Interference between two independent photons for scalable quantum key distribution

De-Wei Liao, Cheng-Yi Lee, Yu-Tung Tsai, Yen-An Shih and Chih-Sung Chuu
Department of Physics, National Tsing Hua University ,Taiwan

Abstract

We demonstrate high-visibility Hong-Ou-Mandel (HOM) interference between two independent attenuated lasers, each probabilistically producing single photons at telecom wavelength (near 1550nm). By employing precise frequency locking, polarization alignment, intensity balancing, and temporal synchronization, we achieve visibility close to the theoretical limit of 50%. Our results are promising for achieving high key rates, enhanced security, and reduced QBER in measurement-device-independent (MDI) QKD, thereby enabling scalable quantum networks.

INTRODUCTION

Hong-Ou-Mandel(HOM) interference

HOM interference occurs when two indistinguishable single photons enter a 50:50 beam splitter from different input ports. Due to quantum interference, the photons always exit together at the same output port.[1]

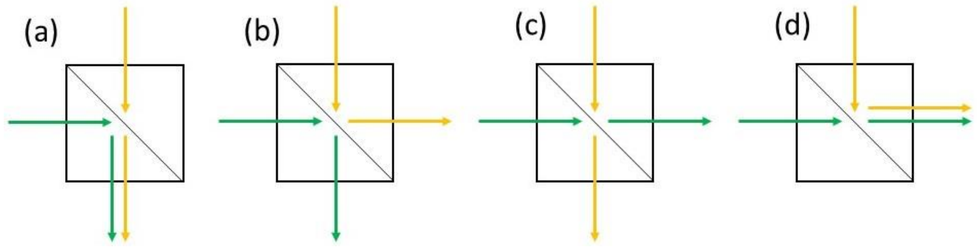

Fig.1 Possible outcomes of two-photon interference at a 50:50 beam splitter

Measurement-Device-Independent(MDI) QKD

Alice and Bob send quantum signals to Charlie, which performs Bell-state measurements (BSM). The final key is derived only by Alice and Bob.[2][3]

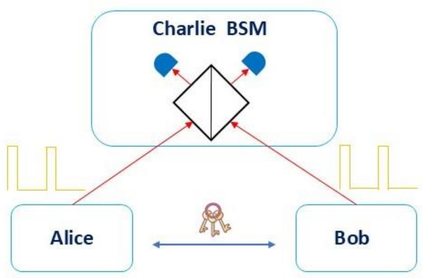

Fig.2 MDI QKD architecture

Advantages of MDI-QKD

- Immune to side-channel attacks (even if the Charlie is untrusted).
- Scalable for large quantum networks.
- No need for a common photon source(each user can use their laser).

Our Goal - Achieve near 50% HOM visibility (Benefits for MDI-QKD)

- High key rates, enhanced security, and reduced QBER.

