Universidad de Sonora

Interferencia de ondas termicas

Dr. Jesus Manzanares Martinez

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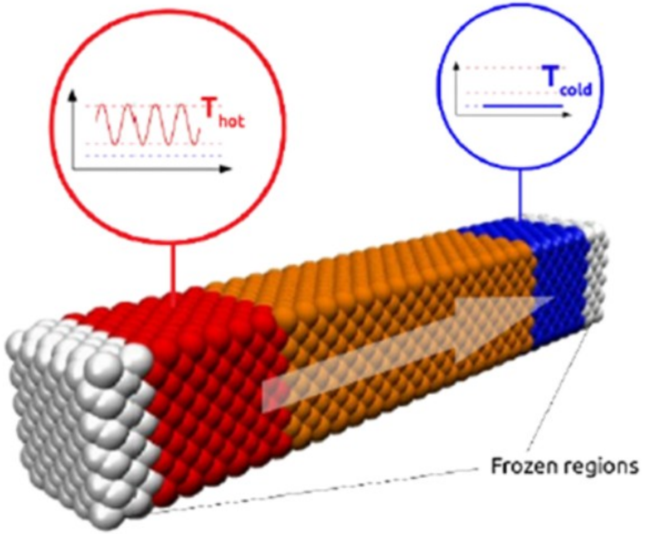
PHYSICS

Observation of second sound in a rapidly varying temperature field in Ge

Albert Beardo[1], Miquel López-Suárez[2,3], Luis Alberto Pérez[2], Lluc Sendra[1], Maria Isabel Alonso[2], Claudio Melis[3], Javier Bafaluy[1], Juan Camacho[1], Luciano Colombo[3], Riccardo Rurali[2], Francesc Xavier Alvarez[1], Juan Sebastián Reparaz[2]*

Second sound is known as the thermal transport regime where heat is carried by temperature waves. Its experimental observation was previously restricted to a small number of materials, usually in rather narrow temperature windows. We show that it is possible to overcome these limitations by driving the system with a rapidly varying temperature field. High-frequency second sound is demonstrated in bulk natural Ge between 7 K and room temperature by studying the phase lag of the thermal response under a harmonic high-frequency external thermal excitation and addressing the relaxation time and the propagation velocity of the heat waves. These results provide a route to investigate the potential of wave-like heat transport in almost any material, opening opportunities to control heat through its oscillatory nature.

Beardo *et al.*, *Sci. Adv.* 2021; **7** : eabg4677 30 June 2021



$$\tau_{ss}\frac{\partial^2 T}{\partial t^2} + \frac{\partial T}{\partial t} - \alpha\nabla^2 T = \frac{1}{\rho C_p}\left(S(\boldsymbol{r},t) + \tau_{ss}\frac{\partial S(\boldsymbol{r},t)}{\partial t}\right)$$

