Time-dependent Ginzburg-Landau equations for rotating two-flavor color superconductors

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TIME-INDEPENDENT GL EQUATIONS FOR THE 2SC PHASE

$$\mathcal{F} = \mathcal{F}_n + \int \left[2\alpha d d^* + \beta \left(d d^* \right)^2 + 2\gamma \left| \left(\hbar \boldsymbol{\nabla} + i \frac{q}{c} \boldsymbol{A}_x \right) d \right|^2 + \frac{1}{8\pi} \left(\mathrm{rot}\ \boldsymbol{A}_x \right)^2 + \frac{1}{8\pi} \left(\mathrm{rot}\ \boldsymbol{A}_y \right)^2 \right] dV, \quad (1)$$

$$\begin{aligned} \boldsymbol{A}_x &= -\sin\theta_M \boldsymbol{A} + \cos\theta_M \boldsymbol{A}_8, \\ \boldsymbol{A}_y &= \cos\theta_M \boldsymbol{A} + \sin\theta_M \boldsymbol{A}_8, \end{aligned}$$

$$\cos\theta_M = \frac{\sqrt{3}g}{\sqrt{e^2 + 3g^2}}, \qquad q = \sqrt{e^2 + 3g^2}/3$$

$$\frac{\delta \mathcal{F}}{\delta d^*} = 0, \qquad \frac{\delta \mathcal{F}}{\delta \boldsymbol{A}_x} = \frac{\delta \mathcal{F}}{\delta \boldsymbol{A}_y} = 0.$$

$$\alpha d+\beta\left|d\right|^{2}d-\gamma\left(\hbar\boldsymbol{\nabla}+i\frac{q}{c}\boldsymbol{A}_{x}\right)^{2}d=0.$$

$$\begin{aligned}\boldsymbol{j}_{x} &= 2i\hbar\gamma q\left(d^{*}\boldsymbol{\nabla}d-d\boldsymbol{\nabla}d^{*}\right)-4\gamma\frac{q^{2}}{c}\left|d\right|^{2}\boldsymbol{A}_{x},\\ \boldsymbol{j}_{y} &= 0,\end{aligned}$$

$$\alpha=\frac{(T-T_{c})}{T_{c}}\nu,\quad \beta=\frac{7\zeta\left(3\right)}{8\left(\pi k_{B}T_{c}\right)^{2}}\nu,\quad \gamma=\frac{p_{F}^{2}}{6\mu^{2}}\beta=\frac{7\zeta(3)}{16(\pi k_{B}T_{c})^{2}}\frac{n_{b}}{\mu},$$

$$d_{0}=\left(-\frac{\alpha}{\beta}\right)^{1/2}=\left[\frac{8}{7\zeta(3)}\left(\frac{T_{c}-T}{T_{c}}\right)\right]^{1/2}\pi k_{B}T_{c}.$$

$$\boldsymbol{A}_{x}\rightarrow\boldsymbol{A}_{x}^{\prime}\equiv\boldsymbol{A}_{x}+\frac{2\mu}{3q}\left[\boldsymbol{\Omega}\times\mathbf{r}\right] \qquad \boldsymbol{B}_{L}=-\frac{4\mu}{3q}\boldsymbol{\Omega}.$$

$$B_{L}\ll H_{c1}$$

TIME-DEPENDENT GL EQUATIONS FOR THE 2SC PHASE

$$-\Gamma\left(\frac{\partial}{\partial t}-\frac{iq}{\hbar}\phi\right)d=\alpha d+\beta\left|d\right|^{2}d-\gamma_{d}\left(\hbar\boldsymbol{\nabla}+\frac{iq}{c}\boldsymbol{A}_{x}\right)^{2}d.$$

$$\gamma_d=\frac{\pi\nu D}{8\hbar k_B T_c}; \qquad \nu = \mu p_F/\pi^2\hbar^3$$

is the density of states at the Fermi surface

$D = v_F^2\tau_q/3,$ is the diffusion coefficient.

$\tau k_b T_c >> \hbar$ weak pair breaking $\qquad \tau >> 4.3\cdot 10^{-19} s.$

$$\Gamma = \frac{\pi\hbar\nu}{8k_B T_c}$$

$$\tau_d = \frac{\Gamma}{|\alpha|} = \frac{\pi\hbar}{8k_B T_c}\left(1 - \frac{T}{T_c}\right)^{-1}$$

$$\boldsymbol{j}_d = 2i\hbar\gamma_d q\left[d^*\boldsymbol{\nabla} d - d\boldsymbol{\nabla} d^*\right] - \frac{4\gamma_d q^2}{c}\left|d\right|^2\boldsymbol{A}_x - \sigma_q\left(\frac{1}{c}\frac{\partial\boldsymbol{A}}{\partial t} + \boldsymbol{\nabla}\phi\right),$$

$$\tau_j = \frac{\sigma_q}{4\gamma_d q^2|d|^2}$$

$$\phi_8 \rightarrow \phi_8' = \phi_8 - \frac{\mu}{3q}\Omega^2 r^2$$

$$\boldsymbol{A}_x \to \boldsymbol{A}'_x = \boldsymbol{A}_x + \frac{2}{3}\frac{\mu c}{q}\left[\boldsymbol{\Omega} \times \mathbf{r}\right]$$

$$\boldsymbol{j}_d = 2i\gamma_d \hbar q\left[d^* \boldsymbol{\nabla} d - d \boldsymbol{\nabla} d^*\right] - \frac{4q^2\gamma_d}{c}\left|d\right|^2 \boldsymbol{A}'_x - \sigma_q \boldsymbol{E}'$$

$$\boldsymbol{E}' \equiv \frac{1}{c}\frac{\partial \boldsymbol{A}_x}{\partial t} + \boldsymbol{\nabla}\phi_8 - \frac{2\mu}{3q}\Omega^2 \mathbf{r} \qquad \phi_r = -\frac{\mu}{3q}\Omega^2 r^2$$

$$W = 2\Gamma\left|\frac{\partial d}{\partial t} - \frac{iq}{\hbar}\phi'_8 d\right|^2 + \sigma_q \boldsymbol{E}'^2$$

$$d = |d| e^{-i\chi}$$

$$W = 2\Gamma\left[\left(\frac{\partial|d|}{\partial t}\right)^2 + |d|^2\left(\frac{\partial\chi}{\partial t} + \frac{q}{\hbar}\phi_8'\right)^2\right] + \sigma_q \boldsymbol{E}'^2,$$

$$\frac{2iq}{\hbar}\left(d\frac{\delta F}{\delta d} - d^*\frac{\delta F}{\delta d^*}\right) = \mathrm{div}\,\mathbf{j}_s$$

$$-\mathrm{div}\boldsymbol{j}_s = \mathrm{div}\boldsymbol{j}_n = \sigma_q \mathrm{div}\boldsymbol{E}',$$

$$\lambda_E^2 \nabla^2 \phi_8' - \frac{|d|^2}{d_0^2}\phi_8' = 0,$$

$$\lambda_E = \left(\frac{\sigma_q \hbar^2}{4\Gamma' q^2 d_0^2}\right)^{1/2}.$$

$$\partial\chi/\partial t = 0 = \partial\boldsymbol{A}/\partial t$$