Master Thesis Proposal
Level attraction in metamaterials and mechanical system

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Coherent coupling between light and matter has been intensively studied in the past decades and generated an enormous number of applications. Level repulsion result from coherently coupled qubit-magnon system has been demonstrated can be used in quantum information procession [1]. Nevertheless, level attraction that given rise by dissipative coupling has been recently discovered experimentally in various systems [2–4]. The recent emergence of level attraction in different systems reveals its inherently nature in different coupled systems. For example, the optomechanic systems [2] and cavity-magnon systems [3–5]. Study on level attraction is the major topic in this master thesis.

There are two main parts in this master thesis. First is the study of level attraction in coupled metamaterials. Metamaterials has certain engineered structures and thus physical properties that are difficult to achieve in conventional, naturally occurring materials [6]. The level repulsion between metamaterials was firstly demonstrated experimentally in 2018 [7]. Here comes the question, can the level attraction be found in coupled metamaterials? By using a cross shape stub microstrip resonator and a split ring resonator (SRR), the level attraction was observed in frequency domain while these two structure was placed near each other. Furthermore, a tunable resonant frequency SRR was fabricated by integrating a voltage controlled varactor diode to realize a continuous adjustable system. The dispersion shows an attraction behavior and it is continuous tunable by external applied voltage. The advantage of this system is that it does not involve large device such as electron magnet and it is easy to fabricate and integrate to on-chip device which provides the opportunity for further application.

Studying the level attraction in coupled mechanical oscillators is another proposed work in this master research. By building mechanical oscillators, the level attraction can be realized and studied in time domain. Two possible approach can be taken experimentally. One is using a dashpot instead of a spring for coupling device. The relative velocity instead relative position of the oscillator would be dominate in the coupling mechanics. The velocity difference would generate force based on the liquid pressure in the dashpot. Another approach is using a conductive oscillator and a magnetic oscillator, the relative velocity induces change of magnetic flux and therefore would produce an eddy current based on Lenz effect. The challenge of this approach is to generate a effective large eddy current and also let the linear coupling term be dominate in the interaction. Theoretically, this would produce a level attraction in frequency domain. This work could expand the boarder of the level attraction to mechanical system.

There are different theory models that can explain the level attraction such as oscillator model and RLC model [4]. The coupled mechanical oscillator is modeled by introducing a damper in the equation of motion while coupled RLC circuits are modeled by mutual resistance between two systems. Exploring the physical meaning and provide trustworthy explanation on this result are also a target in this Master work.

Reference

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