REP

$$Z = Z_0 + Z_1 e^{ix}$$
$$Z = Z_0 + Z_+ e^{+ix} + Z_- e^{-ix}$$
$$\langle n^k \rangle = (-i\partial_z)^k \, \mu(z,t)|_{z=0}$$

$$\mu(z,t) = \mathrm{Tr}\{\underbrace{\rho(z,t)}_{e^{Z(z)\cdot t}\rho_0}\}$$

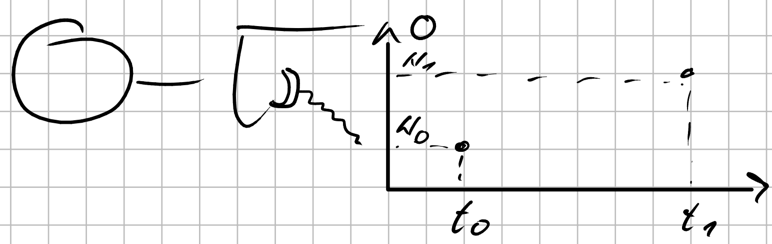
- $C(z,t) = \ln \mu(z,t) \xrightarrow{t\to\infty} \lambda_{dom}(x)\cdot t$
- $I(t) = -i\,\mathrm{Tr}\{Z'(0)\rho(t)\}$

$$\lim_{\varepsilon\to 0} \frac{\lambda(+\varepsilon)-\lambda(-\varepsilon)}{2\varepsilon}$$

3.2. Mikroskop. Ableitung

3.2.1. Zweipunkt-Messung

$$\hat{O} = \sum_\ell O_\ell |\ell\rangle\langle\ell| \qquad [\hat{O}, H_B] = 0$$



$$\bar{\bar{\rho}}_B = \sum_\ell |\ell\rangle\langle\ell|\bar{\rho}_B|\ell\rangle\langle\ell| \to \bar{\rho}_B$$

$$\bar{\rho}_B \xrightarrow{\ell} \frac{|\ell\rangle\langle\ell|\bar{\rho}_B|\ell\rangle\langle\ell|}{P_\ell} = \frac{\rho_B^{(\ell)}}{P_\ell}$$

Mittelung   Differenz

$$\mu(z,t) = \sum_\ell \mathrm{Tr}\{e^{iz(\hat{O}-O_\ell)} \underbrace{u(t)\,\rho_S^0\otimes\bar{\rho}_B^{(\ell)}\,u^+(t)}_{\rho(t)}\}$$
$$= \sum_\ell \mathrm{Tr}\{e^{-iz\hat{O}/2} u(t) e^{-izO_\ell/2} \rho_S^0\otimes\rho_B^\ell e^{-izO_\ell/2} u^+ e^{+iz\hat{O}/2}\}$$
$$= \mathrm{Tr}\{\underbrace{e^{+iz\hat{O}/2} u(t) e^{-iz\hat{O}/2}} \rho_S^0\otimes\bar{\bar{\rho}}_B e^{-iz\hat{O}/2} u^+ e^{+iz\hat{O}/2}\}$$
$$= \mathrm{Tr}\{ u_{z/2}(t)\, \rho_S^0\otimes\bar{\bar{\rho}}_B\, u^+_{-z/2}(t)\} = \mathrm{Tr}\{\rho(z,t)\}$$

$$\frac{d}{dt} u_{z/2}(t) = H_I\left(\frac{z}{2},t\right)\cdot u_{z/2}(t)\cdot(-i)$$

$$H_I(z/2,t) = \sum_\alpha S_\alpha(t)\otimes e^{+iz\hat{O}/2} \tilde{B}_\alpha e^{-iz\hat{O}/2}$$

• alles von links

$$\mathrm{Tr}\{\cancel{e^{+i\tau\hat{O}/2}}\hat{B}_\alpha(t_1)\cancel{e^{-i\tau\hat{O}/2}}\,\cancel{e^{+i\hat{O}\tau/2}}\hat{B}_\beta(t_2)\cancel{e^{-i\hat{O}\tau/2}}\bar{\bar{\rho}}_B\} \to C_{\alpha\beta}(t_1-t_2)$$

