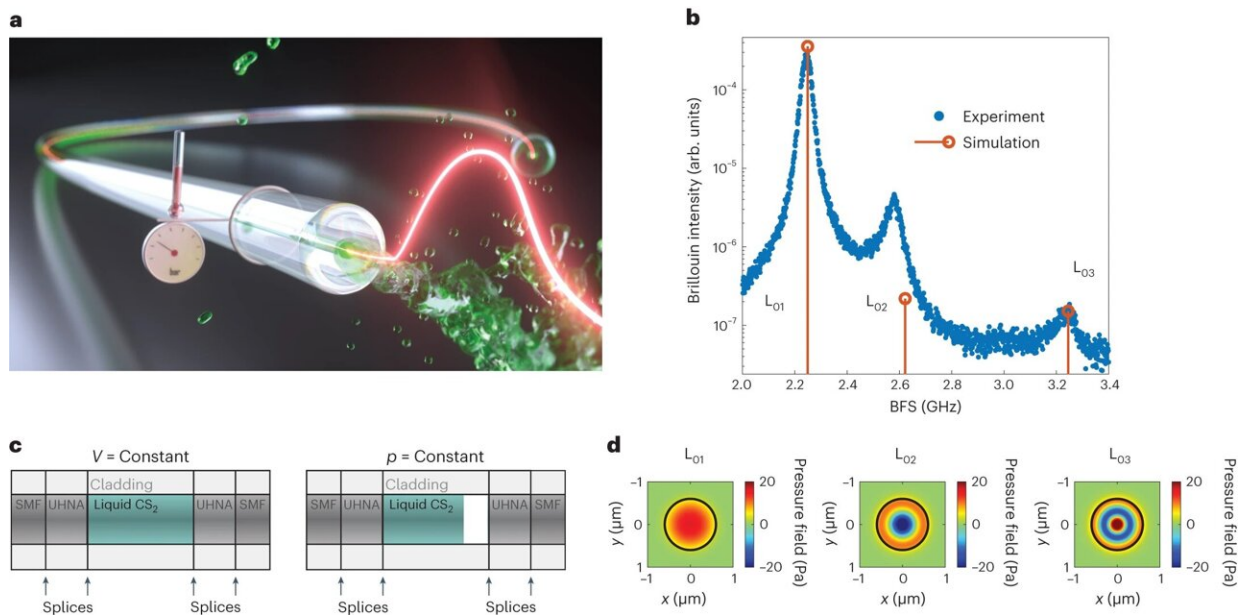


Light and sound waves reveal negative pressure

September 25 2023, by Florian Ritter



Sample geometry and analysis of the integrated Brillouin spectrum at room temperature. **a**, Artist's view of the LiCOF sample with a laser. **b**, Measured spectrum (blue) and simulation (red) of SBS spectrum with 1.125 μm core diameter. **c**, Geometry of the LiCOF sample spliced on both sides with a UHNA fiber for coupling and sealing. SMF is used for integrability. If the capillary is fully filled, the volume (V) stays constant (isochoric regime), whereas if a bubble is present, the pressure (P) stays constant (isobaric regime). **d**, Numerical simulations of the corresponding longitudinal, radially symmetric pressure acoustic modes L_{01} , L_{02} and L_{03} . Panel **a** credit: Long Huy Dao. Credit: *Nature Physics* (2023). DOI: 10.1038/s41567-023-02205-1

Negative pressure is a rare and challenging-to-detect phenomenon in physics. Using liquid-filled optical fibers and sound waves, researchers at the Max Planck Institute for the Science of Light (MPL) in Erlangen have now discovered a new method to measure it. In collaboration with the Leibniz Institute of Photonic Technologies in Jena (IPHT), the scientists in the Quantum Optoacoustics research group, led by Birgit Stiller, can gain important insights into thermodynamic states.

As a physical quantity pressure is encountered in various fields: [atmospheric pressure](#) in meteorology, [blood pressure](#) in medicine, or even in everyday life with pressure cookers and vacuum-sealed foods. Pressure is defined as a force per unit area acting perpendicular to a surface of a solid, liquid, or gas. Depending on the direction in which the force acts within a closed system, very [high pressure](#) can lead to explosive reactions in extreme cases, while very low pressure in a closed system can cause the implosion of the system itself.