- The wave equation

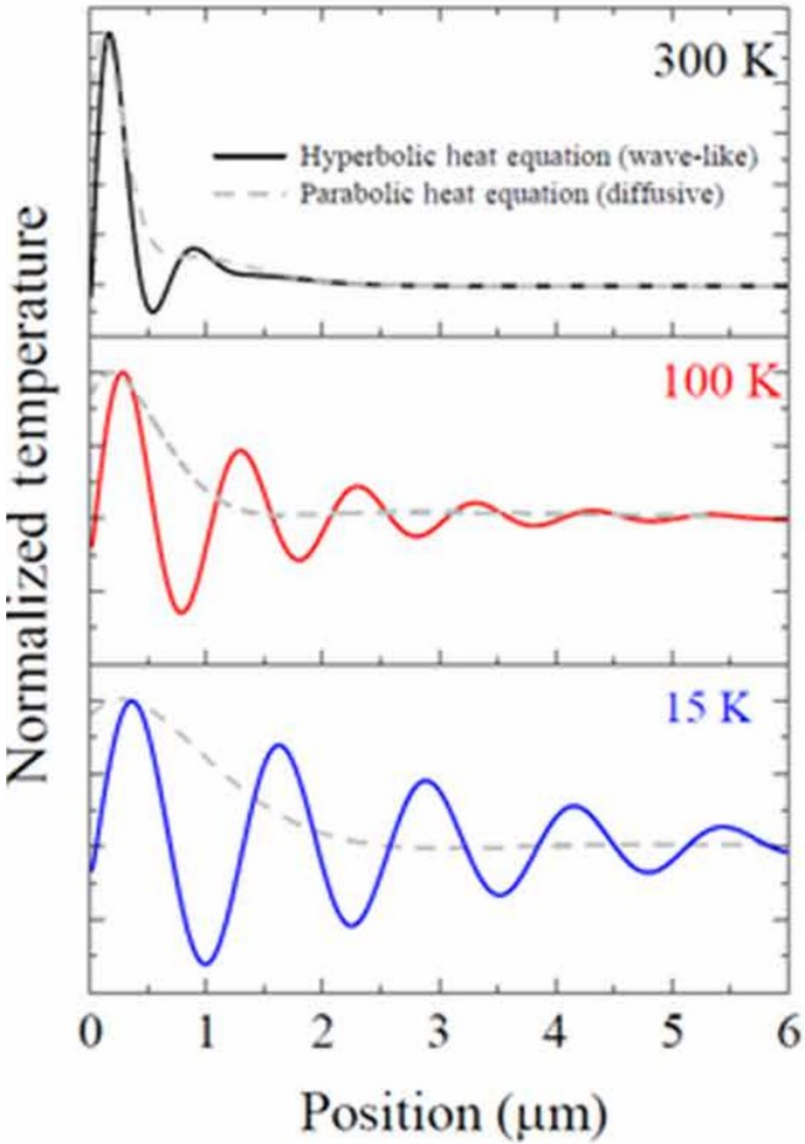
$$u_{tt} - u_{xx} = 0 \qquad \text{is hyperbolic.}$$

- The Laplace equation

$$u_{xx} + u_{yy} = 0 \qquad \text{is elliptic.}$$

- The heat equation

$$u_t - u_{xx} = 0 \qquad \text{is parabolic.}$$



(1) $$\rho c \frac{\partial}{\partial t} T(x,t) = -\frac{\partial}{\partial x} q(x,t)$$ ← Conservacion de la energía

$\rho \rightarrow$ densidad
$c \rightarrow$ capacidad calorifica

$q \rightarrow$ flujo
$T \rightarrow$ temperatura

(2) $$q(x,t) = -K \frac{\partial}{\partial x} T(x,t)$$ ← Ley de fourier

Sustituyendo (2) en (1)

$$\rho c \frac{\partial}{\partial t} T(x,t) = -\frac{\partial}{\partial x}\left[-K \frac{\partial}{\partial x} T(x,t)\right]$$

$$\frac{\partial}{\partial t} T(x,t) = D \frac{\partial^2}{\partial x^2} T(x,t)$$ Ec de Calor (parabolic)

$$D = \frac{K}{\rho c}$$

6:44 a.m. Vie 6 de may 50%

con fase

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$$\rho c \frac{\partial}{\partial t} T(x,t) = -\frac{\partial}{\partial x} q(x,t) \qquad q(x,t) = -K \frac{\partial}{\partial x} T(x,t)$$

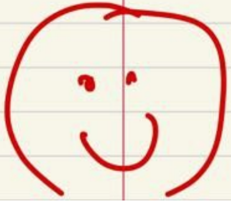
La ley de Fourier esta mal!

$$q(x, t+\tau) = -K \frac{\partial}{\partial x} T(x,t),$$

τ es "time lag", a primer orden en serie de Taylor en el lado izquierdo tenemos

$$q(x, t+\tau) = q(x,t) + \tau \frac{\partial}{\partial t} q(x,t)$$

$$q(x,t) + \tau \frac{\partial}{\partial t} q(x,t) = -K \frac{\partial}{\partial x} T(x,t)$$



NUEVA LEY DE FOURIER!