• analog: alles von rechts $\longrightarrow C_{\alpha\beta}(t_1-t_2)$

• jetzt: ρ mittig

$$\boxed{\begin{aligned} C^\tau_{\alpha\beta}(t_1-t_2) &= \mathrm{Tr}\{e^{-i\hat{O}\tau}\hat{B}_\alpha(t_1-t_2)e^{+i\hat{O}\tau}B_\beta\bar{\bar{\rho}}_B\} \\ \gamma^\tau_{\alpha\beta}(\omega) &= \int C^\tau_{\alpha\beta}(\tau)e^{+i\omega\tau}d\tau \end{aligned}}$$

$$\dot{\rho} = -i[H_S+\sum_{ab}\bar{E}_{ab}L_{ab},\rho] + \sum_{ab,cd}[\gamma^\tau_{ab,cd}L_{ab}\rho L^\dagger_{cd} - \tfrac{1}{2}\gamma^0_{ab,cd}\{L^\dagger_{cd}L_{ab},\rho\}]$$

"tilted" / "generalized" Liouvillian

$$\gamma^\tau_{ab,cd} = \sum_{\alpha\beta}\gamma^\tau_{\alpha\beta}(E_b-E_a)\delta_{E_b-E_a,E_d-E_c}\langle a|A_\beta|b\rangle\langle c|A^\dagger_\alpha|d\rangle^*$$

falls $\hat{O}=H_B$:

$$C^\tau_{\alpha\beta}(\tau) = C_{\alpha\beta}(\tau-\tau)$$

$$\gamma^\tau_{\alpha\beta}(\omega) = e^{i\omega\tau}\gamma_{\alpha\beta}(\omega)$$

3.2.2. Transienter SRL Energiestrom

$$H = \varepsilon d^\dagger d + \underbrace{d}_{S_1}\otimes\underbrace{\sum_k t_k c_k^\dagger}_{B_1} + \underbrace{d^\dagger}_{S_2}\otimes\underbrace{\sum_k t_k^* c_k}_{B_2} + \sum_k \varepsilon_k c_k^\dagger c_k$$

$$\hat{O} = H_B \qquad \bar{\bar{\rho}}_B = \bar{\rho}_B$$

$$C^\tau_{12}(\tau) = \mathrm{Tr}\{\sum_k t_k c_k^\dagger e^{i\varepsilon_k(\tau-\tau)}\sum_q c_q t_q^*\bar{\rho}_B\}$$

$$= \sum_k |t_k|^2 f(\varepsilon_k)e^{i\varepsilon_k(\tau-\tau)} = \frac{1}{2\pi}\int\Gamma(\omega)f(\omega)e^{i\omega\tau}e^{-i\omega\tau}d\omega$$

$$\Rightarrow \gamma^\tau_{12}(\omega) = e^{+i\omega\tau}\cdot\Gamma(-\omega)\cdot f(-\omega)$$

$$\gamma^\tau_{21}(\omega) = e^{+i\omega\tau}\Gamma(\omega)[1-f(\omega)]$$

$$\gamma^z_{ab,ab} = \sum_{\alpha\beta} \gamma^z_{\alpha\beta}(E_b - E_a)\langle a|S_\beta|b\rangle\langle a|S_\alpha^\dagger|b\rangle^*$$

$$\gamma^z_{01,01} = \gamma^z_{21}(+\varepsilon) = \Gamma(\varepsilon)[1-f(\varepsilon)]\,e^{+i\varepsilon z}$$
$$\gamma^z_{10,10} = \gamma^z_{12}(-\varepsilon) = \Gamma(\varepsilon)\cdot f(\varepsilon)\,e^{-i\varepsilon z}$$

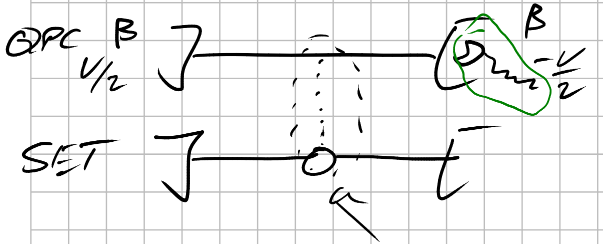
$$\mathcal{L}(z) = \Gamma(\varepsilon)\begin{pmatrix} -f(\varepsilon) & +[1-f(\varepsilon)]e^{+i\varepsilon z} \\ f(\varepsilon)e^{-i\varepsilon z} & -[1-f(\varepsilon)] \end{pmatrix}$$

