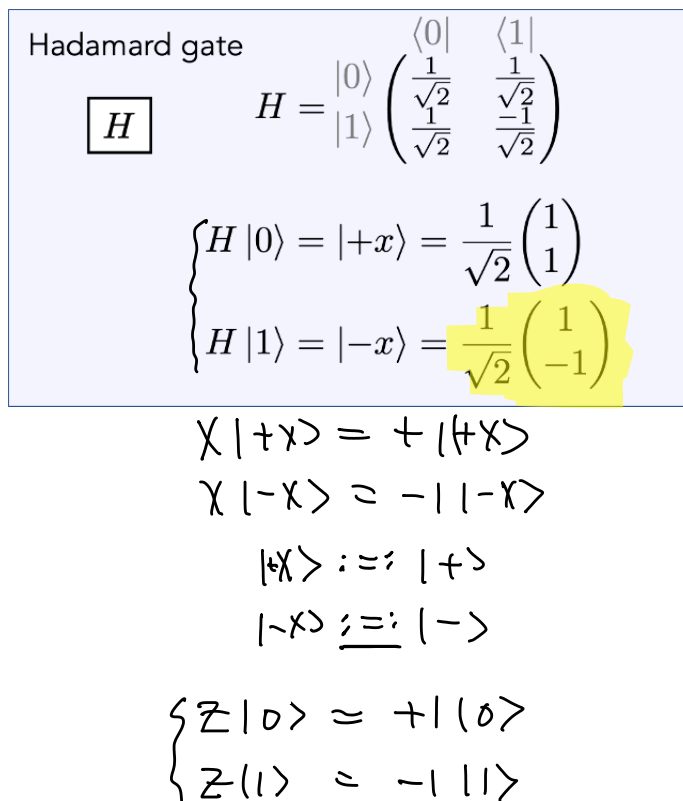


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Coherent errors

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ZZ Interaction

$$\begin{aligned}\hat{H} &= \frac{1}{2} \hbar \omega \hat{Z} \hat{Z} \\ \hat{U}(t) &= \exp(-i \hbar^{-1} \hat{H} t) \\ &= \exp\left(-i \frac{\omega t}{2} \left[\hat{Z} \hat{Z} \right]\right) \\ &= \cos\left(\frac{\omega t}{2}\right) \hat{I} - i \sin\left(\frac{\omega t}{2}\right) \hat{Z} \hat{Z} \\ &= \hat{R}_{ZZ}(\theta = \omega t)\end{aligned}$$

$$\begin{aligned}\hat{R}_X(\theta) &= \exp\left(-i\frac{\theta}{2}\hat{X}\right) \quad X^2 = I \\ &= \cos\left(\frac{\theta}{2}\right) \mathbb{I} - i\sin\left(\frac{\theta}{2}\right) X \\ (\hat{Z}\hat{Z})^2 &= Z^2 Z^2 = \mathbb{I} = \mathbb{I}_4\end{aligned}$$

$$|0\rangle|0\rangle \xrightarrow{H} |+\rangle|+\rangle \xrightarrow{\text{gate}} R_{zz}(\theta)|+\rangle|+\rangle = \cos\frac{\theta}{2}|+\rangle|+\rangle - i\sin\frac{\theta}{2}|-\rangle|-\rangle \xrightarrow{H} \cos\frac{\theta}{2}|0\rangle|0\rangle - i\sin\frac{\theta}{2}|1\rangle|1\rangle$$

$$R_{zz}(\theta) |+\rangle |+\rangle = \cos \frac{\theta}{2} |+\rangle |+\rangle - i \sin \frac{\theta}{2} (Z|+\rangle) \otimes (Z|+\rangle)$$

$$Z|+\rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 1 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -1 \end{pmatrix} = |-\rangle$$

$$Z|+\rangle = |-\rangle$$

$$z \mapsto |+\rangle$$

$$\langle ZI \rangle = \cos \omega t$$

$$\langle 1 | z \rangle = \cos \omega t$$

$$\langle z z \rangle = 1$$