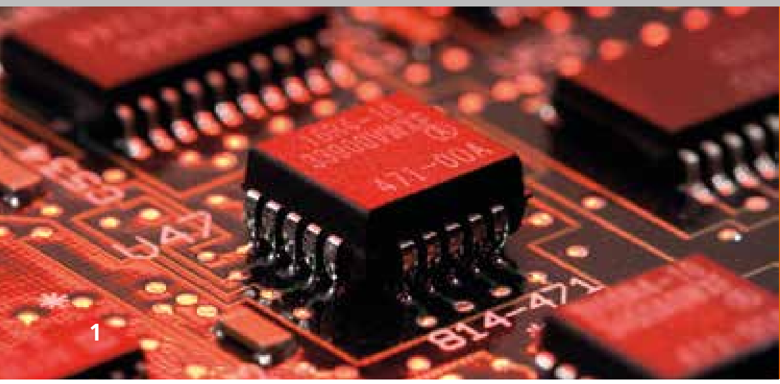
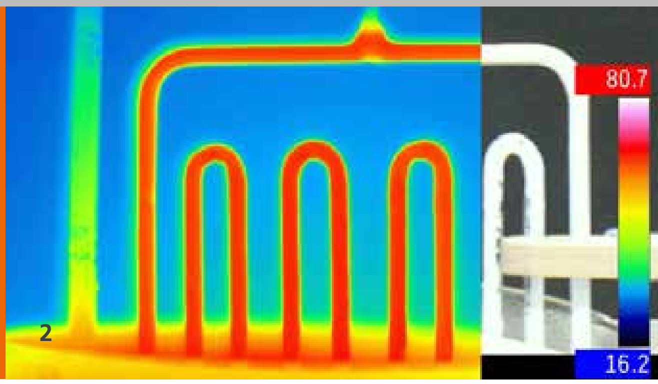
FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM





1 *In view of ever more powerful electronics, heat dissipation of components is becoming increasingly important.*

2 *Thermography image of a pulsating heat pipe (PHP) made of meandering glass tubes submerged in hot liquid. PHP have an extremely high effective thermal conductivity. Compared to a solid copper rod (pictured left), temperature compensation with hot liquid occurs very fast within the whole volume.*

PULSATING HEAT PIPES

EFFICIENT HEAT DISSIPATION AT HOT SPOTS

More power – more waste heat

With increasing power, heat flow and packing density of electronic components, the waste heat generated in confined space rises considerably. This results in dangerously high temperatures, thus increasing the risk of defects in electronic devices. More than 55 percent of electronic component failures are caused solely by overheating.

Fluid-filled channels instead of wick structure

With pulsating heat pipes (PHP), many problems of heat dissipation may be effectively solved. The PHP can be designed as bent pipe or as flat plate. While standard heat pipes usually rely on a wick structure to return the fluid to the heat source, a pulsating heat pipe consists of thin channels with up to several dozens of turns that are partially filled with liquid and evacuated. Due to the surface tension, segments consisting of fluid and vapor are formed. Vapor segments expand at the hot side and shrink or condense again at the cold side. Thus, there are always local temperature and pressure differences which the two-phase system strives to compensate for by shifting forces on the fluid/vapor segments. These forces generate a constant pulsating movement of the segments, such that the system never reaches a static equilibrium.
The movement of the segments induces the fluid transport from the hot side (heat source) to the cold side and with it also the heat transport.

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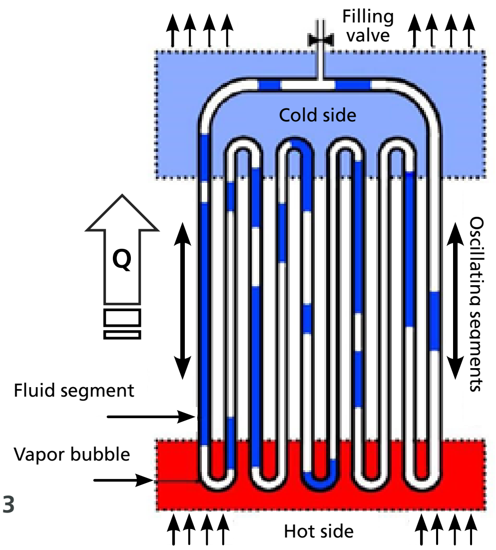

