Dear Editor,

We are submitting our manuscript titled “Temporally multiplexed ion-photon quantum interface via fast ion-chain transport” for consideration for publication in Physical Review Letters.

In this study, we present a multiplexing scheme that is suitable for trapped ion systems towards overcoming the rate limitation of long-distance entanglement distribution. We propose and demonstrate that fast shuttling a linear chain of trapped ions allows for a source of temporally multiplexed single photons which is a building block for large-scale quantum networks. Due to extensive research and high demand on developing scalable quantum systems for quantum computing and networking, we believe that our work will appeal to a broad range of audience from both technological and fundamental perspectives, as further detailed in the following.

First of all, the realization of multiplexing is one of the key requirements to achieve large scale quantum networks over long distances. This concept has been explored extensively and demonstrated in several experiments using ensemble-based light-matter quantum interfaces due to their inherent suitability for multimode operation. However these systems have limited processing capability, making them unsuitable for distributed quantum information processing. In contrast, single atom or ion based systems are native quantum information processing elements with excellent networking capabilities, but implementing a multiplexed operation in these systems is quite challenging. To date, there has been only one experimental demonstration, exploring multiplexing with single ions (PRX Quantum **5**, 020308), but the presented approach is severely limited in terms of scalability and potential multiplexing capabilities. In our study, we present the first demonstration of a scalable multiplexing scheme with trapped ions for quantum networks. This approach can also be applicable to an array of neutral atoms controlled by optical tweezers.

In addition, fast ion chain transport forms the backbone of our multiplexing scheme, which determines the attempt rates and the number of modes that can be accommodated within a given communication distance. We realized shuttling a 9-ion chain across 74 micrometers within 86 microseconds in conjunction with photon generation attempts, marking the fastest ion chain transport to date. Furthermore, we characterized the coherent excitation of the center of mass mode and determined that it is heated to approximately the Doppler temperature after one round of shuttling.

Based on these factors, we believe our study will have a great impact on the communities of quantum computing and networking from both technological and fundamental perspectives. We hope to disseminate this work through Physical Review letters and would like