Lattice-induced nuclear excitation and coherent energy exchange in the Karabut experiment

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More than a decade ago Karabut reported the observation of collimated x-rays in experiments with a high-current glow discharge. At the time, Karabut attributed the effect to x-ray laser emission. From our perspective, the development of a population inversion in the keV regime under the conditions of the experiment is problematic.

We have been interested in coherent energy exchange between a highly-excited vibrational mode and nuclei for many years; such energy transfer would require that the large nuclear quantum be fractionated into a great many oscillator quanta for energy transfer from the nuclei; or massive multi-phonon up-conversion in the case of energy transfer from the oscillator to the nuclei. From the beginning when we first noticed the effect in the lossy spin-boson model more than a decade ago, our models have suggested that such an effect should be possible. In the case of nuclear excitation starting from a highly-excited vibrational mode, we might call the effect lattice-induced nuclear excitation.

The suggestion by one of our colleagues that a lattice-induced nuclear excitation is impossible prompted us to see whether we could design a system based on theory to demonstrate the effect. The design that emerged some years ago involved a sample with many square meters of area driven in the THz regime, which if it worked would produce collimated x-rays from ^{201}Hg near 1.5 keV. At some point we recognized that this is what Karabut's experiment did, and that somehow nature was managing to accomplish the conversion far more effectively than was done in our models. This prompted us to understand whether there might exist some stronger coupling than what we had assumed, which led us to the recognition of a direct coupling between vibrations and internal nuclear degrees of freedom in the relativistic version of the problem. Subsequently we have understood much better why, and under what conditions, these relativistic transitions might be accessible.

Last year we presented results from a model which we thought implemented these ideas. We found that the results seemed to be in agreement with experiment; unfortunately, we understood subsequently that the associated model was broken. At this point, we have developed a new formulation that fixes the errors in last year's version of the model. The issues and modelling are technically involved, and we have submitted abstracts for presentations that focus on the different parts individually.

In this presentation, we present a brief high-level overview of the approach and model, and then discuss results. The results are relevant to the Karabut experiment, and also to a new controlled version of the Karabut experiment that we hope to test later this year.