8:18 a.m. Vie 6 de may

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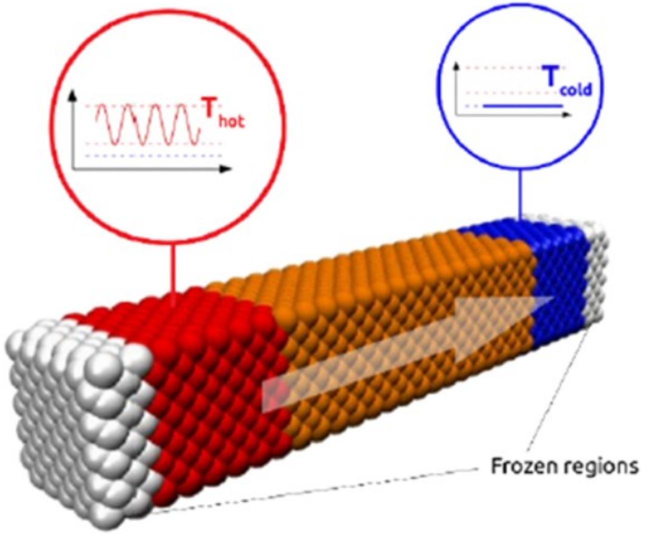
$$\frac{\partial}{\partial t}\left[q(x,t) + \tau \frac{\partial}{\partial t} q(x,t)\right] = \frac{\partial}{\partial t}\left[-k \frac{\partial}{\partial x} T(x,t)\right]$$

$$\frac{\partial}{\partial t} q(x,t) + \tau \frac{\partial^2}{\partial t^2} q(x,t) = -k \frac{\partial}{\partial x}\left[\frac{\partial}{\partial t} T(x,t)\right]$$

$$\rho c \frac{\partial}{\partial t} T(x,t) = -\frac{\partial}{\partial x} q(x,t) \rightarrow \left[\frac{\partial}{\partial t} T(x,t)\right] = -\frac{1}{\rho c}\frac{\partial}{\partial x} q(x,t)$$

$$\frac{\partial}{\partial t} q(x,t) + \tau \frac{\partial^2}{\partial t^2} q(x,t) = +\frac{k}{\rho c}\frac{\partial^2}{\partial x^2} q(x,t)$$

