphor paints easily cover large or complicated structures, providing full-surface information with a single measurement.



Furnace tests of binder/phosphor combinations showed detectable fluorescence above the background radiation on ceramic and metal substrates. This image was recorded at about 700 °C.

Oak Ridge National Laboratories developed and tested the high-temperature binders and phosphors under the direction of the NASA Glenn Research Center. Refractory materials doped with rare earth metals were selected for their performance at high temperature. Survivability, adhesion, and material compatibility tests were conducted at high temperatures in a small furnace while the fluorescent response from the phosphors was being measured. The preceding photograph shows a painted sample in a furnace with a clearly visible fluorescing dot excited by a pulsed laser. Measuring the decay time of this fluorescence yields the surface temperature.

One new paint was recently tested in a rocket test stand at Glenn. The floor of a square duct nozzle was painted, and full-field lifetime decay measurements were acquired for multiple firings of the rocket. Good agreement with predicted results was obtained, matching temperature gradients along the length of the nozzle and clearly showing shock structures. These good results were very satisfactory given that the measurements were made looking through the combustion plume. Infrared pyrometry was incapable of making the surface measurements because of the interference from the rocket exhaust, which contaminated the infrared signature.



The fluorescence lifetime dependence of the phosphor YAG:Dy (0.28 percent) at high temperatures.

Long description of figure 2 This semi-log plot shows a stable lifetime of about 900 microseconds from 100 to 800 degrees C. The lifetime starts to slowly roll off, dropping to about 500 microseconds by 1200 degrees C and 2 microseconds at 1600 degrees C. Responses to two wavelengths are shown (480 and 575 micrometers); the responses are practically the same.

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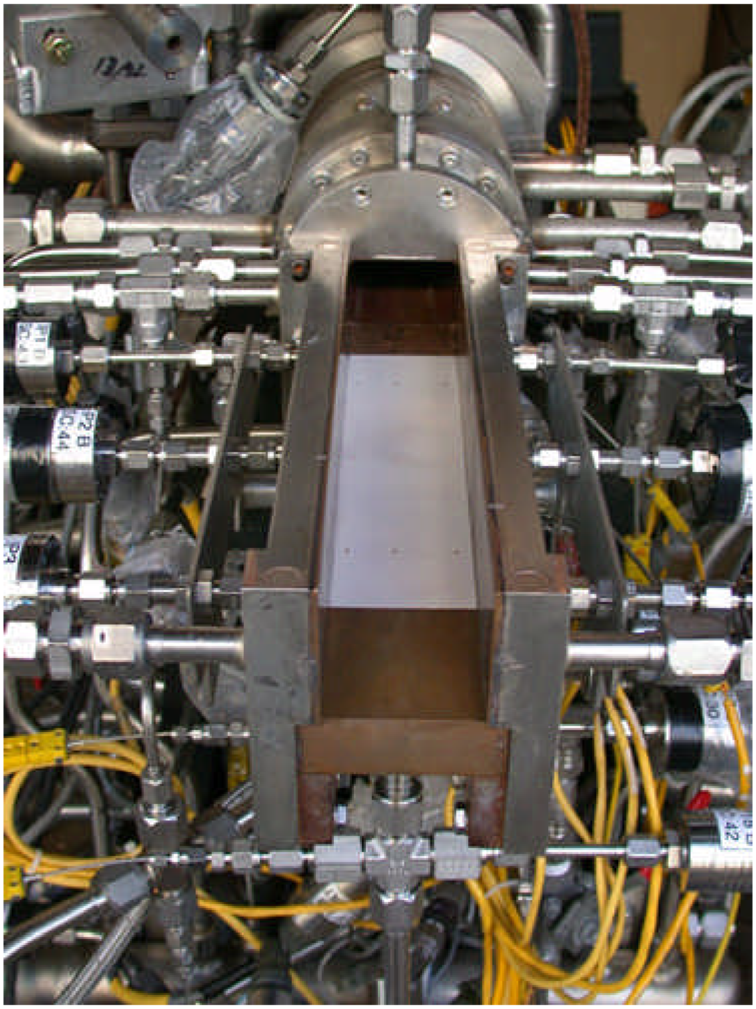

A water-cooled rocket nozzle painted in place with high-temperature phosphor paint. Flow is from back to front, and the excitation light source and camera are mounted above. The entire channel fills with flame when fired.

Long description of figure 3. A large section of a horizontally mounted, flat copper plate is painted white. Stainless steel sides form a rectangular channel with the copper plate. The channel is mounted to a cylindrical rocket combuster so that the exhaust plume covers the painted surface when the rocket is fired.

Find out more about the research of Glenn's Optical Instrumentation Technology Branch.

Glenn contact: Timothy J. Bencic, 216-433-5690, Timothy.J.Bencic@nasa.gov
Author: Timothy J. Bencic
Headquarters program office: OAT
Programs/Projects: Hypersonics, STPO, Information Rich Test Instrumentation, Propulsion Systems R&T, RLV