New potential in quality control

The Fraunhofer ILT is using the optris PI 640i infrared camera to further develop laser powder bed fusion as a 3D printing process. The precise measurement possibilities offered by the Optris camera enable temperatures during the production process to be studied with exceptional accuracy.

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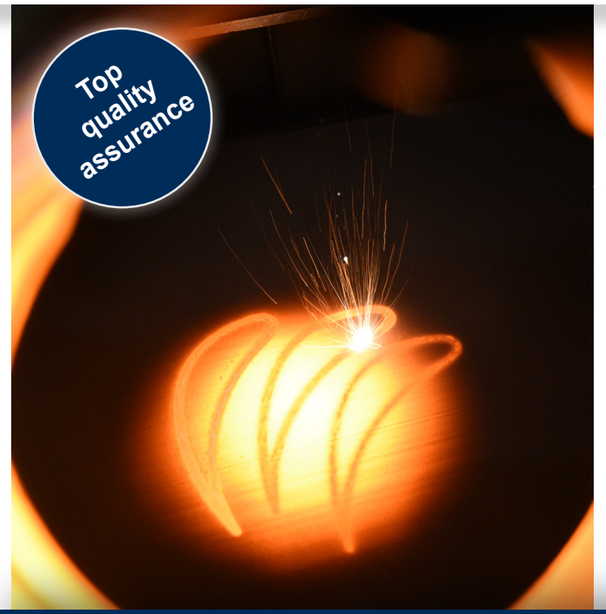
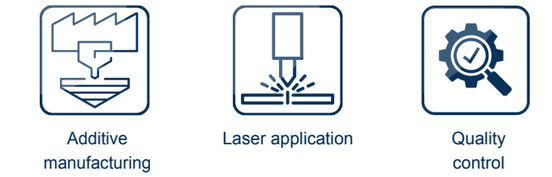
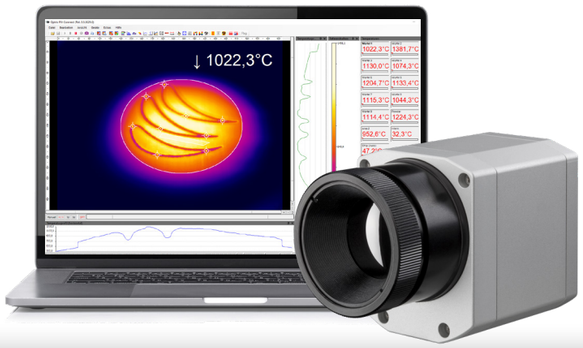
APPLICATION ARTICLE 3D printing







Infrared measurement technology in 3D printing

The temperatures have to be right

Metal 3D printing has experienced a real boom in recent years. In particular laser powder bed fusion, which enables very complex and delicate structures, is constantly opening up new applications. The quality of the process depends significantly on achieving the correct temperatures. The scientists at the Fraunhofer ILT measure them with an Optris infrared camera.

Laser powder bed fusion (LPBF) has been one of the most promising processes for the additive manufacturing of metals for more than 25 years. Developed and patented by the Fraunhofer Institute for Laser Technology ILT in 1996, the process is ideally suited to producing components with complex geometries. The high-precision process makes it possible to produce parts that simply cannot be achieved with subtractive methods.

But in order to optimize the process, precise temperature monitoring is required. This is where the optris PI 640i infrared camera comes in. The thermal imager can measure temperatures of up to 1,500 °C. The camera is mounted outside the build chamber, which has a zinc selenide window integrated into it for this purpose. The infrared camera is very compact and therefore easy to mount above the window. With a resolution of 640 × 480 pixels, it can resolve even small component structures.

