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# Pattern Formation in Ice Under Selective Infrared Radiation

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Spontaneous self-organization of a system can lead to pattern formation. Many examples for that are found in nature, such as dividing cells in the developing embryo, dendritic growth of crystals, and the formation of brine channels in sea ice. Here we present a new pattern formation in ice under selective infrared (IR) radiation. Unlike Tyndall flowers, which are dendritic melting of super heated ice under IR radiation, we demonstrate a completely different pattern of thin ice crystals in the shape of holes and micro-channels. The difference in the IR absorption of ice and water enabled us to heat ice more than water in an ice/water system. We illuminated 10 - 80 μm thick ice crystals in solution using up to 2 W IR radiation (1540 nm). The system developed spatial pattern, and under some conditions, also growth and melt oscillations. Applying the ice-selective radiation resulted in pattern that started with holes of 7±1 μm diameter that, with time, became smaller and closed. Equal-sized holes were opened again in various areas of the ice crystal and eventually developed into micro-channels. We were able to inhibit the pattern formation by using carbon black particles, which elevated the water absorption while maintaining the ice absorption. In addition, under water-selective radiation up to 4 W (980 nm), the ice crystals assumed a pattern of stripes while growing.
Heat transfer and phase field simulations showed that larger ice crystals absorb more energy than the smaller ones, and implied that there is a typical width of the micro-channels, similar to the experimental value. We interpreted our results as a unique pattern formation that stems from a negative feedback of growth and melt. We showed that selective radiation influences ice morphology. Therefore, it holds the potential to interfere and affect ice growth, and thus, improve cryopreservation protocols.

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## Significance statement

We present a new physical phenomenon involving pattern formation of ice under selective infrared radiation, in which thin ice crystals assumed a spatial pattern of holes and micro-channels.

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