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Anomalous Damping in Coupled Torsion Pendula

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Abstract

We report an anomalous damping term in a pair of magnetically coupled torsion pendula that cannot be explained by eddy-current losses alone. The excess damping scales with the square of coupling strength rather than linearly, suggesting a parametric loss channel not captured by the standard coupled-oscillator model.

1 Introduction

Coupled torsion pendula are a standard testbed for precision measurements of weak forces, and their damping behaviour is normally well described by independent eddy-current losses in each pendulum plus a coupling-independent background. In the course of a routine calibration run, we observed a damping excess that grows with coupling strength in a way the standard model does not predict.

2 Apparatus

Two aluminium torsion pendula, each with a natural period of 4.2 s, were coupled via a pair of neodymium magnets mounted at matching radii on each pendulum's disk. Coupling strength was varied by adjusting the gap between the magnet pairs across seven settings, from 2 mm (strongest coupling) to 14 mm (weakest).

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3 Results

At each coupling setting, the free-decay envelope of both pendula was fitted to an exponential to extract a quality factor Q. The standard model predicts Q^{-1} should be independent of coupling strength, since eddy-current losses in each pendulum's aluminium disk do not depend on the neighbouring pendulum. Instead, we observe Q^{-1} growing approximately quadratically with the inverse of the magnet gap, i.e. with the square of coupling strength.

We considered three conventional explanations before concluding the loss channel is genuinely anomalous: (i) mutual eddy-current coupling between the two disks, which would predict a linear rather than quadratic scaling; (ii) mechanical crosstalk through the shared mounting frame, ruled out by repeating the measurement with the pendula on independent mounts; and (iii) air damping changes from the closer magnet proximity, ruled out by repeating in vacuum with no change to the scaling exponent.

4 Discussion

The quadratic scaling is consistent with a parametric loss mechanism in which the coupling itself modulates an internal degree of freedom in each magnet's mounting, rather than acting purely as a lossless torque coupling between the two pendula. We do not yet have a first-principles model for this channel, and flag it as an open question for follow-up work with magnet mounts of varying stiffness.