

# PSNR Characteristics of Quantum Ghost Imaging with Multiple Positions Illumination

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**Abstract.** We evaluate the PSNR performance of quantum ghost imaging depending on illuminated positions  $N$ . As a result, when the attenuation is severe, large  $N$  shows better performance than small  $N$ , but when the attenuation is low, too large  $N$  degrades the performance.

**Keywords:** Quantum ghost imaging, Quantum protocol, PSNR

## 1 Introduction

One of the protocols using entanglement[1] is quantum ghost imaging (QGI)[2]. The essential components of GI include a light source correlated spatially, a detector  $D_A$  with no spatial resolution, a detector  $D_B$  with spatial resolution, and a correlator to correlate the outputs from detectors. In addition, an object is placed between  $D_A$  and the source. Then, repeating the illumination to  $D_A$  and  $D_B$ , the image is constructed from the object information by  $D_A$  and the positions information by  $D_B$ . We devised a QGI analysis using the product states and showed error performance[3]. In this study, focusing long acquisition time, we consider a protocol to illuminate multiple positions and compare PSNR depending on the number of illuminated positions.

## 2 Protocol

The specific procedure in this study is as follows. First, the light correlated spatially is illuminated on  $D_A$  and  $D_B$ . Then, by detecting the light with  $D_A$  and  $D_B$ , information on the object is obtained with  $D_A$  and information on the illuminated position is obtained with  $D_B$ . Repeating these processes, the image is constructed by linearly normalizing the correlations of the outputs from  $D_A$  and  $D_B$ .

Let  $A_p$  ( $B_p$ ) be the mode illuminating the position  $p$  of  $D_A$  ( $D_B$ ), and we use the following state,

$$|\Psi_P\rangle = \bigotimes_{p \in P} |1\rangle_{A_p} |1\rangle_{B_p} \bigotimes_{p \notin P} |0\rangle_{A_p} |0\rangle_{B_p}, \quad (1)$$

where  $P$  is a set of  $N$  positions and  $|0\rangle$  and  $|1\rangle$  are the vacuum and single photon states, respectively.

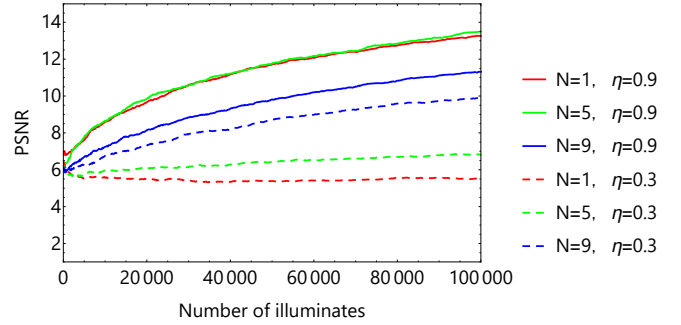


Figure 1: Average PSNR calculated for 100 trials with  $\eta = 0.3, 0.9$  and  $N = 1, 5, 9$ .

## 3 Simulation results

The input state for  $D_A$  is considered to be an  $\eta$ -attenuated photon number state with the number of photons through the slit. On the other hand, we assume  $D_B$  obtains  $P$  without errors. Then, Figure 1 shows the average PSNR for 100 calculations, with  $\eta = 0.3, 0.9$  and  $N = 1, 5, 9$ . A high PSNR means that the imaging results are accurate.

When  $\eta = 0.3$ , only the protocol with  $N = 9$  can obtain a clear image. However, when  $\eta = 0.9$ , the protocol with  $N = 9$  shows lower performance than others. This is because a large  $N$  increases the count of photons in the non-slit part.

## 4 Conclusion

We evaluated the PSNR of QGI depending on  $N$ . As a result, the protocol with  $N = 9$  performed better than the others under the severe attenuation and worse under the low attenuation. The presentation will include an explanation for the performance.

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