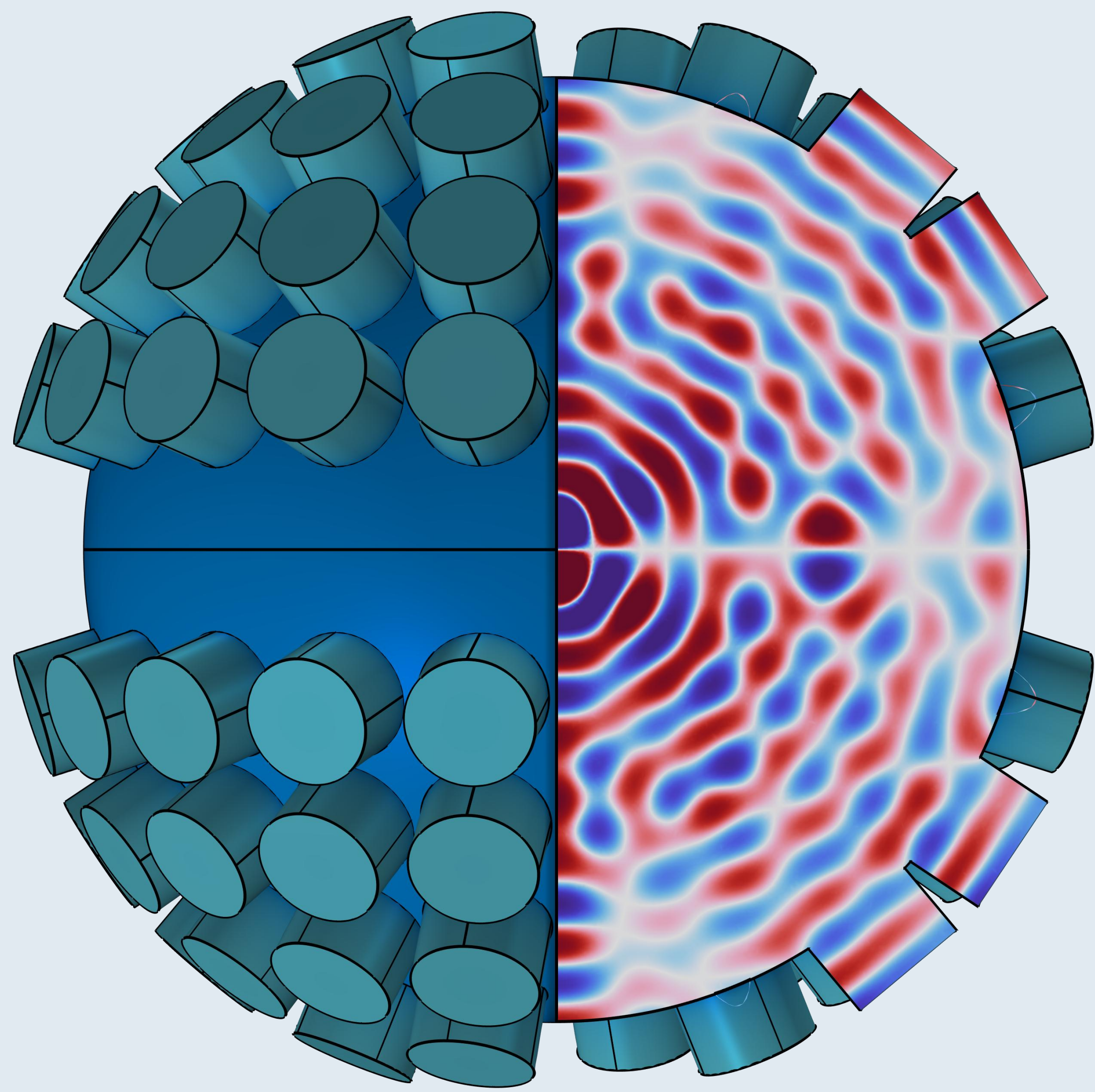




Acoustic Levitation of Magmatic Samples for (Exo)planetary Research

The LEViathan is a research prototype developed for contactless studies of molten rocky materials using acoustic levitation. Samples are suspended while an external heating source is applied (e.g. laser).

A. Korocencev¹

1. ETH Zürich, Zürich, Switzerland

Introduction

ETH Zurich's Experimental Planetology group studies how planets form and evolve by recreating important processes in the laboratory [1]. In these experiments, tiny rock samples are melted into lava and exposed to a controlled atmosphere, allowing changes in both the lava and gas to be measured in detail. Because contact with a container could contaminate the lava and alter the measurements, the samples are suspended without touching any surface. The group's existing laser-heated aerodynamic levitation furnace makes these experiments possible [2].

