Negative currents in Fabry-Pérot cavities are caused by interfering paths

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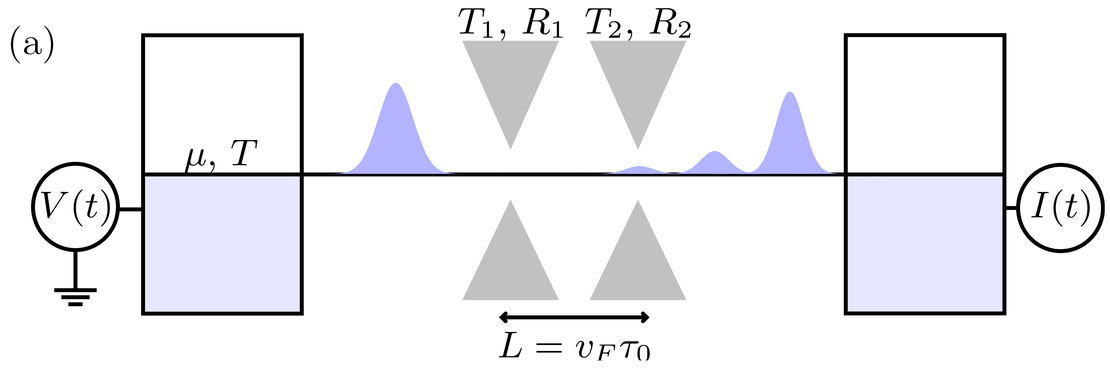
The time-dependent electric current in a Fabry-Pérot cavity can turn negative even if the time-dependent voltage is always positive [1]. Here we present an analytic theory of this surprising phenomenon, showing that it is a purely quantum mechanical effect [2]. It only occurs at low temperatures, and it is caused by interferences between paths through the cavity with different numbers of round trips.

➢Fabry-Pérot Cavity

An electronic Fabry-Perot cavity made up of two quantum point contacts that are separated by the distance L. A time-dependent voltage is applied to one of the electrodes.



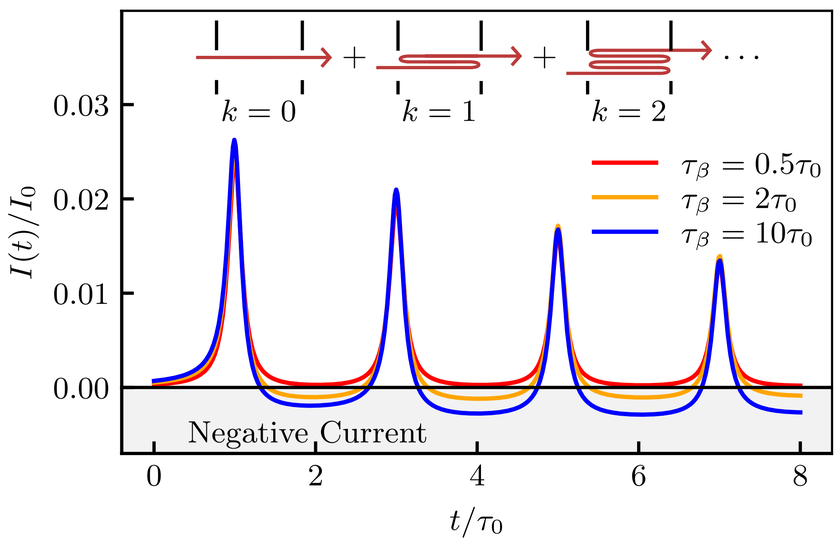
➢Theory and Results

We use Floquet scattering theory to calculate time-dependent electric and heat currents. Total transmission amplitude of the set-up is