Overpressure always means that the gas or liquid pushes against the walls of its container from the inside, like a balloon expanding when more air is added. Regardless of whether it's high or low pressure, the numerical value of pressure is always positive under normal circumstances.

However, liquids exhibit a peculiar characteristic. They can exist in a specific metastable state corresponding to a negative pressure value. In this metastable state, even a tiny external influence can cause the system to collapse into one state or another. One can imagine it as sitting at the top of a roller coaster: the slightest touch on one side or the other sends you hurtling down the tracks. In their current research, the scientists are examining the metastable state of liquids with negative pressure.

To achieve this, the research team combined two unique techniques in a study published in *Nature Physics* to measure various thermodynamic states. Initially, tiny amounts—nanoliters—of a liquid were encapsulated

in a fully closed [optical fiber](#), allowing both highly positive and negative pressures. Subsequently, the specific interaction of optical and acoustic waves in the liquid enabled the sensitive measurement of the influence of pressure and temperature in different states of the liquid.

Sound waves act as sensors for examining negative pressure values, exploring this unique state of matter with high precision and detailed spatial resolution.

The influence of negative pressure on a liquid can be envisioned as follows: According to the laws of thermodynamics, the volume of the liquid will decrease, but the liquid is retained in the glass fiber capillary by adhesive forces, much like a water droplet sticking to a finger. This results in a "stretching" of the liquid. It is pulled apart and behaves like a rubber band being stretched.

Measuring this exotic state typically requires complex equipment with heightened safety precautions. High pressures can be hazardous endeavors, particularly with toxic liquids. Carbon disulfide, used by the researchers in this study, falls into this category. Due to this complication, previous measurement setups for generating and determining negative pressures have required significant laboratory space and even posed a disturbance to the system in the metastable state.

With the method presented here, the researchers have instead developed a tiny, simple setup in which they can make very precise pressure measurements using light and [sound waves](#). The fiber used for this purpose is only as thick as a human hair.

"Some phenomena which are difficult to explore with ordinary and established methods can become unexpectedly accessible when new measurement methods are combined with novel platforms. I find that exciting," says Dr. Birgit Stiller, head of the Quantum Optoacoustics

research group at MPL.

The sound waves used by the group can detect temperature, [pressure](#), and strain changes very sensitively along an optical fiber. Furthermore, spatially resolved measurements are possible, meaning that the sound waves can provide an image of the situation inside the optical fiber at centimeter-scale resolution along its length.

"Our method allows us to gain a deeper understanding of the thermodynamic dependencies in this unique fiber-based system," says Alexandra Popp, one of the two lead authors of the article. The other lead author, Andreas Geilen, adds, "The measurements revealed some surprising effects. The observation of the [negative pressure](#) regime becomes abundantly clear when looking at the frequency of the sound waves."

The combination of optoacoustic measurements with tightly sealed capillary fibers enables new discoveries regarding the monitoring of chemical reactions in toxic liquids within otherwise difficult-to-investigate materials and microreactors. It can penetrate new, hard-to-access areas of thermodynamics.

"This new platform of fully sealed liquid core fibers provides access to high pressures and other thermodynamic regimes," says Prof. Markus Schmidt from IPHT in Jena, and Dr. Mario Chemnitz, also from IPHT in Jena, emphasizes: "It is of great interest to investigate and even tailor further nonlinear optical phenomena in this type of fiber."

These phenomena can unlock previously unexplored and potentially new properties in the unique thermodynamic state of materials. Birgit Stiller concludes, "The collaboration between our research groups in Erlangen and Jena, with their respective expertise, is unique in gaining new insights into thermodynamic processes and regimes on a tiny and easy-to-

handle optical platform."

More information: Geilen, A. et al, Extreme thermodynamics in nanolitre volumes through stimulated Brillouin–Mandelstam scattering, *Nature Physics* (2023). DOI: [10.1038/s41567-023-02205-1](https://doi.org/10.1038/s41567-023-02205-1).
www.nature.com/articles/s41567-023-02205-1

Provided by Max Planck Society

Citation: Light and sound waves reveal negative pressure (2023, September 25) retrieved 29 April 2024 from <https://phys.org/news/2023-09-reveal-negative-pressure.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.