Higher Order Harmonic Detection for Exploring Nonlinear Interactions with Nanoscale Resolution

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Abstract: Nonlinear dynamics underpin a vast array of physical phenomena ranging from interfacial motion to jamming transitions. In many cases, insight into the nonlinear behavior can be gleaned through exploration of higher order harmonics. Here, a method using band excitation scanning probe microscopy (SPM) to investigate higher order harmonics of the electromechanical response, with nanometer scale spatial resolution is presented. The technique is demonstrated by probing the first three harmonics of strain for a Pb(Zr1-xTix) O-3 (PZT) ferroelectric capacitor. It is shown that the second order harmonic response is correlated with the first harmonic response, whereas the third harmonic is not. Additionally, measurements of the second harmonic reveal significant deviations from Rayleigh-type models in the form of a much more complicated field dependence than is observed in the spatially averaged data. These results illustrate the versatility of nth order harmonic SPM detection methods in exploring nonlinear phenomena in nanoscale materials.