

Level attraction and idler resonance in a strongly driven Josephson cavity

Quantum circuits offer a plethora of new phenomena, and their versatility could set the steppingstone for the technologies of the future. In a recent work published in Physical Review Research, researchers from the Steele Lab, at the Quantum Nanoscience department of the TU Delft, present their results on the study of Josephson cavities, showing new phenomena that has not been observed before.

What is a Josephson cavity? We can first consider an optical cavity, a *box* containing electromagnetic waves reflecting back and forth. If we send a beam of light to this cavity the outcome will strongly depend on the frequency of the incoming pulse. At a certain frequency called the resonance frequency, the energy of the incoming light will be stored. It turns out that this type of behaviour is not restricted to optical cavities, electronic circuits can also act as resonators and are widely used as selectors of frequency and amplifiers.

On the other hand, a Josephson Junction is a device which consists of two superconducting parts separated by a thin insulating layer. If we connect two Josephson Junctions in parallel, we will get a SQUID, one of the most sensitive devices we can make. Implementing one of these SQUIDs in a certain way we can create a quantum circuit that acts as a resonator: a Josephson Cavity. In their experiments Steele and collaborators send two pulses to such a circuit and study the different regimes that appear. They send two pulses: a pump pulse (first) and a probe pulse (second).

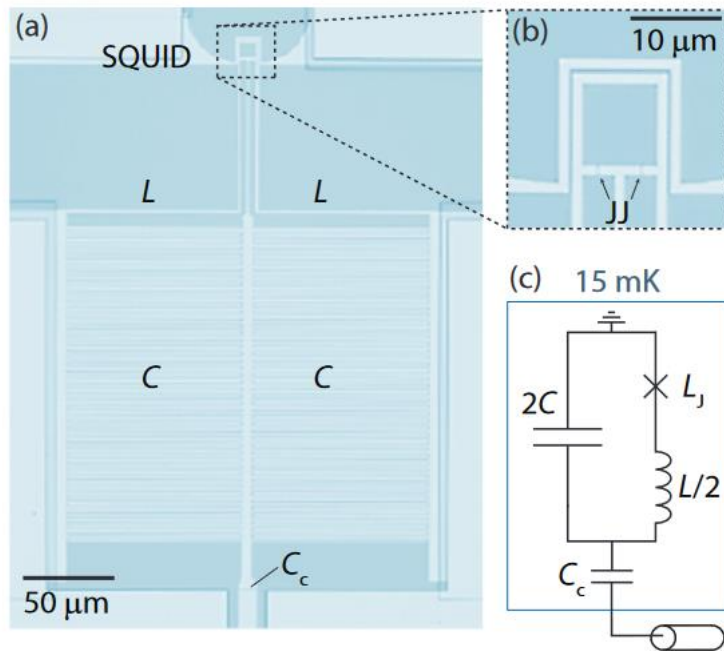
The first thing they find is that sending a pump pulse whose frequency is slightly above the resonance of the cavity shifts the resonance of the cavity. This is analogous to the Stark effect, a phenomenon from atomic physics! In a second experiment they send the pump pulse now with a frequency that is below the resonance of the cavity, and they find that the behaviour is completely different!

When the power of the pump pulse is low, the frequency of the cavity changes, but now it approaches the pump frequency. The unexpected thing occurs when they hit a certain power: the resonance of the frequency abruptly jumps to a value which is below to the pump frequency! This is accompanied by another striking feature: the appearance of a new mode. If we change the frequency of the probe laser to higher frequencies the pulse will be amplified! For the same pump power, we have **two coexisting and symmetric modes**: absorbing and amplifying. This second mode is called the **Idler mode**, and this is the first time that such behaviour is observed in quantum circuits. These experiments show that Josephson cavities have a bifurcation point, a regime in which we can have two modes coexisting for the same conditions. Moreover, for certain conditions their frequencies are the same. This is called **Level attraction**, a phenomenon that had never been observed in quantum circuits. In this regime the two modes overlap, defining an **instability point in which the cavity is extremely sensitive to noise**.