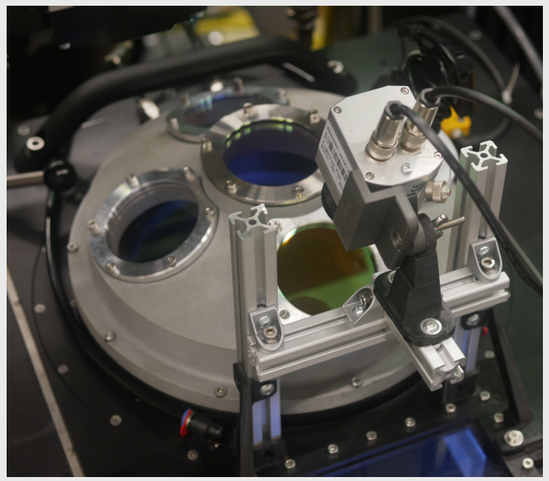
Emissivity changes

One challenge for temperature measurement is the emissivity of surfaces. “The emissivity of powders and solids of the same metal are different, for instance,” says Andreas Vogelpoth: “And the emissivity also depends on the surface properties.” Emissivity was therefore determined in a series of different experiments in which the temperature of the powder or solid was measured not only with the infrared camera, but simultaneously using thermocouples. In the experiments, which are conducted during a component build, the infrared camera measures the temperature of the component after the melt pool has hardened. The system’s control triggers the infrared camera via a digital interface. This can happen shortly after the laser has been switched off and before the next layer of powder is applied. This allows various effects to be studied. Typical measurements determine variables such as the cooling behavior after remelting or the conduction of heat via the powder bed. In this way, the heating of the component can be adjusted to avoid defects.

Simplifying the evaluation of thermographic images

The PI 640i infrared camera is connected via a USB port to a PC, which has the PIX Connect analysis software installed. Optris supplies the software together with the infrared camera. The software analyzes the thermographic images in real time and offers extensive recording and evaluation possibilities. Recordings can also be archived. “Storing the images in an open format is very important for us,” says Andreas Vogelpoth, highlighting one of the system’s advantages. Very convenient evaluation of the thermographic images in PIX Connect is another important point for him. The PI 640i has been used at the Fraunhofer ILT for around five years. Prior to that, pyrometers were often the sole temperature measurement technology used, but they can measure temperatures only up to a certain point.

“All in all, the Optris infrared camera is excellently suited to our purposes,” says Tim Lantzsch: “It’s compact and hence easy to integrate mechanically and simple to operate.”



A zinc selenide window gives the infrared camera a view of the process. *(Photo: Fraunhofer Institute for Laser Technology ILT)*

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Fraunhofer ILT

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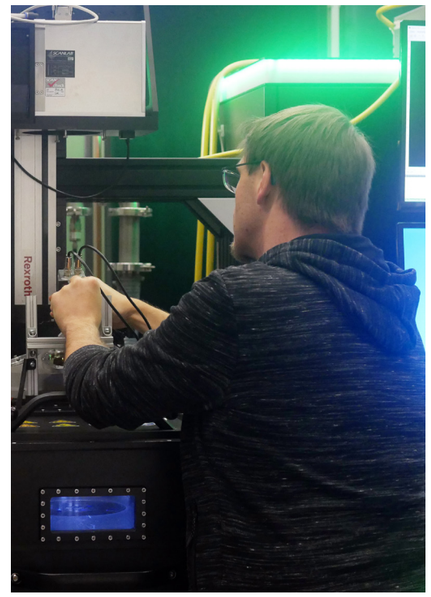

Andreas Vogelpoth from ILT
(Photo: Fraunhofer Institute for Laser Technology ILT)

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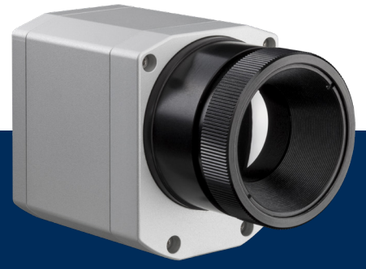


optris PI 640i

Advantages:

- 640 × 480 pixels
- Outstanding thermal sensitivity of 40 mK
- Radiometric video recordings at 32 Hz, 125 Hz in subframe mode
- Interchangeable lenses: 15°, 33°, 60° and 90°
- License-free analysis software and complete SDK included

Specifications:

