
**Fano Resonances**

Fano resonances arise in transmission if there is
- a single resonant term
- an additional approximately constant background \( I_0 \)

Examples: neutron scattering, dissipation spectra, quantum dots

Transmission amplitude:
\[
|t(k)|^2 = \frac{\Gamma/2}{k^2 - k_0^2 + i\eta^2} + I_0
\]

Fano profile:
\[
|t(k)|^2 = |\beta| \frac{|q|}{\pi} \frac{1}{\pi + 1} \quad \text{with} \quad q = i + \frac{z}{\eta}
\]

- \( \epsilon = (k - k_0)^2/(\Gamma/2) \): rescaled wavenumber
- \( q \): Fano parameter describes the asymmetry of the resonance
- \( q = 0 \) \( \Rightarrow \) window or “anti-resonance”
- \( q = \pm \infty \) \( \Rightarrow \) Breit-Wigner resonance

**Microwave Experiments - Quantum Mechanics**

From Maxwell’s equation for microwave resonators with parallel bottom and top plate we obtain the two-dimensional Helmholtz-equation for the z-component of the electrical field \( E_z(x, y) \):
\[
\left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) E_z(x, y) = -k^2 E_z(x, y),
\]

There exists a full correspondence between Eq. (1) with the two-dimensional Schrödinger-equation
\[
\frac{\hbar^2}{2m} \left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \psi(x, y) = E \psi(x, y)
\]

if we identify
\[
\psi = E_z, \quad E \equiv k^2, \quad \frac{\hbar^2}{2m} = \frac{q}{\pi}
\]

**Model for Dissipation**

Dissipation is modelled by many, weakly attached channels, where the flux leaves the cavity.

Effective description by
\[
k \rightarrow k + i \epsilon
\]

- \( \psi(q) = i + \frac{z}{\eta} \)
- \( \chi = \frac{\Gamma_0}{\Gamma + 2\epsilon} \): measure for the dissipation strength
- \( q \): Fano parameter for the system without dissipation
- \( q(q) \): straight line from \( q_0 \) to \( i \)

**Model for Dephasing**

Dephasing is modelled by attached phase breaking channels where the flux into the channel is re-injected with an arbitrary phase.

Also dephasing leads to a complex Fano parameter, but with a circular dependence on the dephasing strength \( \chi \)
\[
\psi(q) \propto \chi = \frac{\Gamma_0}{\Gamma + 2\epsilon}, \quad \text{measure for the dephasing strength}
\]

**Experimental and Numerical Results**

- Three different cavities: copper, brass, and steel (same size as cavity shown above)
- Two temperatures: room temperature and liquid nitrogen
- Shutter opening: \( d = 7.8 \) mm

**Scaling for Dephasing**

- Measurements in microwave transmission fitted with Fano lineshape
- Fano parameter extracted for resonances with different material parameters and temperatures
- Parameters reduced to \( q_0 = 1 \)
- Symbols for the same resonances are connected (empty/filled symbols stand for nitrogen/room temperature)
- Linear scaling behavior is successfully reproduced

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**Probing decoherence through Fano resonances**


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