Coupling between two singing wineglasses

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Coupling between two singing wineglasses was obtained and investigated. Rubbing the rim of one wineglass produce a tone and due to the coupling induces oscillations on the other wineglasses. The needed coupling strength between the wineglasses to induce oscillations as a function of the detuning was investigated.

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A wineglass can be made to "sing" by gently rubbing its rim with a moist finger. The friction between the finger and the rim of the wineglass causes the wineglass to oscillate, to produce a loud, pure tone [1]. The frequency of the oscillations depends on the volume of liquid inside the wineglass, whereby adding liquid increases the fluid pressure that retards the wineglass vibration so as to lower the frequency [2]-[3].

Here we investigate how two singing wineglasses can be coupled to each other. Specifically, we show that when the natural oscillating frequency of each wineglass is comparable to each other, it is relatively easy to induce oscillations of the same frequency and phase from one wineglass to the other. However, when their natural oscillation frequencies differ, it is more difficult to induce the oscillations, if at all. Such coupling plays an important role in many ensembles such as coupled bubbles [4], coupled lasers [5], etc.

The experimental arrangement is schematically shown in Fig. 1. Two wineglasses were submerged in a water container, and the oscillating frequency of each wineglass was obtained by illuminating them with laser beams derived from a HeNe laser and detecting the reflected light. In this arrangement the ease of introducing oscillations from one wineglass to the other, i.e, the coupling strength between the wineglasses depends on the distance between them, on the water level in the container and on the difference between the natural oscillation frequencies of the wineglasses (detuning).

We began our experiments by measuring the natural frequency of each wineglass as a function of volume of water inside them. We found, as expected, that the natural oscillating frequency decreases from 700HZ to 450HZ as the volume of water inside them increases. Then, we investigated the behavior and content of the induced oscillations as compared to the detuning oscillations, when the water level inside each was the same as the other. This was done by rubbing the rim of only one wineglass to produce a natural oscillation frequency with a certain amplitude and measuring the amplitude of the oscillation frequency that is induced in the other wineglass. The coupling strength between the wineglasses corresponds to the ratio of amplitudes of the oscillation frequencies. A representative example of the oscillation frequencies, amplitudes and phases for the rubbed wineglass (driving wineglass) and the unrubbed wineglass (driven wineglass) is shown in Fig 2. As evident, the frequencies and phase of both the driving and induced oscillations are essentially identical. Clearly indicating that frequency locking and phase locking accrue.

In order to determine the influence of distance between wineglasses and detuning, we repeated the measurement

FIG. 1: Experimental arrangement for investigating the coupling between two wineglasses.

FIG. 2: Oscillation frequencies and amplitudes for two coupled wineglasses. Dashed curves denote the driving wineglass and solid curves the driven. The level of the water in the container was 13cm. The distance between the wineglasses was 5mm.
above at different distances and different detuning conditions. The results are presented in Figs. 3, 4. Figure 3 shows the coupling strength as a function of distance between the wineglasses, for different levels of water in the container. As evident, the coupling strength decreases significantly as the distance between the wineglasses increases. On the other hand, the influence of water levels of water in the container is not significant.

![FIG. 3: Coupling strength between two wineglasses as a function of the distance between them.](image)

Figure 4 shows the coupling as a function of the detuning between them, for a certain level of water in the container (13cm) and a certain distance between the wineglasses (25mm). The detuning was achieved by simply varying the volume of water inside one of the wineglasses. As evident, the induced frequency amplitude decreases as the detuning is increased. There is a point of critical detuning which indicates that induced oscillations can no longer be achieved in the driven wineglasses at a certain coupling strength.

![FIG. 4: Ratio of amplitudes of the two wineglasses’ oscillations as a function of detuning between them. The distance between the wineglasses was 25mm, and the water level in the container was 12cm.](image)

Finally, Fig. 5 shows the critical detuning as a function of coupling strength, for different levels of water in the container. As evident, when the coupling strength which induce oscillations in the driven wineglass increases, the critical detuning increases as well. Also, when the level of water in the contained increases the slopes of the curves increase, probably due to changes in the damping strength which depend on the water level in the container.

![FIG. 5: Critical detuning as a function of coupling strength for different water levels in the container.](image)

To conclude, the critical detuning of two wineglasses is directly related to the coupling strength between them and vice versa. For higher coupling strength the critical detuning is higher. For large detuning, it is necessary to increase the coupling strength in order to ensure that induced oscillations will accrue in the driven wineglass.

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