Nueva ecuación de calor: Modelo de Cattaneo-Vernotte



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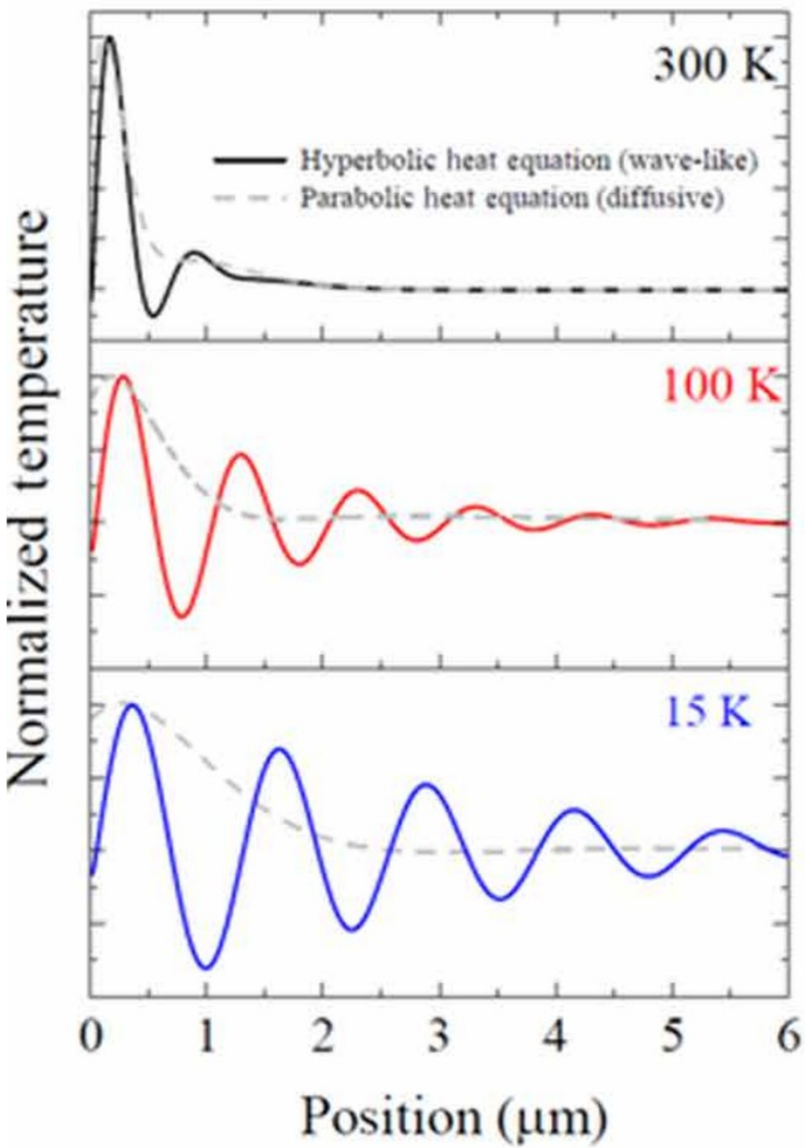
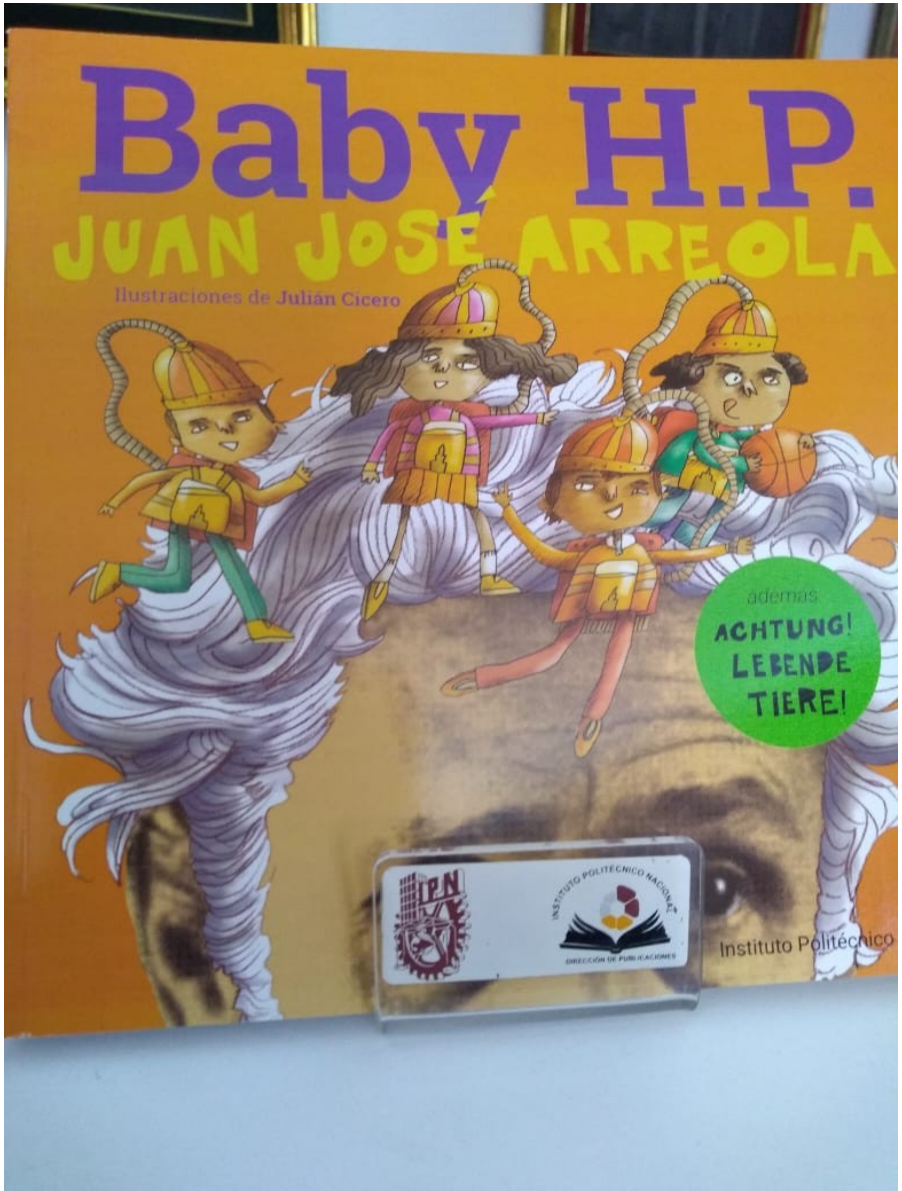


