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**1 + 2** *CAD model of a magnetocaloric cooling system. A rotating permanent magnet generates a magnetic field that heats and cools the series-connected magnetocaloric segments.*

MAGNETOCALORICS AND ELECTROCALORICS

# Efficient heat transfer in magnetocaloric cooling circuits

Magnetocaloric cooling technology is a promising candidate for efficient and environmentally friendly cooling technology. The future market viability of this technology depends on its ability to transfer heat between a magnetocaloric material and a heat exchanger as efficiently as possible. To this end, Fraunhofer IPM has developed a new concept based on so-called heat pipes.

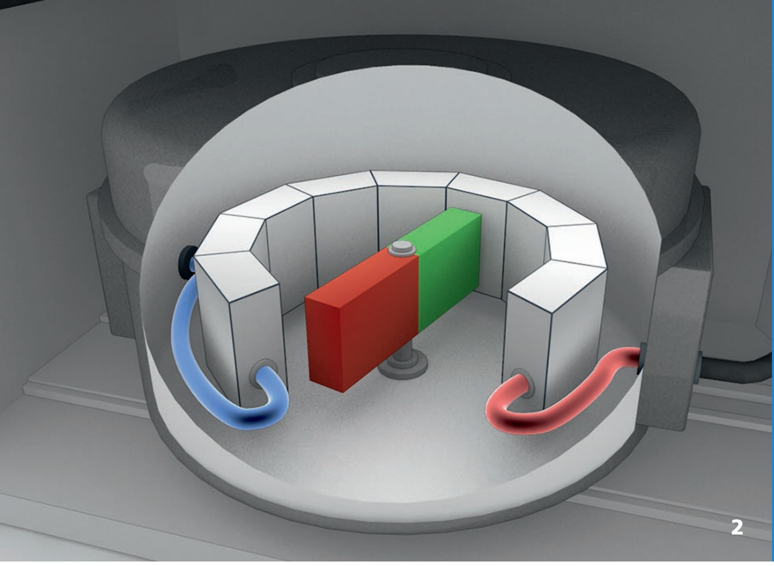
In terms of cooling technology, the industry relies almost exclusively on compressor-based systems; however the refrigerants needed to operate these systems pose a danger to the environment and/or health and are therefore increasingly regulated or even prohibited across the EU. In the future, magnetocaloric cooling cycles could make cooling systems up to 30 percent more efficient. These systems are generally quiet and low-maintenance, and operate without using controversial refrigerants.

### Increased material efficiency

Magnetocaloric (MC) materials heat up when exposed to a magnetic field and cool down again once this field is removed. To implement a cooling cycle, a magnetic field is applied to the MC material, and the heated material is connected to a heat sink in order to transfer the heat produced. If the magnetic field is removed, the MC material cools down again, reaching a lower temperature than at the start of the cycle. The material is then connected to the system to be cooled and can absorb heat until it returns to its starting temperature. Magnetocaloric cooling circuits were first implemented in the 1970s. Due to the increasing efficiency of MC materials, today magnetocaloric heat pumps can achieve a pump capacity of several kilowatts. As part of the »MagCon« project (Magnetocalorics: Development of refrigerant-free, highly efficient heat pumps for heating and cooling), scientists at the Institute are collaborating with colleagues at Fraunhofer IFAM to develop a prototype for a magnetocaloric cooling circuit with a new, patented heat transfer concept that functions on the heat pipe principle. The goal is to develop the world's first refrigerant-free cooling system with a heat pump capacity of 300 W, a temperature change of 35 K and a coefficient of performance of > 5.

### Heat pipes facilitate fast heat transfer

The efficient transfer of heat between the MC material and the heat exchanger is a decisive factor in the overall efficiency of the magnetic cooling cycle. Previous prototypes are based on the concept of »active magnetic regeneration« (AMR), in which a fluid is pumped through the MC material to transfer heat. A low heat transfer coefficient and the resulting low cycle frequency as well as the large amount of pumping energy required make AMR concepts inefficient overall. The heat pipe concept for heat transfer developed by Fraunhofer IPM facilitates passive





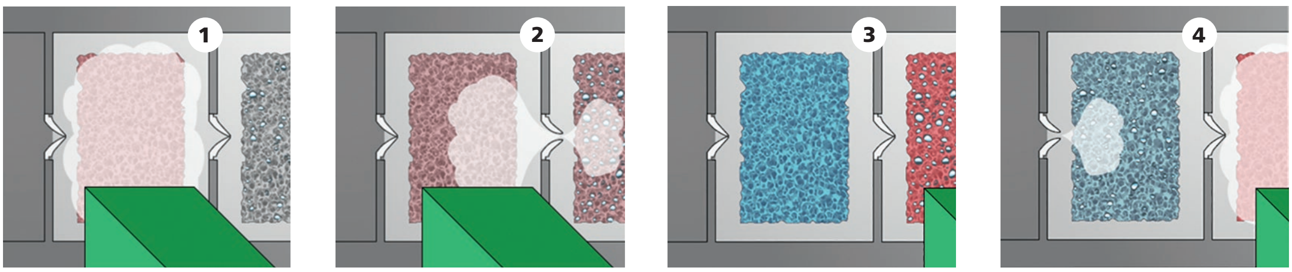

heat transfer through the evaporation and condensation of a fluid in a hermetically sealed volume. Such heat exchangers, also known as thermosiphons, are used as solar collectors or in computer cooling. The heat pipe concept is an innovative method for implementing a magnetocaloric cooling cycle.

The whole system is efficient and fast: By evaporating a fluid such as water or ethanol at the heat source and subsequently condensing it at the heat sink, it is possible to achieve heat transfer coefficients that are several orders of magnitude higher than those achieved in traditional heat transfer by means of thermal conduction or convection. Simulated calculations have shown that transporting thermal energy from one magnetocaloric segment of only a few centimeters in size to the next occurs in a matter of milliseconds, making it fundamentally possible to establish cooling cycles with a frequency of more than 10 Hz. Fraunhofer IPM has developed heat pipes which are thermal diodes and only allow heat to flow in one direction only.

Efficient, refrigerant-free heat pumps based on the magnetocaloric cycle have the potential to revolutionize cooling technology. The best part: Magnetocaloric heat pumps can also be used for heating, making them an important element of the HVAC technology of the future.

## MAGNETOCALORIC COOLING CIRCUITS

The heat is »driven forward« in only one direction according to the principle of a thermal diode: The heat generated by the magnetic field causes the fluid in the MC material to evaporate (1), increasing the pressure in the segment. The pressure relief valve opens, allowing the vapor to flow into the adjoining element (2). Once the magnet has been switched off, the MC material cools down below the starting temperature (3) and the vapor pressure drops. A vacuum develops in relation to the previous segment. Gaseous fluid flows in and heat from the previous segment is absorbed (4).

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