Fraunhofer HHI at ILA 2026: thermal management for aerospace

Efficiently Cooling Satellite Components in Space

The vacuum of space makes cooling extremely challenging. The Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI is developing technologies for thermal management in aerospace applications. The research team is using femtosecond and nanosecond lasers to treat the outer surfaces of satellite components and rocket nozzles to improve their heat dissipation. The researchers will be at the joint Fraunhofer booth at ILA 2026 to demonstrate that metal surfaces structured for high-emissivi-ty ensure significantly more efficient cooling.

Space is a vacuum. Heat therefore cannot be transferred to the surroundings by thermal conduction. This poses a problem for any type of space-capable electronics, which can quickly overheat under these conditions. The only way to dissipate heat in space is through radiation into space. A radiator converts the heat into thermal radiation. The material used must emit as much thermal radiation as possible for the process to work efficiently. Researchers at Fraunhofer HHI are therefore functionalizing metal surfaces so that they can radiate heat highly efficiently in a vacuum. The research scientists have developed these surface treatments in various projects, including in collaboration with the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS.

"Because smooth metal surfaces like the aluminum outer walls of satellites, the outer surfaces of rocket nozzles or the cases for power electronics are very poor at dissipating heat, we use a laser to roughen them. The rough textured surface essentially acts like a radiator and radiates heat very effectively," says Eike Hübner, research group manager and research scientist at Fraunhofer HHI. "We can functionalize all geometries, including complex shapes such as curved surfaces."

Passive cooling based on laser-structured surfaces

The metals are irradiated with a femtosecond laser, causing part of the surface to vaporize. Because the laser pulses are extremely short, the bulk material remains undamaged. Cones on the order of one micrometer in size are laser-etched into the previously smooth surface. The advantage of this process is that the surface is physically optimized without chemically altering the material. Textured surfaces also help reduce launch costs, as the launch weight of carrier rockets is reduced by eliminating the paint coatings previously used. With laser structuring, the researchers at Fraunhofer HHI have succeeded in increasing the thermal emissivity of rough surfaces made of aluminum, stainless steel, titanium or copper to between 95 and

99 percent. For comparison, the emissivity of the untreated bare metals is roughly ten percent. The structured aluminum surfaces withstood test temperatures of up to 650 degrees Celsius. Because they remain stable up to the melting point of the metal used, the surfaces are not damaged when used on suitable materials, even if temperatures reach over 650° degrees. Unlike painted surfaces that release solvents over time, there is also no risk of outgassing (release of gases).

The laser-treated milled surface is currently black. Hübner and his team are currently investigating how to make the functionalized areas appear white. "Depending on which side of the Earth they are on, satellites can be exposed to solar radiation. Black surfaces absorb sunlight thus heating the radiator. We want to avoid this problem by using white surfaces that reflect sunlight," the research scientist explains.

The team also further developed the laser process in collaboration with Azimut Space GmbH. The costly, sensitive femtosecond laser processes are to be replaced with more affordable, robust nanosecond laser processes that can generate comparable milled structures in metal surfaces under a reactive gas atmosphere, i.e., in pure oxygen. "Although this will slow down the process and we will only achieve a thermal emissivity of roughly 85 percent, it will significantly reduce investment costs," says Hübner.

Material specimens are on their way back to Earth from the ISS

Several laser-structured aluminum and titanium specimens from Fraunhofer HHI have been in space for testing since December 2024. In a project with the European Space Agency (ESA) and with the participation of Azimut Space GmbH, the high thermal-emissivity surfaces were mounted on the outer hull of the International Space Station (ISS) in the direction of flight as radiative heat sinks for evaluation under real-world conditions. "The metal specimens are now on their way back to Earth. "The analysis and examination for material aging, potential damage and changes in thermal radiation are therefore still pending," says Hübner.

The researcher and his colleagues Hanan Al-Haddar and Ahmad Abdalwareth from Fraunhofer HHI plan to commercialize their research findings in startup Dythalis. This Fraunhofer spin-off will be launched in May of this year, primarily targeting manufacturers of satellites and thrusters. One month later—from June 10 to 14—the researchers will present electronic boxes and nozzles structured using femtosecond lasers at the joint Fraunhofer *Space* booth in Hall B 240 at ILA 2026 in Berlin.

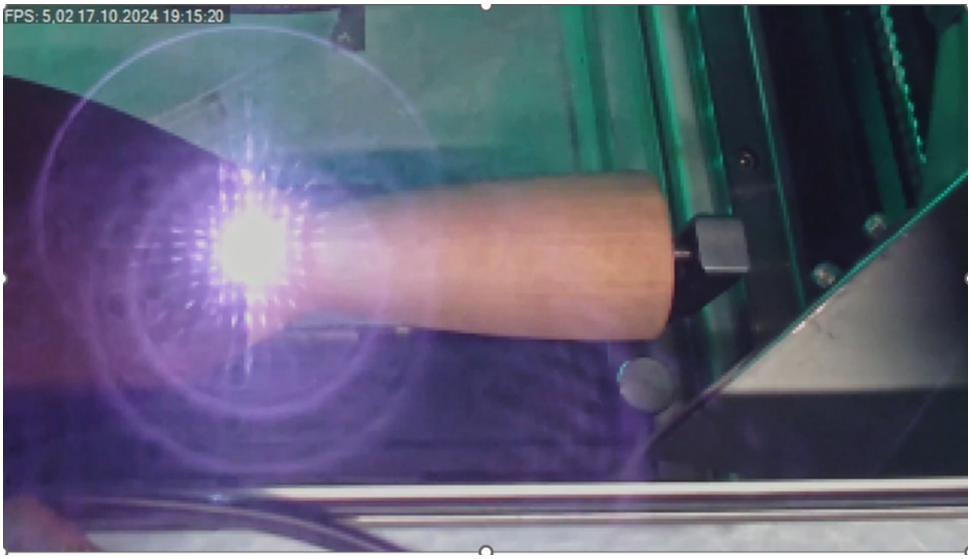


Fig. 1 Femtosecond laser structuring of a de Laval nozzle made of CuCrZr (copper alloy with chromium and zirconium) with a high-emissivity surface © Fraunhofer HHI



Fig. 2 Thermal test of a stainless steel de Laval nozzle © Fraunhofer HHI



Fig. 3 Seamless high-emissivity laser-textured aluminum box for electronic components
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