Simulation Results for Dyakonov-Shur Instability in the Corbino Geometry

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1 Momentum Relaxation

1.1 Results

First, I explored the effect of the momentum-relaxing term. Reference [1] finds that, for $\eta = 0$, the instability *cannot persist past a certain critical value of* γ.

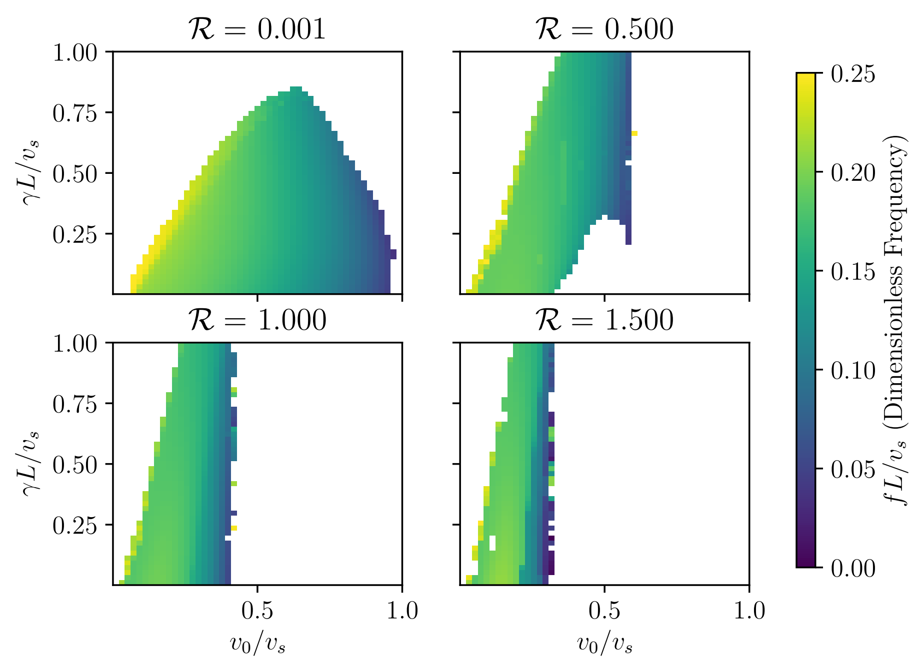

Figure 1: Dependence of the emitted frequency f on the bias current v_0 and the relaxation rate γ. The different panes correspond to different values of $\mathcal{R} \equiv L/a$. For these simulations, $\tilde{\eta} = 0.001$. The colour white means the instability does not exist.

The first panel of Fig. (1) makes that property clear — once the dimensionless $\tilde{\gamma} = \gamma L/v_s$ reaches a value just around 0.75, we observe no instability for any value of the bias current v_0. But, as we increase $\mathcal{R} = L/a$ through $\mathcal{R} \to 0$ to $\mathcal{R} = 1.5$, the critical value of γ increases. That means that there is a narrow window of bias currents — it looks like around $\tilde{v_0} = 0.0 - 0.4$ — where the instability can persist to higher γs than it could in the linear geometry.

Fig. (1) has a few issues that I am still investigating. One is the 'noise' that appears around the edges of the unstable region, especially in the last two panels. I am still working on finding a way to more accurately measure the frequency — my current method is getting confused by some other features in the oscillator. Another is that an average of five of the 2500 simulations failed for each plot, and I have not had a chance to re-run them yet, so they show up as white 'holes" in the graph.

I also plotted snapshots to illustrate the dynamics of the momentum and density over one period of the oscillator. Those are given in Fig.(2).