LEViathan is a new acoustic levitator developed to enable similar lava experiments under elevated pressure. It is currently an unheated prototype: acoustic levitation of hot or molten rock has not yet been demonstrated. COMSOL Multiphysics® calculates its trapping force and investigates how a modelled hot-gas plume and increasing pressure affect the acoustic field. These simulations assess whether the concept could eventually operate under the required hot, pressurized conditions.

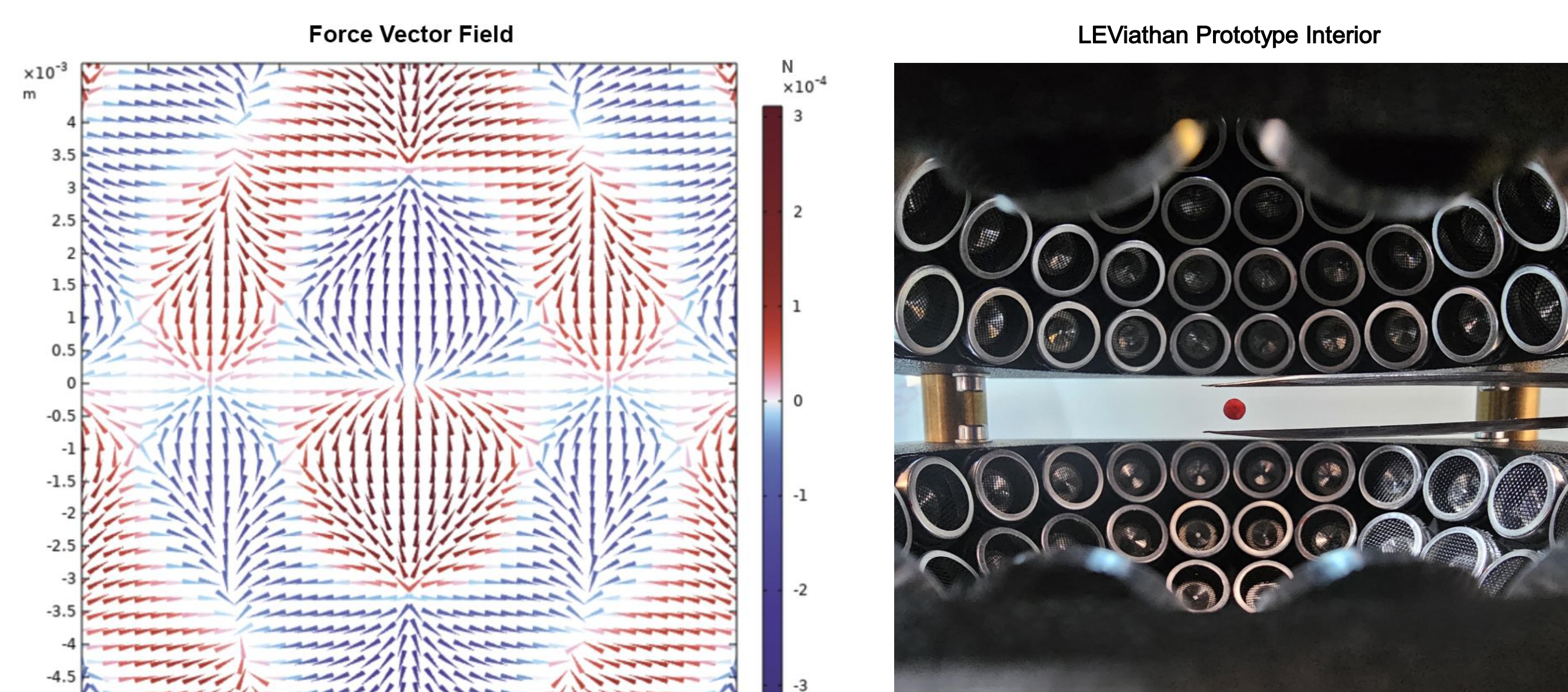


Figure 1. Left: simulated acoustic radiation-force vector field acting on a 2 mm diameter sphere. Right: assembled LEViathan, comprising 120 × 40 kHz transducers to levitate a sample, which has a maximum diameter of 5 mm.

Methodology

The acoustic field generated by LEViathan is modelled at 40 kHz using the Pressure Acoustics, Frequency Domain (acpr) interface in COMSOL Multiphysics®. The calculated pressure field is converted into the so-called Gor'kov potential U [3]. Its gradient gives the acoustic radiation force acting on a spherical particle, $F_{rad} = -\nabla U$, producing the force-vector map shown in Figure 1 and revealing the predicted trapping positions.

To model a laser-heated levitating sample, the Heat Transfer with Surface-to-Surface Radiation and the Nonisothermal Flow multiphysics interfaces are utilized, capturing conduction, convection, and blackbody radiation. The temperature field is linearly interpolated onto the acoustic mesh to define temperature-dependent gas properties, revealing plume-induced distortion of the sound field. Further simulations assess how gas pressure affects the trapping force.

