Progress on Quantum Frequency Conversion of Photons Emitted by a Yb^+ Ion

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Abstract

We demonstrate UV-to-visible quantum frequency conversion (QFC) using a periodically-poled lithium niobate waveguide and 1950-nm pump laser. This validates the first step toward UV-to-telecom QFC for long-distance quantum networking.

I. Introduction

Trapped ions are a promising platform for realizing quantum computers and quantum networks, owing to their long coherence times [1] and high-fidelity gate operations [2]. Among the various atomic species used in trapped-ion systems, Ytterbium (Yb^+) stands out as a leading candidate due to its favorable electronic structure, long coherence times, and scalability [3]. However, a major challenge arises from the fact that photons emitted from Yb^+ ions lie in the ultraviolet (UV) range, which undergoes strong attenuation in optical fibers, thus limiting long-distance quantum communication. To address this limitation, quantum frequency conversion (QFC) from the UV to the telecom band is essential. In this work, we present our successful demonstration of the first stage of QFC—from the UV to the visible range—as a key step toward complete UV-to-telecom conversion.

II. Method

Single-stage QFC from UV to the telecom band suffers from significant noise due to spontaneous parametric downconversion and stimulated Raman scattering [4]. We propose a three-stage difference-frequency generation (DFG) scheme as a practical alternative to the two-stage approach—one that requires sub-2 μm poling periods and also suffers from noise issues. In this work, we experimentally demonstrate the first DFG stage (UV to visible), which significantly relaxes fabrication constraints while achieving high conversion efficiency. We tested the first-stage DFG setup using a 369-nm continuous-wave UV laser and a 1950-nm pump laser, coupled into a ridge waveguide on periodically-poled lithium niobate with a 2.9 μm poling period. In this talk, we will present our conversion result.

Also, we achieved frequency conversion of photons emitted by a $^{174}Yb^+$ ion into the visible range by integrating our first-stage DFG setup with a single-photon generation system [5], and this result will be also presented.

III. Conclusion

We successfully demonstrated the first stage of QFC from the UV to the visible range and experimentally verified that a single photon emitted by a $^{174}Yb^+$ ion can be converted. These experimental results lay the groundwork for completing the full UV-to-telecom QFC process of photon emitted from Yb^+ Ion through integration of the remaining DFG stages. Ultimately, this three-stage QFC system—when combined with remote entanglement generation schemes—has the potential to enable scalable quantum networks over kilometer-scale distances.

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