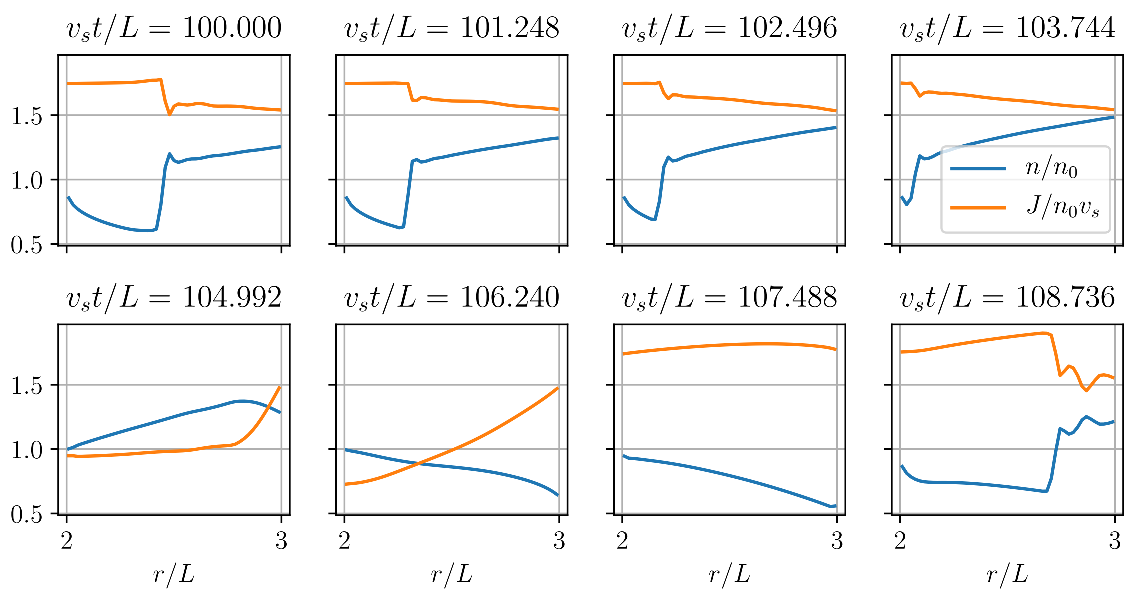

Figure 2: For $\mathcal{R} = 1.5$ and $\tilde{v_0} = 0.5$, $\tilde{\gamma} = 0.5$, snapshots of n and J over the period of the oscillator.

1.2 Comparison to Linear Theory

The results of Fig.(1) has some similarities and some differences with the linear theory, and these are summarized in Fig.(**??**).

The slope of the leftmost edge agrees with the numerics in each plot, but the linear theory fails to predict the disappearance of the instability as v_0 is increased to the right, and it also predicts a much less steep decrease in the frequency with v_0. That is to be expected because according to the analytic expression, the dependence on v_0 is second order in v_0, at least.

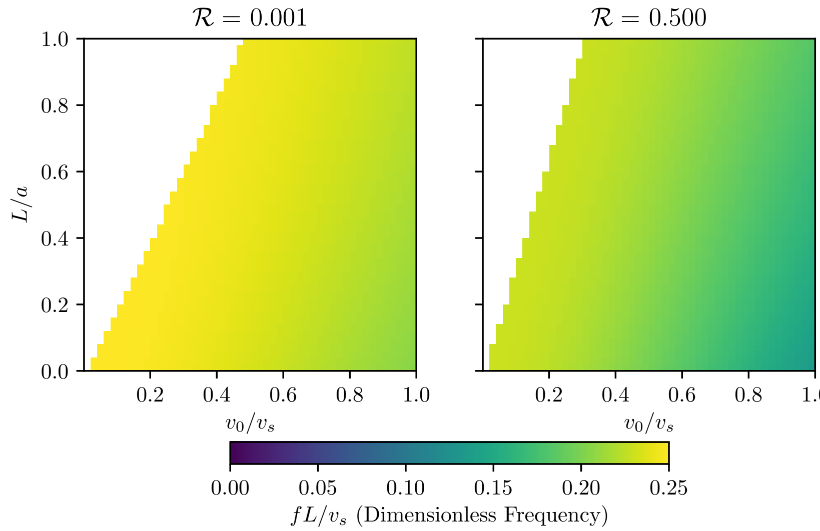

Figure 3: Results using the linearized equations at the same values as the first two panels of Fig. (1).

2 Viscosity

I also explored the effect of the viscous term. The simulations here were run at $\tilde{\gamma} = 0.100$, a value estimated by reference [1] when the channel has length $L \equiv b - a = 1.0\ \mu$m.

