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Quantitative Assessment of Microphonic Effects on Signal Integrity in High-Q Experiments for Dark Sector Searches

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In the pursuit of dark sector phenomena, particularly in the ultralight regime, high-Q experiments offer promising enhancements to signal sensitivity under ideal conditions. However, these experiments also introduce complex challenges related to frequency matching and stabilization. One such challenge is the frequency deviation induced by microphonics, colloquially referred to as "jittering," which can occasionally exceed the Lorentzian linewidth, thereby compromising the experiment's integrity. In this work, we carry out the first study on these effects for dark sector searches, which paves the road for future works and improvements for our searches. Previous work, exemplified by the Dark SRF experiment, adopted a highly conservative approach in modeling microphonic effects, projecting a signal power reduction by a factor exceeding 10ˆ5. By contrast, our study employs a rigorous modeling methodology for microphonics and reveals a substantially lower signal penalty factor, on the order of 10ˆ1. We further demonstrate that this penalty factor is intricately dependent on both the system's characteristic jittering time and its damping factor. Our findings substantially revise the perceived impact of microphonics in high-Q experiments, providing compelling evidence for their reduced influence. This research serves as a critical foundation for the optimization of future high-Q experimental designs.

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