Linear Optics Quantum Computation: an Overview

C. R. Myers and R. Laflamme

Quantum Information Processing with Linear Optics

Quantum Optics

Classical Electromagnetism

EM waves emerge from the source free Maxwell equations

$$\nabla^2 \mathbf{E}(\mathbf{r},t) = \frac{1}{c}\frac{\partial^2}{\partial t^2}\mathbf{E}(\mathbf{r},t)$$

This has the positive and negative field solutions

$$\mathbf{E}(\mathbf{r},t) = i\sum_k \left(\frac{\hbar\omega_k}{2}\right)^{1/2}\left[a_k \mathbf{u}_k(\mathbf{r})e^{-i\omega_k t} + a_k^* \mathbf{u}_k^*(\mathbf{r})e^{i\omega_k t}\right]$$

The energy associated with these fields is given by

$$H = \frac{1}{2}\int_V (\mathbf{E}^2 + \mathbf{B})\,\mathrm{d}\mathbf{r} = \sum_k \left(\frac{\hbar\omega_k}{2}\right) a_k a_k^*$$

Quantisation

To quantise the field $\mathbf{E}(\mathbf{r},t)$ we convert the coefficients a_k into mode operators, which satisfy the canonical commutation relation

$$\left[\hat{a}_i, \hat{a}_j^\dagger\right] = \delta_{ij}$$

This results in the energy defined as

$$\hat{H} = \sum_k \hbar\omega_k \left(\hat{a}_k^\dagger \hat{a}_k + 1/2\right)$$

which resembles a harmonic oscillator.

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LOQC and Quantum Error Correction