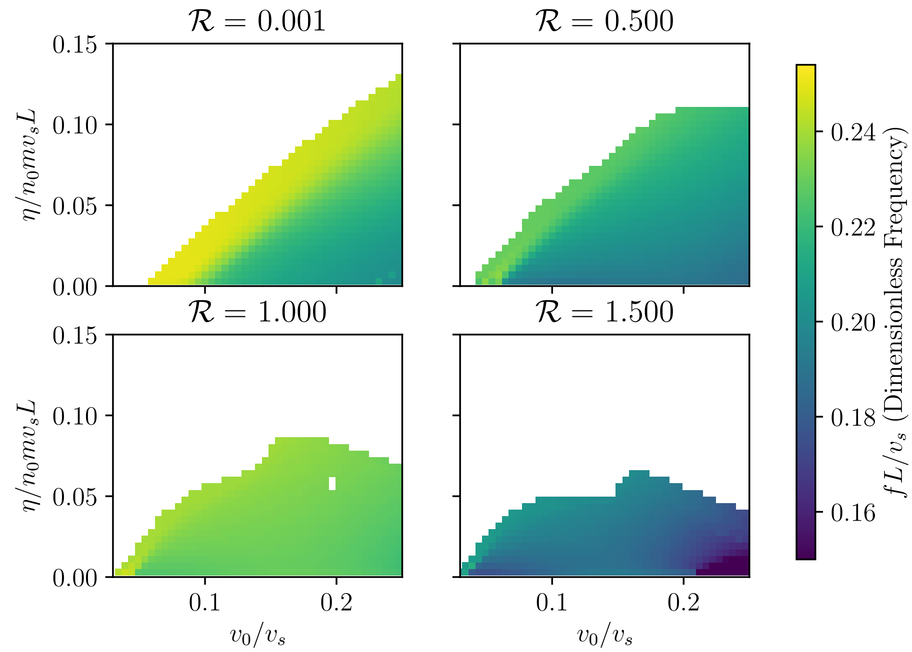

Figure 4: At $\tilde{\gamma} = 0.100$, the dependence of the emitted frequency on v_0 and eta. The colour white means the instability does not exist.

The plot in the first panel of Fig. (4) is close to the one from Fig. 4 of [1]. Increasing $\mathcal{R}$ in the other panels, we notice a quick decrease in the frequency. But the stable region also shifts slightly to the 'left' — this is clear looking at the $\mathcal{R} = 0.005$ panel compared to the $\mathcal{R} = 0.001$ panel. In the third panel, the region translates further to the left, but another effect becomes more clear as well — the instability disappears for higher v_0 if η is too large.

These plots still have the same problems as those in Section 1, namely, trouble calculating the frequencies and telling exactly where the instability disappears, and also some failed simulations resulting in missing values. So I still need to rerun these.

3 Radius

I also wanted to see how the instability depends of v_0 and $\mathcal{R}$ exactly — can you decrease v_0 arbitrarily and still observe emitted radiation? That is summarized in Fig. (5).

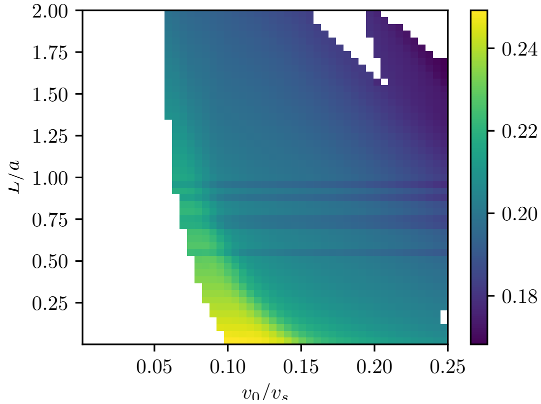

Figure 5: Dependence of the frequency on $\mathcal{R}$ and v_0 at $\tilde{\eta} = 0.03$ and $\tilde{\gamma} = 0.100$

References

[1] Christian B. Mendl, Marco Polini, and Andrew Lucas. Coherent Terahertz Radiation from a Nonlinear Oscillator of Viscous Electrons. sep 2019.