EXPERIMENTAL SETUP

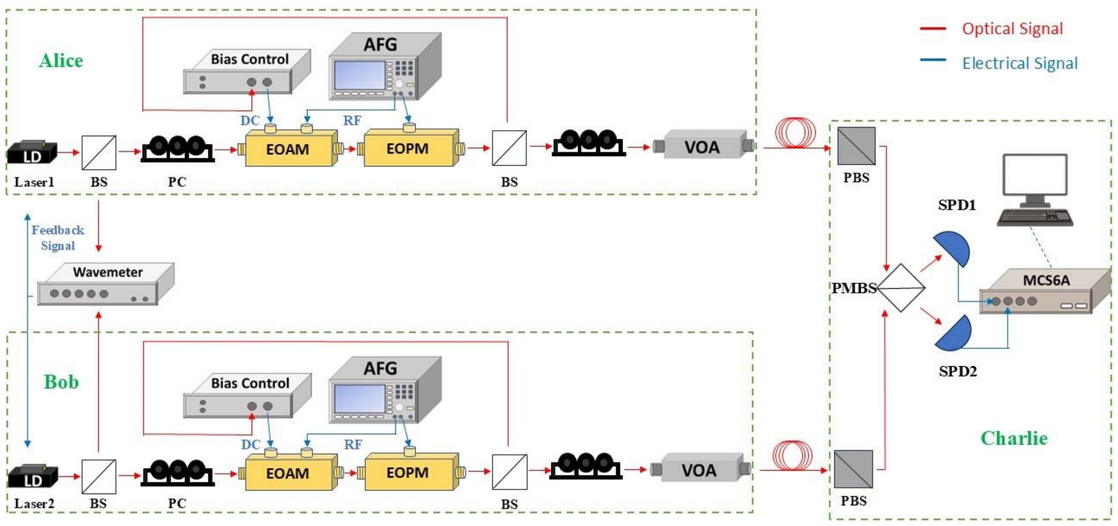

Fig.3 Experimental setup for two laser HOM interference

Ensuring two indistinguishable photons for HOM interference

Frequency matching

- Wavemeter stabilizes two lasers with a frequency difference following a Gaussian distribution (FWHM : 23.6 MHz, centered near 0 MHz)

Polarization alignment

- Polarizing beam splitters (PBS) ensure both photons are horizontally polarized.

Probability amplitudes

- Attenuators adjust the mean photon number to 0.15 for both paths.[4]

Temporal synchronization

- Trigger signals synchronize Alice and Bob's AFG and Charlie's time analyzer (MCS6A), ensuring both photons arrive simultaneously at BS.

RESULTS

We investigate the HOM interference visibility using both a single laser and two independent lasers.[4]

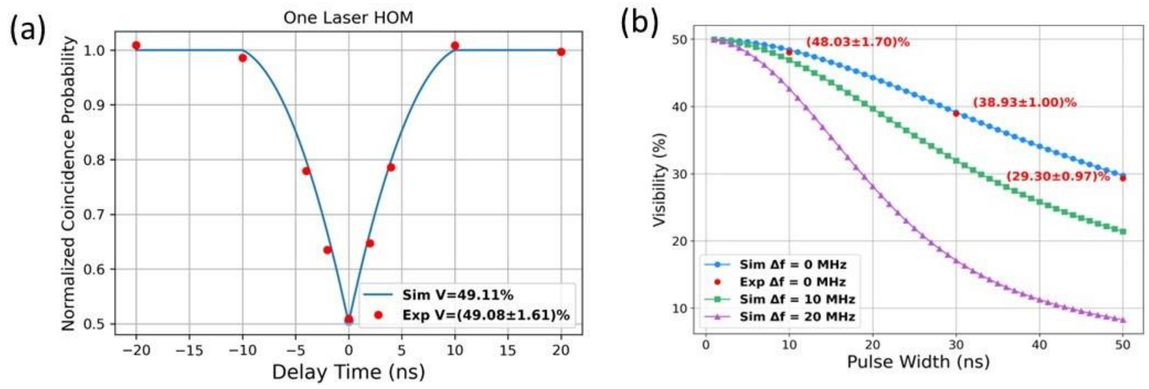

Fig.4(a) HOM interference using a single laser split into two paths.
Fig.4(b) Effect of pulse width on HOM visibility for two independent lasers with Gaussian-distributed frequency differences (FWHM 23.6 MHz) centered at 0 MHz, 5 MHz, and 10 MHz.

Compared Sim and Exp HOM visibility at a frequency distance near 0 MHz.

- At 10 ns: Exp. 48.03% vs Sim. 48.41%
- At 30 ns: Exp. 38.93% vs Sim. 39.12%
- At 50 ns: Exp. 29.30% vs Sim. 29.73%

CONCLUSIONS and FUTURE WORK

Conclusion

- We optimized experimental parameters to achieve HOM visibility near 50%.
- These results validate the feasibility of doing for MDI-QKD.

Future Work

- Integrate two-laser HOM interference into a full MDI-QKD platform.
- Increase the QKD transmission distance for Alice and Bob to 50 km.
- Extend this setup to three participants, forming a scalable QKD network.

REFERENCES

[1] Hong, Chong-Ki, Zhe-Yu Ou, and Leonard Mandel. Physical review letters(1987)
[2] Lo, Hoi-Kwong, Marcos Curty, and Bing Qi. Physical review letters (2012)
[3] Zhou, Xing-Yu, et al. Physical Review Applied (2021)
[4] Ferreira da Silva, Thiago, et al. Journal of the Optical Society of America B (2015)