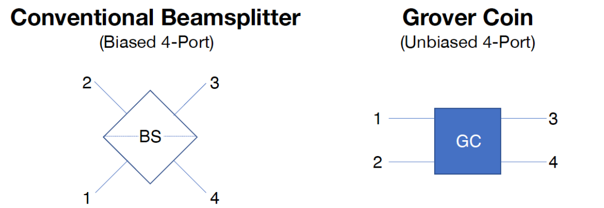
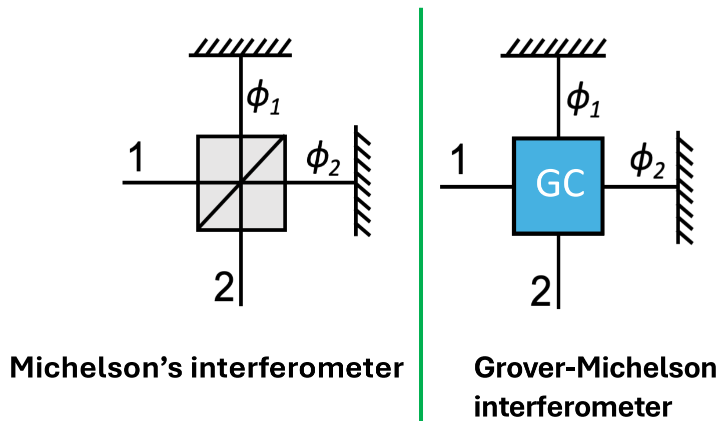


$$\begin{bmatrix} E_3 \\ E_4 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & i \\ i & 1 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix}$$

$$\begin{bmatrix} E_1' \\ E_2' \\ E_3' \\ E_4' \end{bmatrix} = \frac{1}{2} \begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{bmatrix}$$

Fig. 1. 4-dimensional gauge invariant directionally unbiased Grover coin versus a traditional beamsplitter.



$$r = -\frac{1}{2}(e^{i\phi_1} + e^{i\phi_2}),$$
$$t = -\frac{1}{2}(e^{i\phi_1} - e^{i\phi_2}).$$

$$r' = \frac{t^2}{2r^2 - 2} + \frac{r}{2} - \frac{1}{2}$$
$$t' = r' + 1$$

Fig. 2. Traditional Michelson interferometer linear amplitudes (r, t) and Grover-Michelson nonlinear (r', t').

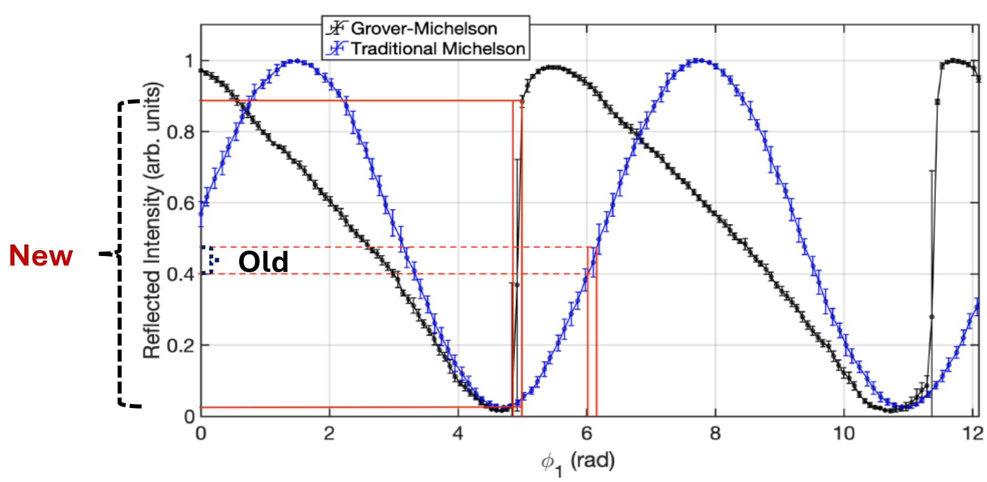


Fig. 3. Experimental comparison of Michelson and Grover-Michelson slopes and intensity responses to the same phase shift φ_1.

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