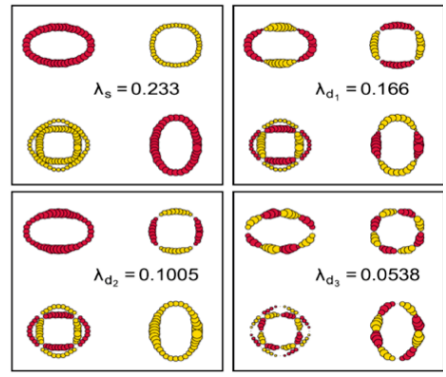
Theoretical foundation for probing the pairing mechanism in iron-based superconductors using Raman spectroscopy

Achievement: A general theory for the Raman response of multi-band systems is developed and used to identify new spectroscopic features in unconventional superconductors.

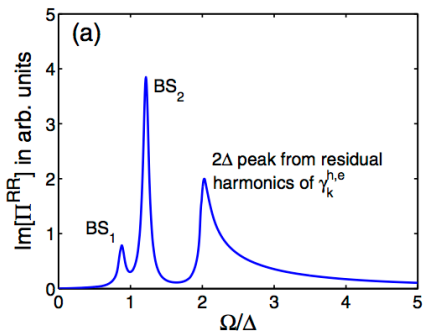
Significance and Impact: Work shows how Raman spectroscopy can identify multiple sub-leading pairing channels as collective modes in addition to the ground state.

Research Details:

- General microscopic theory is developed that identifies multiple collective modes in the Raman spectrum and connects their weights to sub-leading superconducting gap structures.
- Results are applied to interpret the Raman scattering response in hole doped $BaFe_2As_2$.



Leading s-wave (top left) and subleading d-wave gap structures calculated for hole doped $BaFe_2As_2$.



Calculated Raman response with multiple in-gap Bardasis-Schrieffer collective modes

Sponsor/Facility: This research was conducted at the Center for Nanophase Materials Sciences, which is a Department of Energy (DOE) Office of Science User Facility.

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Overview:

In unconventional superconductors, understanding the form of the pairing interaction that gives rise to superconductivity is the primary goal. In the iron-based superconductors, the pairing appears to be s-wave, with the order parameter changing sign between the electron and hole Fermi surface pockets. The nature of the interaction that gives rise to this gap structure, however, continues to be a matter of wide debate. Theoretical calculations based on spin fluctuation theory do indeed find an s-wave ground state and predict multiple subleading d-wave states that can be strongly competitive. From previous work of Bardasis and Schrieffer it is known that a subdominant d-wave pairing channel can lead to a collective excitonic mode, a Bardasis-Schrieffer mode, that consists of two quasiparticles in a Cooper pair d-wave state. The energy of this mode lays below the pair-breaking edge of the condensed s-wave system and can be detected in electronic Raman scattering. In this work, a theory of the Raman response was developed for systems like the iron-based superconductors, in which not one, but multiple pairing channels are sub-dominant. This theory identifies the signatures of multiple Bardasis-Schrieffer type collective modes and connects the weights of these modes to the subleading gap structures predicted by the calculations. This work thus delivers an important contribution for interpreting the Raman response of multi-band superconductiors, thereby establishing Raman spectroscopy as a unique and useful tool for probing the predictions of pairing theories.

In this regard, Raman spectroscopy is a very useful tool, as it identifies the ground state and also the subleading pairing channels by probing collective modes.