Scientists discovered mysterious wavelengths in germanium, which may turn waste heat from machines into treasures

2022-05-06 22:58 HKT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A study published in "Science Advances" reported for the first time an unexpectedly observed thermal wave in the semiconductor material germanium. This phenomenon may significantly improve the performance of our electronic devices in the near future. The research was led by researchers from the Institute of Materials Science of Barcelona (ICMAB, CSIC) in collaboration with researchers from the Autonomous University of Barcelona and the University of Cagliari.

As we know, heat originates from the vibration of atoms and is transferred through diffusion at ambient temperature. The trouble is that heat is difficult to control, and there is currently no effective way to control heat. This is why a lot of waste heat accumulates in our computers, mobile phones, and most electronic devices in general.However, if heat is transmitted through waves, such as light, this will provide new alternatives to control it, especially through the unique and inherent characteristics of waves.

To date, thermal waves have only been observed in a few materials, such as solid helium or more recently in graphite. Now, researchers from the Institute of Materials Science of Barcelona (ICMAB, CSIC) collaborated with researchers from the Autonomous University of Barcelona and the University of Cagliari, published in the "Science Progress". This study reports the thermal effects of solid germanium at room temperature. Wave observation.

Germanium is a semiconductor material commonly used in electronic products, similar to silicon. Sebastián Reparaz, the person in charge of this research, said: “On this type of material and under this condition, I did not expect to encounter these wave-like effects, the so-called second sound.”

This observation occurred when studying the thermal response of a germanium sample under the action of a laser, and a high-frequency oscillating heating wave was generated on its surface. Experiments have shown that, contrary to what has been believed so far, heat does not dissipate through diffusion, but propagates into the material through thermal waves.

In addition to the observation itself, in this study, the researchers unlocked the way to observe thermal waves in any material system.

The second sound is a heat transmission mechanism, first observed on solid helium in the 1960s, and refers to heat transmission through waves. For a long time, researchers have tried repeatedly to prove that it also has a second voice in other materials.

"The possible applications of the second voice are limitless," Sebastián Reparaz said. However, realizing these applications requires a deep understanding of how to unlock this heat propagation mechanism on any given material. The ability to control heat propagation through the characteristics of waves opens up new ways of designing future generations of thermal equipment, similar to the established light developments. "Specifically, the second acousto-thermal mechanism can be used to rethink how we deal with waste heat," he added.

The findings of this research can be integrated with the current theoretical model, so that the second sound observed in different materials can be described by the same equation. This observation establishes a new theoretical framework that may significantly improve the performance of our electronic devices in the near future.

Anuncios:

- Se les invita a dar platicas en nuestro Seminario de Divulgacion de la Ciencia. Viernes a las 12:00

- Se les invita a un “verano de la ciencia”

Beardo, Albert, et al. "Observation of second sound in a rapidly varying temperature field in Ge." Science advances 7.27 (2021): eabg4677.