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Cooling in summer, heating in winter: all through one smart window

Cooling and heating homes, shops and other indoor spaces consume roughly 15% of the world's energy supply, underscoring the need for an improved system for cooling in summer and heating in winter.
ICFO researchers propose novel smart windows for efficient thermal control, with tunable properties that enable harnessing heat in winter and releasing heat in summer. These results, recently published in Nanophotonics, are crucial to reduce the world's energy consumption spent in heating and cooling indoor spaces. These windows could reduce the energy demand for buildings in Barcelona by more than 40%.

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A promising approach to control heat in indoor spaces is thermally smart windows -windows whose radiative absorption, emission, and/or transmission can be tuned on demand. There are two frequency ranges of particular interest for thermal regulation: the near-infrared (where solar radiation peaks, and can therefore be harnessed for heating) and the mid-infrared (where atmospheric absorption drops to near zero, allowing heat to radiate out to the universe for cooling).

Previous research in thermally smart windows is limited, and most studies address either the near- or mid-infrared region, but rarely both simultaneously. In a recent Nanophotonics publication, ICFO researcher **Dr. Julien Legendre** and **Prof. at ICFO Dr. Georgia Papadakis have investigated a smart window that simultaneously operates in these two frequency ranges**. They have considered the benefit in terms of electricity demand for heating and cooling, and have shown that these devices could be built with existing architectures that can be fabricated in the laboratory.

Taking a step back to see the gaps in smart window's research

The field of smart windows, referring mostly to windows that can convert from transparent to visible light to opaque, emerged less than 15 years ago and has expanded rapidly ever since. This boom has given rise to many different research directions, but interaction between them is often minimal. ï¿½We thought it was a good time to take a step back, to take the time

o properly understand these different directions in which research is moving,ï¿½ recalls Dr. Julien Legendre, first author of the study. ï¿½We actually found that people never eally investigated designs combining near- and mid-infrared modulation, even though these could lead to significant improvements in terms of thermal regulati
n.ï¿½ The researchers then set to work, extensively analyzing the potential of controll ng each spectral range for thermal regulation. Ultimately, they proposed a design that ombines phase-change materials and liquid crystals. **The resulting windows could reduce the energy demand of buildings at Barcelona's latitude by more than 40%** compared to traditional silica glass.
Nevertheless, the researchers also uncover the main material and structural limitations that may hinder the window's performance and should therefore guide future research. The team identifies limited near?infrared tunability as the primary obstacle; scalable fabrication, cost, and material sustainability also emerge as milestones we should seriously consider. ï¿½ e believe that improving these aspects will be critical for the democratization of sma t windows,ï¿½ shares Dr. Legen
re. Even though thermal management is the main motivation for developing these s art windows, the authors are also considering other applications, such as thermal camoufl ge, where the devices blend into the thermal image of the surroundings by tuning their radia ive properties in the infrared. According to Prof. Georgia Papadakis, senior author of the art cle and group leader of the Thermal Photonics group at ICFO: ï¿½We actually started work ng on thermal camouflage since the beginning of the year, through the European P oject CATHERINA. In this way, we hope to create valuable synergies between these different areas of resear

Reference:

Legendre, Julien and Papadakis, Georgia T. "Energy-efficient thermally smart windows with tunable properties across the near- and mid-infrared ranges" Nanophotonics, 2025.
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