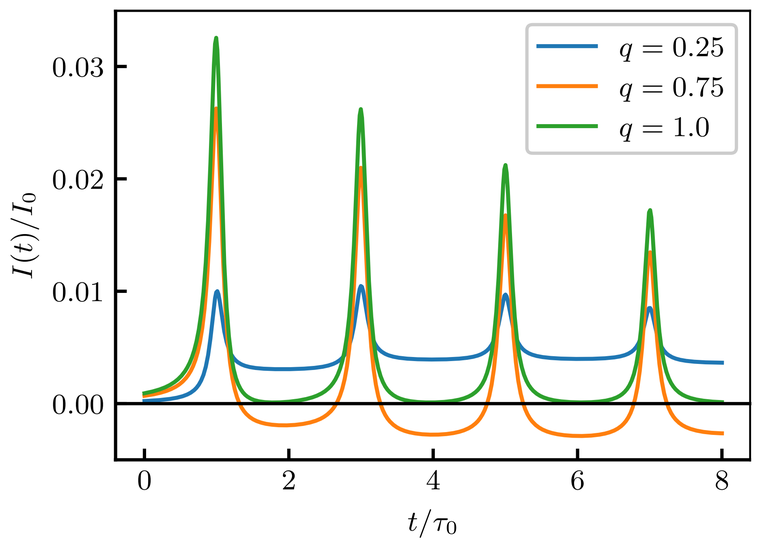
$$t(E) = t_1 t_2 exp\left(\frac{iE\tau_0}{\hbar}\right)\sum_{k=0}\left[r_1 r_2\, exp\left(i\left(\frac{2E\tau_0}{\hbar}\right)\right)\right]^k$$

Electric current for an arbitrary voltage, $V(t)$, is given by

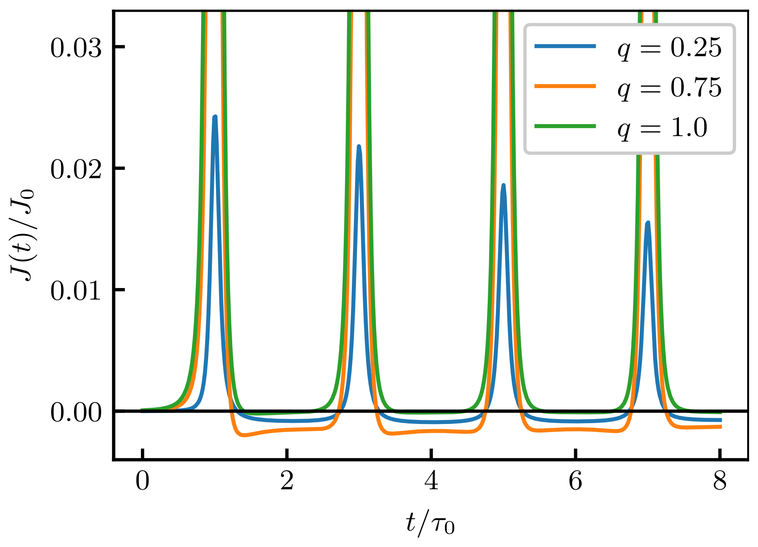
$$I(t) = T_1 T_2 \sum_{k=0}^{\infty}(R_1R_2)^k\{V(t-\tau_k) + 2\sum_{k=1}^{\infty}(r_1\, r_2)^l \chi(\tau_{l-\frac{1}{2}}/\tau_\beta)\Re[G^1(t-\tau_k, t-\tau_{k+l})]$$



- Electric current for Lorentzian voltage pulse at different temperatures, charge, q = 0.75



- Electric current for different charges



- Heat current for different charges

➢ Conclusions

- We have presented an analytic theory of negative currents in Fabry-Pérot cavities, showing that they are rooted in interfering scattering paths through the device with different numbers of round trips.
- Our work also has implications for the field of quantum thermodynamics regarding the currents that flow and the work that is performed because of an external driving field

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References

[1] B. Gaury and X. Waintal, Dynamical control of interference using voltage pulses in the quantum regime, Nat. Commun. **5**, 3844 (2014).
[2] M. Saha, L. Horray, P. Portugal, C. Flindt, Phys. Rev. B 112 (8), L081408 (2025), *Editors' Suggestion*