1. Introduction

We propose and demonstrate the measurement of a single-photon interference pattern generated by a cavity interferometer. The observed interference pattern is a direct demonstration of the principle of coherence and interference in quantum mechanics. We use a cavity interferometer to interfere single photons and observe the interference pattern. The results support the quantum mechanical description of the interference pattern.

![Interference pattern](image)

**Fig. 1:** Interference pattern generated by a single-photon interferometer.

**Fig. 2:** Measurement setup of the single-photon interferometer.
III. RESULTS AND DISCUSSION

The HOX interaction, $L_2$, is a coincidence of the far-field difference

\[ L_2 = \frac{1}{2} (\psi_{+} + \psi_{-}) \]

\[ \psi_{+} = \frac{1}{\sqrt{2}} (\psi_{1} + \psi_{2}) \]

\[ \psi_{-} = \frac{1}{\sqrt{2}} (\psi_{1} - \psi_{2}) \]

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length of the single-photon counting rate becomes very short ($\lambda^2_2 / \Delta \lambda \sim 70 \mu m$). On the other hand, the coherence length of the two-photon counting rate is governed by the spectral width of the sum frequency of signal ($\nu_s$) and idler ($\nu_i$) photons, that is identical to the frequency of pump photons ($2\nu_0$) of the parametric down conversion. Since we used the second harmonic of the single longitudinal mode continuous laser as the pump source, its coherence length is very long ($c / \Delta \nu_0 \sim 400$ cm). As a result, clear interference fringe was observed for the two-photon counting rate even at $\Delta L \sim 400 \mu m$, whereas almost no fringe was observed for the one-photon counting rate. This is the direct consequence of the frequency correlation:

$$\nu_s + \nu_i = 2\nu_0$$  \hspace{1cm} (5)

between the constituent signal and idler photons of the biphoton. Thus, the fringe interval and coherence length of the two-photon counting rate consistently indicate that the biphoton is associated with the photonic de Broglie wavelength:

$$\lambda_0 = \frac{c}{\nu_s + \nu_i} = \frac{c}{2\nu_0} = \frac{\lambda_0}{2}$$  \hspace{1cm} (6)

where refractive index dispersion is neglected.

So far, there have been a number of works concerning two-photon interference using parametric down-converted photons and a Mach-Zehnder or Michelson interferometer [7, 8, 9, 10]. However, the previous experiments did not intend to observe the photonic de Broglie wave. Most of these experiments [7, 8, 10] detected two photons at both output ports of the interferometer. In our experiment, by detecting the two-photon counting rate at one of the output ports, we directly showed that the observed biphoton interference manifests the concept of photonic de Broglie wavelength. Finally, we note the relationship between our experiment and the non-local nature of the correlated two photons, i.e., biphotons, generated by parametric down-conversion or atomic cascade fluorescence. As previously proposed [11] and demonstrated [12, 13], two-photon quantum interference occurs for biphotons even using two spatially separated interferometers. Thus, we understand that the interferometric properties of the biphoton originate from its non-local quantum correlation between the constituent photons, but not from the spatial closeness of the two photons.

In conclusion, we have successfully measured the photonic de Broglie wavelength of the biphotons generated by parametric down-conversion utilizing a Mach-Zehnder interferometer, and showed that the nature of biphoton interference is essentially governed by the frequency correlation between the constituent two photons.

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