- Temperature ranges:
  - −20 to 100 °C
  - 0 to 250 °C
  - 150 to 900 °C
  - Optional: 200 to 1500 °C
- Spectral range: 8 to 14 µm
- Ambient temperature: 0 to 50 °C
- System accuracy: ±2°C or ±2%, whichever value is greater

For more information about the optris PI 640i, go to www.optris.com/en/product/infrared-cameras/pi-series/pi-640i/

Building components layer by layer

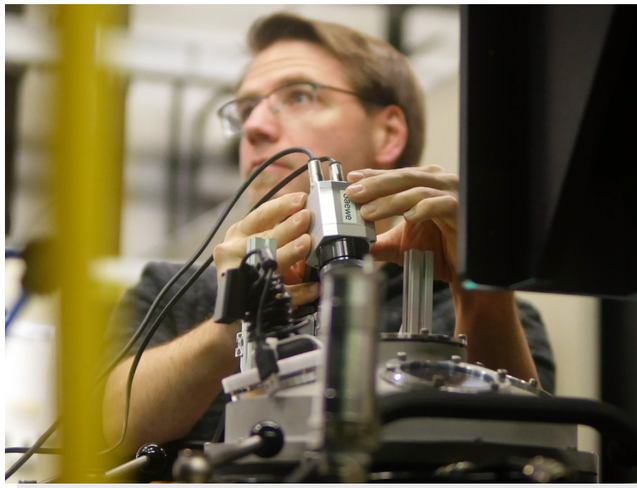
The base material in LPBF is in powdered form and applied to a build plate in a thin layer. A laser beam then melts the areas of the powder that will form the component. After it hardens, a firm layer of material is produced. In the next step, the build plate is lowered, and another layer of powder is applied. The process is then repeated layer by layer to create a three-dimensional component. All it needs now is the excess powder removing. Depending on the use case and the material used, the layers are between 10 and 100 micrometers thick. The components manufactured with this process are characterized by a high specific density of up to 100 %. This means that the component's mechanical properties are indistinguishable from a part manufactured in a subtractive process. However, the immense flexibility possible with LPBF has a disadvantage: the production process is comparatively slow. The process is therefore predominantly used to manufacture prototypes or small batches.

The Fraunhofer ILT is continually enhancing the process. For example, feasibility studies are being conducted in collaboration with cooperation partners. In addition to manufacturing ever more complex geometries, the scientists are also exploring the possibility of using other materials. "Our current projects are examining using metals with a high melting point, such as tungsten or molybdenum, for example," says Tim Lantzsch, head of the Laser Powder Bed Fusion Department at the Fraunhofer ILT. However, due to their high melting points, which can be in excess of 3,000 °C, these metals are difficult to work with a high degree of process reliability. To conduct research projects like these and similar studies, the Fraunhofer ILT operates several lab-based LPBF systems.

Temperature: a crucial measurement variable

Temperatures play a critical role throughout the entire LPBF process. The laser beam is capable of warming the material extremely rapidly – increases of up to 1 million kelvin per second are possible. Immediately afterward, the material cools quickly. This creates the risk of producing stresses, shrinkage, phase changes or other physical effects that adversely affect quality. "Cracks or plastic deformations can ultimately lead to rejects," says Tim Lantzsch, summing up typical problems. To avoid defective components, a variety of approaches have been developed at the Fraunhofer ILT. "For example, we warm the build plate to minimize stresses resulting from excessive temperature gradients," explains Andreas Vogelpoth, who works in the department in the Process & Systems Engineering Group. How much heat is applied to the build plate depends on the material used, among other factors.

However, the parameters that influence the temperature of the component change during the process: "The distance from the heated build plate increases with each layer, the powder bed is a poor thermal conductor, radiation plays a role, and the laser naturally adds heat as well," says Andreas Vogelpoth. This means that the heating needs to be adjusted during the process.



Alignment of the IR camera for optimum process monitoring. Thermographic images can be easily analyzed in the software.
(Photo: Fraunhofer Institute for Laser Technology ILT)

The LPBF system's control triggers the camera after a layer has been completed.
(Photo: Fraunhofer Institute for Laser Technology ILT)