Fraunhofer IPM

Pulsating heat pipes
Efficient heat dissipation at hot spots

Slim shape for enhanced heat transport

Base plate of a pulsating heat pipe (PHP) with milled channels. After soldering the base plate to the cover and filling it with fluid, the PHP is ready to use.

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

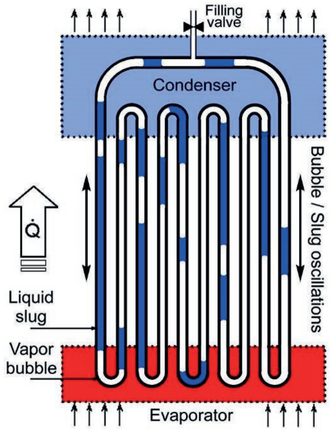
With pulsating heat pipes (PHP), many problems of heat dissipation may be effectively solved. The PHP can be designed as bent pipe or as flat plate. While standard heat pipes usually rely on a wick structure to return the fluid to the heat source, a pulsating heat pipe consists of thin channels with up to several dozens of turns that are partially filled with liquid and evacuated.

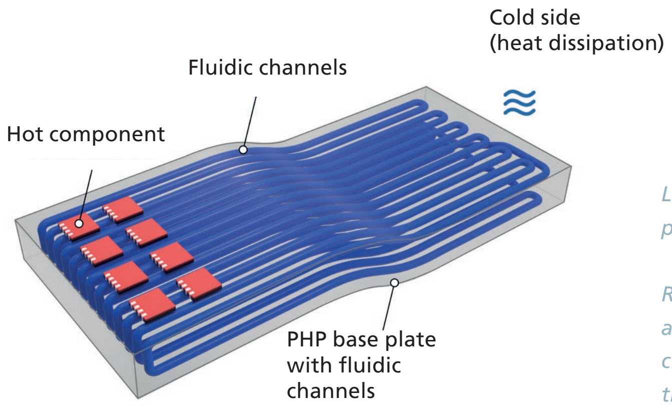
Due to the surface tension, segments consisting of fluid and vapor are formed. Vapor segments expand at the hot side and shrink or condense again at the cold side. Thus, there are always local temperature and pressure differences which the two-phase system strives to compensate for by shifting forces 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.

Our offer

- Heat pipe consulting with a view to their specific applications
- Development and manufacture of heat pipe prototypes using different production methods such as vacuum brazing, additive manufacturing (3D printing)
- Characterization of heat pipes
- Support in heat pipe manufacturing: from test sample to batch production

Don't hesitate to get in touch!





Left: Operating principle of a pulsating heat pipe.

Right: Prototypical design of a PHP with a multilayer fluid channel structure for high thermal power densities.

Advantages of pulsating heat pipes

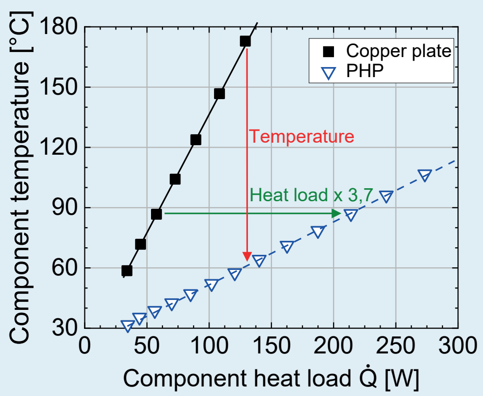
High heat transport in a small space
With thicknesses of only 2–3 mm, PHP can be designed very flat and compact, and at the same time transport heat extremely efficiently. For example, a copper flat-plate PHP with dimensions of $100 \times 50 \times 2.5$ mm^3 features up to six to nine times higher effective thermal conductivity than a solid copper plate of the same size – which is comparable to diamond. This way, large quantities of heat from component hot spots can be dissipated. The heat transport capacity depends on the position and size of the component and the heat sink.

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. The PHP typically works in both horizontal and vertical orientation.

Stability and weight
PHP contain far smaller cavities than conventional heat pipes or vapor chamber-based heat spreaders, which guarantees high mechanical stability. At the same time, the weight is lower than that of a solid plate. This is an important advantage in particular in aerospace applications.

Freedom of design and easy integration
PHP can also be fabricated by additive manufacturing (3D printing). This allows the PHP (including heat sink) to be designed freely and integrated directly into load-bearing components or housings. Moreover, multilayer fluid channel structures with very high maximum dissipatable thermal power densities can be realized this way. The use of lightweight aluminum alloys for the PHP is possible.

Copper plate vs. PHP: Temperature of a hot component at different heat flows



PHP are characterized by high heat transfer capacity and low thermal resistance. Placed on a PHP (here 100 x 50 x 2.5 mm³, 21 °C cold side temperature), a hot component reaches a much lower temperature (blue data points) than on a copper plate of the same size (black data points). A critical temperature of typically around 80–90 °C is only reached at three to four times higher heat loads.

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