$$M=\begin{pmatrix} -\Gamma_1 & -\Gamma_1 & -\Gamma_1 & 0 & 0 & -i\Omega_1 & i\Omega_1 & 0 & 0 \\ -\Gamma_2 & -\Gamma_2 & -\Gamma_2 & 0 & 0 & 0 & 0 & -i\Omega_2 & i\Omega_2 \\ 0 & 0 & -\Gamma_3 & 0 & 0 & i\Omega_1 & -i\Omega_1 & i\Omega_2 & -i\Omega_2 \\ 0 & 0 & 0 & -i\Delta_d & 0 & -i\Omega_2 & 0 & 0 & i\Omega_1 \\ 0 & 0 & 0 & 0 & i\Delta_d & 0 & i\Omega_2 & -i\Omega_1 & 0 \\ -i\Omega_1 & 0 & i\Omega_1 & -i\Omega_2 & 0 & \lambda_1 & 0 & 0 & 0 \\ i\Omega_1 & 0 & -i\Omega_1 & 0 & i\Omega_2 & 0 & \lambda_1^* & 0 & 0 \\ 0 & -i\Omega_2 & i\Omega_2 & 0 & -i\Omega_1 & 0 & 0 & \lambda_2 & 0 \\ 0 & i\Omega_2 & -i\Omega_2 & i\Omega_1 & 0 & 0 & 0 & 0 & \lambda_2^* \end{pmatrix}, \tag{A18}$$

and $B=(\Gamma_1,\Gamma_2,0,0,0,0,0,0,0)^T$. Here we have defined $\Delta_d \equiv \Delta_1-\Delta_2$, $\lambda_1 \equiv -(i\Delta_1+\frac{1}{2}\Gamma_3)$, and $\lambda_2 \equiv -(i\Delta_2+\frac{1}{2}\Gamma_3)$. From Eq. (A17), the steady-state solution of the vector $\langle\hat{\sigma}\rangle$ is calculated as

$$\langle\hat{\sigma}^{\rm st}\rangle = M^{-1}B. \tag{A19}$$

Applying the Laplace transform to Eq. (A17), one obtains

$$s\langle\widetilde{\sigma}(s)\rangle - \langle\hat{\sigma}(0)\rangle = M\langle\widetilde{\sigma}(s)\rangle + \frac{B}{s}. \tag{A20}$$

Moreover, the ith component of the vector $\langle\widetilde{\sigma}(s)\rangle$ is given by

$$\langle\widetilde{\sigma}_i(s)\rangle = \sum_{k=1}^{9} L_{ik}[\langle\hat{\sigma}_k(0)\rangle + \frac{B_k}{s}]. \tag{A21}$$

Here the matrix L is defined as $L=(sI-M)^{-1}$ where I denotes the identity matrix. Assuming that the TQD has already attained its steady-state at initial time $t=0$, i.e., $\langle\hat{\sigma}(0)\rangle = \langle\hat{\sigma}^{\rm st}\rangle$, using Eqs. (A15), (A16), (A19), (A21) and the quantum regression theorem [34], one can obtain the correlation function $G(s)$ and the scattering rates $A_{\pm}$ as given in Eq. (A12).

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