$$\dot{P}_n = \sum_m W_{nm} P_m - \sum_m W_{mn} P_n$$

E_n $\quad M_n$

Konvention $\rightarrow e^{\pm iz(E_n - E_m)}$

3.2.3. SET gemessen von QPC



$$H_{QPC} = \sum_n \varepsilon_{nL}\gamma^\dagger_{nL}\gamma_{nL} + \sum_n \varepsilon_{nR}\gamma^\dagger_{nR}\gamma_{nR}$$

$$H_{SET} = \varepsilon d^\dagger d + \ldots$$

$$H_I = \underbrace{[\mathbb{1} - \alpha d^\dagger d]}_{S} \otimes \underbrace{\Big[\sum_{nn'} t_{nn'}\gamma_{nL}\gamma^\dagger_{n'R} + h.c.\Big]}_{B}$$

$$\hat{O} = \sum_n \gamma^\dagger_{nR}\gamma_{nR}$$

$$C^z(\tau) = \mathrm{Tr}\{e^{-i\hat{O}z}e^{+iH_{QPC}\tau}B\,e^{-iH_{QPC}\tau}e^{+i\hat{O}z}B\,\bar{\rho}_B\}$$
$$= e^{-iz}\left(\frac{1}{2\pi}\right)^2\int d\omega\, d\omega'\, T(\omega,\omega')e^{+i(\omega'-\omega)\tau}[1-f_L(\omega)]\cdot f_R(\omega')$$
$$+ e^{+iz}\left(\frac{1}{2\pi}\right)^2\int d\omega\, d\omega'\, T(\omega,\omega')e^{-i(\omega'-\omega)\tau} f_L(\omega)\cdot[1-f_R(\omega')]$$

$$T(\omega,\omega') = (2\pi)^2\sum_{nn'}|t_{nn'}|^2\,\delta(\omega-\varepsilon_{nL})\,\delta(\omega'-\varepsilon_{n'R})$$

$$\gamma^z(\Omega) = \int C^z(\tau)e^{+i\Omega\tau}d\tau$$
$$= \frac{e^{-iz}}{2\pi}\int d\omega\, T(\omega,\omega-\Omega)[1-f_L(\omega)]\, f_R(\omega-\Omega) \qquad R\rightarrow L$$
$$+ \frac{e^{+iz}}{2\pi}\int d\omega\, T(\omega,\omega+\Omega)\, f_L(\omega)\,[1-f_R(\omega+\Omega)]$$

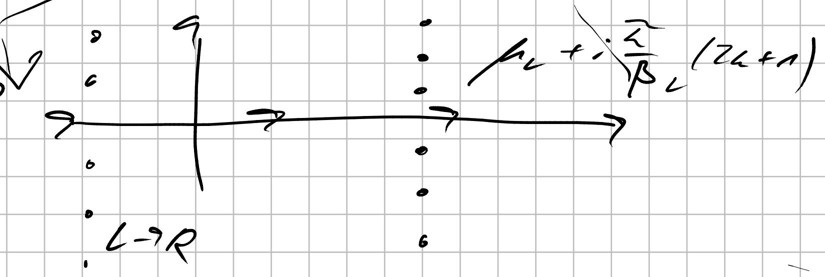
$$\lambda_{QPC}(z) = \begin{pmatrix} 1 & 0 \\ 0 & |1-\alpha|^2 \end{pmatrix} f_{QPC}(z)$$

$$f_{QPC}(z) = \mathcal{T}^z(0)$$

$$= \frac{e^{-iz}-1}{2\pi}\int T(\omega,\omega)\,[1-f_L(\omega)]\,f_R(\omega)\,d\omega$$

$$+ \frac{e^{+iz}-1}{2\pi}\int T(\omega,\omega)\,f_L(\omega)\,[1-f_R(\omega)]\,d\omega$$

$$T(\omega,\omega) = T_0$$



$$\lambda = \lambda_{SET} + \lambda_{QPC}(z) = \lambda(z)$$

$$\rho(z,t) = e^{\lambda(z)\cdot t}\rho_0$$

$$\rho^{(n)}(t) = \frac{1}{2\pi}\int e^{\lambda(z)\cdot t}\rho_0\, e^{-inz}\,dz$$

$$P_n(t) = \frac{1}{2\pi}\int \underbrace{\mathrm{Tr}\{e^{\lambda(z)\cdot t}\rho_0\}}_{h(z,t)\approx e^{\lambda(z)t}} e^{-inz}\,dz$$