Frequency Tunable Coherent Perfect Absorption and Lasing in Radio-frequency System for Ultrahigh-sensitive Sensing

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Abstract— The CPAL (coherent perfect absorption-lasing) point is a singular point in non-Hermitian physics [1]. By modulating the amplitude and phase of the signals at the two input ports, the CPAL system can attain a coherent perfect absorption state and a lasing state at the designated frequency, with a theoretical infinite output amplitude. This has been harnessed for various applications [2]. However, practical implementation of CPAL systems faces extreme challenges because of the deviations of electronic components from ideal values, which makes it difficult to attain the designated CPAL state. Recent researches showed that signal amplitudes are normally smaller than 30 dB [3], a value considerably lower than the ideal theoretical values, which adversely impacts system performance, particularly in the field of ultra-sensitive sensing. Moreover, amplitude-based output is prone to interference from noise or environmental factors, making it less reliable for applications compared to frequency shift-based sensing.

In this study, we explore the effects of component deviations on general CPAL systems and introduce an eigenstate tuning method specifically designed for radio-frequency (RF) CPAL systems. This approach facilitates the realization of CPAL states at any desired frequency with dynamic ranges of signal amplitudes exceeding 60 dB experimentally or operating at a frequency shift-based sensing mode [4].

Furthermore, we examine the sensing principles of the RF CPAL system from three perspectives: sensing eigenstate, sensor location and configuration in the system, and operating frequency. Subsequently, a CPAL-based RF sensor system is developed for validation, exhibiting an ultrahigh sensitivity of 1.9 dB/10fF by measuring output coefficient variation or 9.4 MHz/pF by assessing frequency shift.

Building upon the aforementioned research findings, we proceed to incorporate a phase shifter (between the positive and negative resistor) on one side of the transmission line to establish a phase-adjustable transmission line. This enables control of the CPAL operating frequency and results in a broadband adjustable RF CPAL system. These outcomes would significantly expand the potential applications of CPAL systems. Details will be reported at the conference.

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