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EXPERIMENTAL VALIDATION OF A SOLID STATE MAGNETOCALORIC COOLER IN A SPACE ENVIRONMENT

Abstract

Thermal regulation of a spacecraft is a highly complex process due to the environmental conditions in space. Generated heat must be transported to a radiator, as thermal radiation is the only way to dissipate heat in a vacuum. This is typically realized through fluid-based cooling systems, such as heat pipes or pumped-fluid loops. Although the existing systems have been proven effective and are operated successfully, fluid-based systems have inherent drawbacks, such as high mass and large size. In addition, some systems contain many moving parts and are therefore mechanically very complex. Current design trends are shifting towards smaller spacecraft such as CubeSats, while capabilities and power demands are rising. Especially on-board computing and data handling have increased significantly, which results in localized thermal hot-spots during mission time. This eventually leads to designs where the desired small form factor of a satellite is no longer sufficient to support the necessary cooling systems to deal with the increasing heat generation. Novel concepts are required, which provide high and efficient heat transfer capabilities on a small-scale and preferably with low-complexity. A promising field of research is fluid-less cooling, which can also drastically reduce the complexity. The Efficient MagnetoCaloric Cooling Components (E-mc^3) project aims to lay the foundations for a new fluid-less cooling system based on the magnetocaloric effect. This effect describes the temperature change of a magnetocaloric material (MCM) caused by a change in the external magnetic field. The internal temperature rises when subjected to a magnetic field and decrease if the field is removed. This can be utilized in a thermodynamic cycle for cooling. Here, we present a first design of a magnetocaloric cooler without liquids as a proof of concept. Gadolinium has been selected for the MCM. The required strong and switchable magnetic field is realized by a pair of rotating permanent magnets. In addition, Peltier elements are used as thermal switches. An on-ground validation campaign performed in a thermal vacuum chamber is presented and discussed. The demonstrated proof of concept highlights the viability of pursuing the technology further and lays the foundation for future endeavors.