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High-resolution spatio-temporal strain imaging reveals loss mechanisms in surface acoustic wave device

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Surface acoustic wave (SAW) devices are key components for processing radio frequency signals in wireless communication, known for their high performance, compact size and low cost. A quantitative understanding of energy conversion and loss mechanisms is essential to improving device structures and materials. Using the 100 ps bunch length of The European Synchrotron ESRF, our stroboscopic full-field diffraction x-ray microscopy (s-FFDXM) studies of a prototypical one-port resonator device reveals multiple sources of acoustic loss. The exceptional strain sensitivity allows measurement of acoustic waves with picometer-scale amplitude. A difference in the apparent resonant frequencies observed in the x-ray and electrical measurements results from the spatial non-uniformity of the acoustic excitation and from substantial leakage out of the active area. The high-resolution spatiotemporal imaging demonstrated in this work is generally suited for studying nanophononics, specifically when the feature size is smaller than the optical wavelength. Applying s-FFDXM and an associated wave decomposition analysis method in combination, we achieve high-resolution spatiotemporal imaging of the acoustically induced strain waves. The method has a strain sensitivity of ~ 10−7, corresponding to a surface displacement on the order of 1 pm. Measurements on a prototypical one-port SAW resonator reveal multiple mechanisms of acoustic loss with distinct spatial and time dependencies. Specifically, the maximum acoustic energy in the cavity area was not observed at the intended resonance frequency despite a well-matched IDT period and a higher reflector efficiency. A substantial amount of acoustic energy was leaked to the side (22%) and through the reflector (13%), leading to a shift in the resonance frequency of −9 MHz.

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Dynamics of surfaces, interfaces, and nanostructures

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