Loophole-free tests of the Bell inequalities by distributing ion-photon entanglement through hybrid quantum network

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We are developing a long term program to implement loophole-free tests of the Bell inequalities by generating entangled ion-photon pairs over long distances. Time-like interval and high detection efficiency are two essential components for a loophole-free test of the Bell inequalities. In our scheme, a pair of entangled photons (local and remote photon) from narrow-band spontaneous parametric down conversion (SPDC) will be used to produce time-like interval through a telecom fiber linking two cities separated by a distance of over 100 km in Anhui, China. Then an up-conversion quantum interface will coherently transfer the qubit stored in the local SPDC photon to another photon at 370 nm which coincides the spontaneous emitted photon from trapped Yb ions. We will then implement a herald entanglement scheme by a joint measurement of both the up-conversion photon and the spontaneous emitted photon which is entangled with a trapped Yb ion. Thus ion-photon entanglement can be generated between the remote SPDC photon and the trapped ion. Assuming perfect detection efficiency of the ion, minimum detection efficiency 0.50 of the SPDC photon is required to close the detection loophole. We will present an analysis of this experimental scheme and report the current experimental progress.

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