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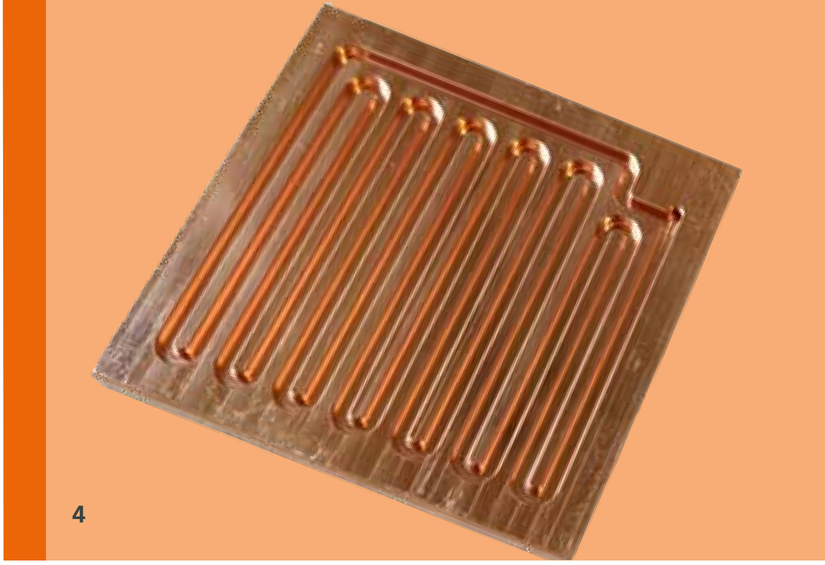

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Advantages of pulsating heat pipes

- **Considerably higher heat transport in a small space**. PHPs by Fraunhofer IPM transport heat extremely efficiently. For example, a copper flat-plate PHP with dimensions of 100 × 50 × 2.5 mm³ features up to six times higher effective thermal conductivity than solid copper – which is comparable to diamond!
- **Technical simplicity and reliability:** The movement of the heat-carrying liquid plugs is self-driven and does not require any external driving force apart from a temperature difference between hot and cold side. In other words, PHP work like an integrated water cooling system. No movable parts or power supply are required. This results in high operational stability and reliability. The PHP typically works in both horizontal and vertical position.
- **Stability and weight:** PHPs contain far smaller cavities than conventional heat pipes or vapor chamber based heat spreaders. Thus, the structure of a PHP integrated as heat spreader is much more stable, for example with regard to pressing processes that occur during PCB stack fabrication. At the same time, the weight is lower than that of a solid plate. This is an important advantage in particular in aerospace applications.
- **Extremely good heat spreading** effect due to the PHP operating principle. The effect depends on the position and size of the hot component and the heat sink.
- **Easy integration:** with thicknesses of only 2-3 mm, the PHP is flat and very compact. This allows very good thermal coupling, in particular for embedded power components.

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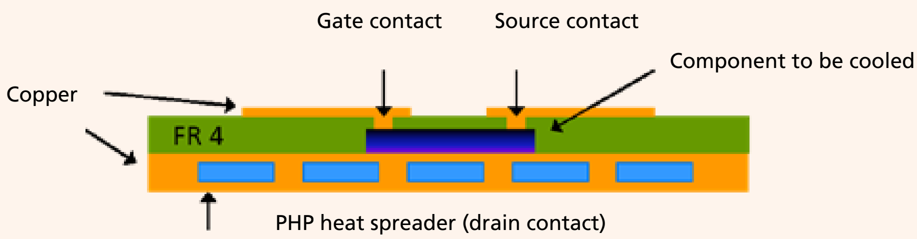

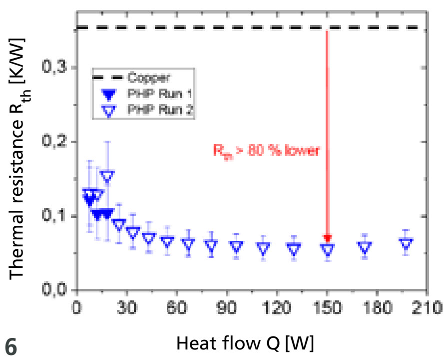

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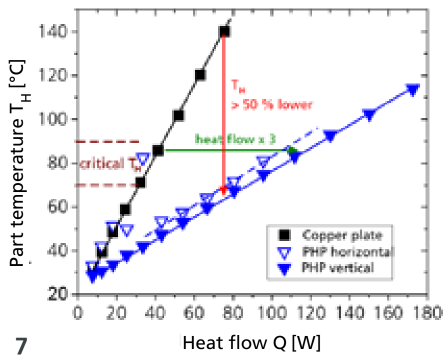

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3 *Operating principle of a pulsating heat pipe.*

4 *Base plate of a PHP with milled channels. After soldering the base plate to the cover and filling with the fluid, the PHP is ready to use.*

5 *Possible concept for integrating a PHP in a PCB stack, including connection to the electric component to be cooled.*

6 *Thermal resistance of a PHP in vertical operation for different heat flows (blue triangles). Compared to an equal-sized plate consisting of solid copper (dashed line), more than 80 percent lower thermal resistances can be reached.*

7 *Temperature of a hot component for different heat flows or electrical powers. If the component is installed on a PHP, it reaches less than half of the temperature (blue triangles) for the same heat flow compared to an equal-sized copper plate (black squares). Or, in other words, a critical temperature of typically about 80–90 °C is only reached for a heat flow three times as high (green arrow).*