Results

A laser-heated molten rock sample creates a hot plume that rises above it. To let this plume escape, thermal simulations determined that a 30 mm opening at the north pole is sufficiently large (Figure 2). Mapping the resulting temperature field onto the acoustic model showed that the plume acts as an acoustic lens, distorting the sound field. The central trapping region nevertheless remained stable while the plume rose vertically.

Simulations at higher ambient pressures showed that the acoustic radiation force rises almost linearly with pressure. The levitator is therefore predicted to operate more efficiently at higher pressure, which could partly compensate for heat-induced acoustic distortion. This assumes constant transducer output.

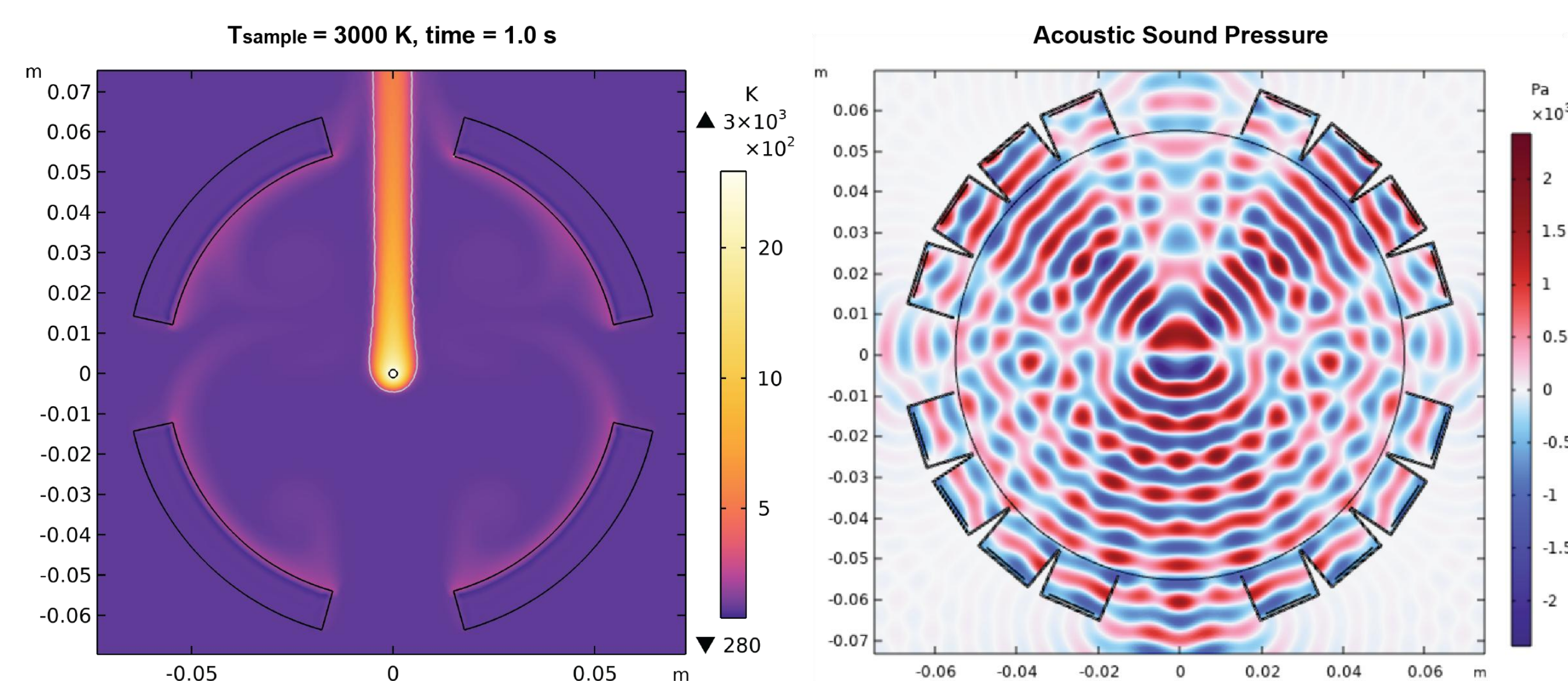


Figure 2. Left: simulated temperature field around a 2 mm diameter sample at 3000 K after 1 s. Right: acoustic pressure field recalculated using this temperature distribution to visualize acoustic lensing distortions.

REFERENCES

[1] ETH Zurich Experimental Planetology, "About the group." <https://planetology.ethz.ch/group.html>.

[2] Badro, J. et al., "Experimental investigation of elemental and isotopic evaporation processes by laser heating in an aerodynamic levitation furnace," *Comptes Rendus Géoscience* (2021). doi:10.5802/crgeos.56.

[3] L. P. Gor'kov, *Soviet Physics Doklady* 6, 773–775 (1962).