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Measurement of magnetic dynamics driven by heat flow in a plasma

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The role of magnetic fields in reducing heat flow in plasmas is well known, but less familiar is how heat flow also leads to substantial changes in the magnetic field through the Nernst effect. Steep temperature gradients perpendicular to a magnetic field lead to an induced electric field and advection of the magnetic field with a velocity proportional to the heat flow. In hot plasmas away from equilibrium, the Nernst effect is the dominant process affecting the magnetic field, but due to the complex coupling between heat and the field in laser-plasma interactions this effect is difficult to study.

By heating a gas jet with a nanosecond duration laser pulse within an applied magnetic field, we describe the first direct measurement of Nernst-driven cavitation in the magnetic field inside a plasma. We reconstruct the magnetic field map using proton radiography, and show that the heat flow causes rapid expulsion of the magnetic field from the hottest regions of the plasma, before hydrodynamic motion begins to play a role. This allows us to estimate the Nernst velocity as $(1.5 \pm 0.5) \times 10^6$ m/s at early times, with the heat flow reaching a substantial fraction of the free streaming limit. We can therefore explore at plasma densities from $10^{18} - 10^{19}$ cm^{-3} both how the heat flow advects the magnetic field, and how the magnetic field restricts the heat-flow.