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High Strain-rate Soft Material Characterization via Inertial Cavitation

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Abstract

Mechanical characterization of soft materials at high strain-rates is challenging due to their high compliance, slow wave speeds, and non-linear viscoelasticity. Yet, knowledge of their material behavior is paramount across a spectrum of biological and engineering applications from minimizing tissue damage in ultrasound and laser surgeries to diagnosing and mitigating impact injuries. To address this significant experimental hurdle and the need to accurately measure the viscoelastic properties of soft materials at high strain-rates (10^3 – 10^8 s^{-1}), we present a minimally invasive, local 3D microrheology technique based on inertial microcavitation. By combining high-speed time-lapse imaging with an appropriate theoretical cavitation framework, we demonstrate that this technique has the capability to accurately determine the general viscoelastic material properties of soft matter as compliant as a few kilopascals. Similar to commercial characterization algorithms, we provide the user with significant flexibility in evaluating several constitutive laws to determine the most appropriate physical model for the material under investigation. Given its straightforward implementation into most current microscopy setups, we anticipate that this technique can be easily adopted by anyone interested in characterizing soft material properties at high loading rates including hydrogels, tissues and various polymeric specimens.

Keywords: dynamics, viscoelastic material, mechanical testing, inertial cavitation, high strain rate

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