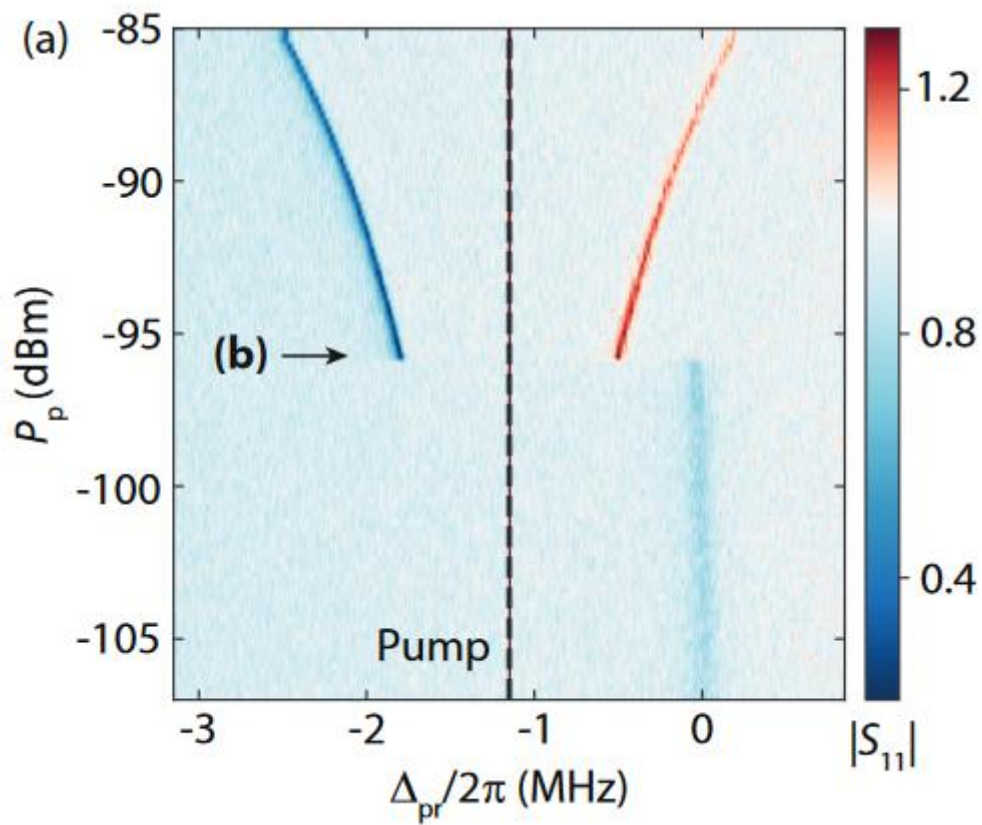
This paper serves as a starting point for exploring new phenomena in this type of cavities, which can be useful for the development of new technologies related to quantum computing or new ways to manipulate signals. You can read the original work *Level attraction and idler resonance in a strongly driven Josephson cavity* from Physical Review Research:

<https://doi.org/10.1103/PhysRevResearch.3.043111>

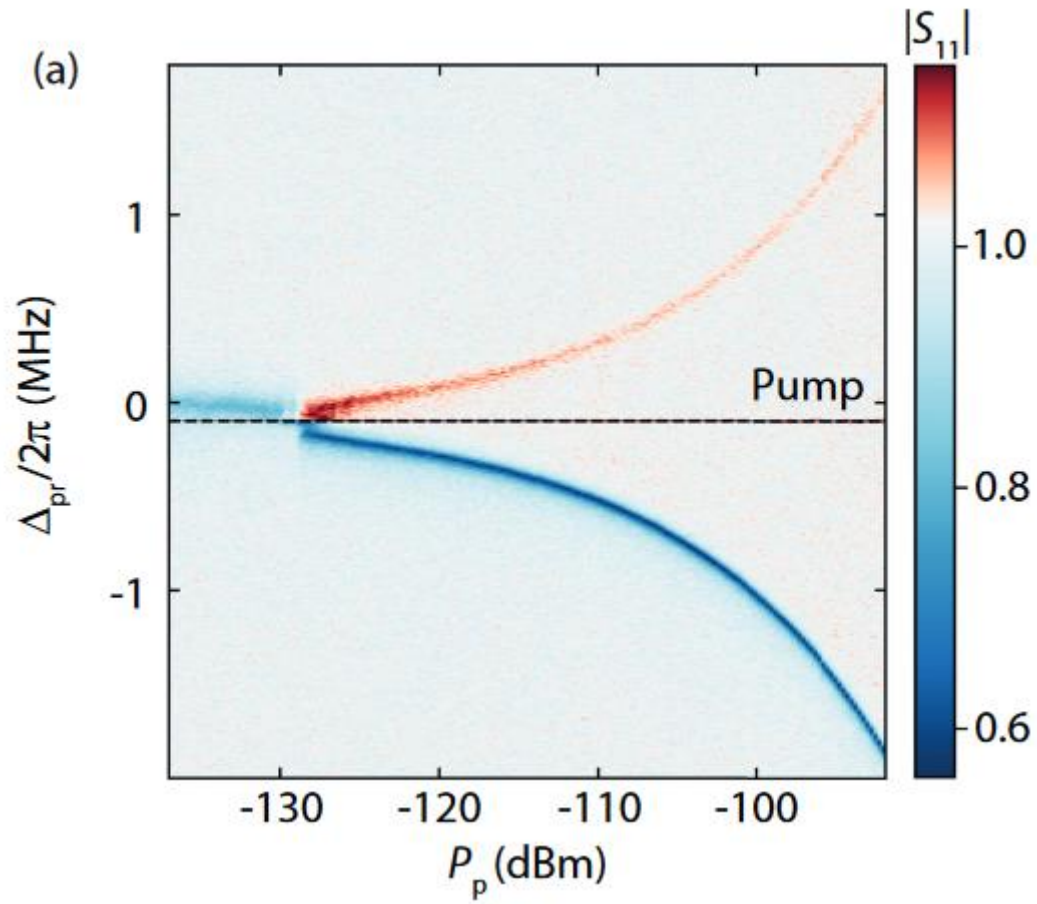
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Quantum Circuit used by researchers [1].



Bistability regime in a Quantum Circuit.[1]



Level attraction. [1]

[1] *Level attraction and idler resonance in a strongly driven Josephson cavity*, Physical Review Research, <https://doi.org/10.1103/PhysRevResearch.3.043111>