Quantum-memory-based superadditive receiver for classical communication

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Binary phase shift keying (BPSK) is a common encoding format based on an alphabet of two coherent states with opposite phases and the same average photon number $\bar{n}$. Optimal individual detection at the output yields maximum transmission rate scaling linearly at low photon numbers $\bar{n} \ll 1$ as $\bar{n}$ as $R_1 \approx 2\bar{n}/\ln 2$. This performance can be improved through collective detection, with the ultimate limit given by the Holevo bound $\chi \approx \bar{n}\log_2(1/\bar{n})$. A feasible strategy to achieve superadditivity, described recently by Guha [1], is to prepare sequences of BPSK states with signs defined by rows of a Hadamard matrix. These words can be converted by a unitary transformation into the pulse position modulation (PPM) format, which allows e.g. for direct detection [2].

A practical problem is to realize the unitary transformation when the transmitted sequence occupies L successive time bins in the same spatial mode. We propose here to map instantaneously the incoming signals onto polariton modes of quantum memories while performing elementary beam splitter transformations as demonstrated in [3]. This scheme, shown in Fig. 1, allows to implement on-the-fly an arbitrary $L \times L$ unitary transformation [4]. Following [1], at the output ports we consider direct detection (DD) , or a combination of direct detection and a Dolinar receiver (Do&DD) used to discriminate sequences $(++\ldots+)$ and $(--\ldots-)$. In the DD case all Hadamard sequences are equiprobable, whereas for Do&DD the two sequences producing a pulse in the Dolinar receiver mode are taken with a probability different from all other sequences maximizing mutual information.

The enhancement of the transmission rate R_L/R_1 is presented in Fig. 2 for $\bar{n}$ =**0.0005**. The Do&DD option gives enhancement already for sequences of length $L = 2$, whereas above $L \geq 16$, DD is more beneficial of the two schemes considered here.

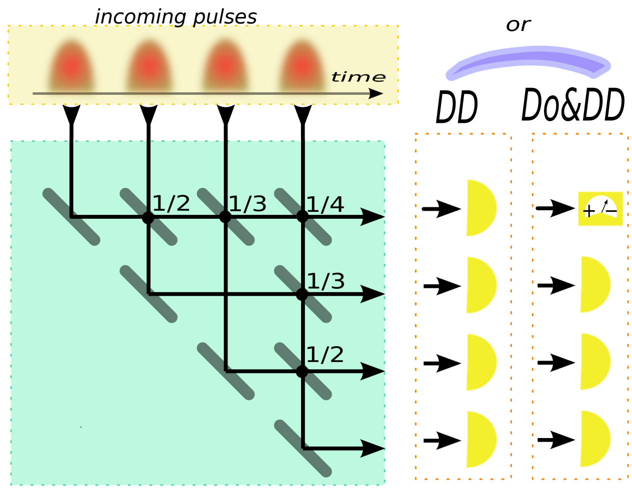

FIG. 1. Realization of a superadditive receiver based on quantum memories. The incoming impulses are mapped on-the-fly into different polariton modes of quantum memories while subjected to beam splitter transformations. Fractions labelling beam splitters indicate power transmissions required to implement the unitary Hadamard transformation. This maps BPSK sequences onto the PPM format which can be detected using either direct detection (DD) or a combination of direct direction and a Dolinar receiver at one output port (Do&DD).

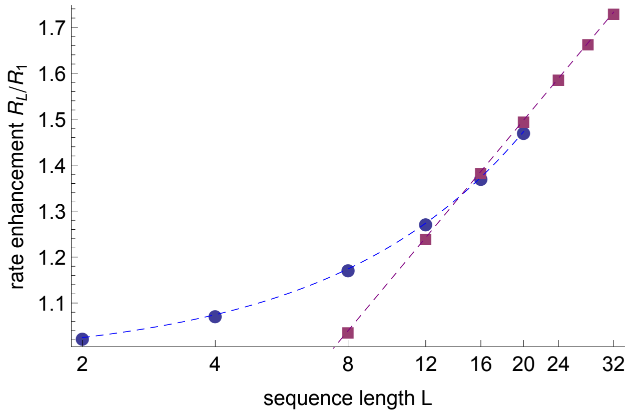

FIG. 2. Enhancement of the maximum transmission rate R_L/R_1 as a function of the sequence length L for direct detection (purple squares) and the Do&DD scheme (blue dots). The average photon number per time bin used in the calculations is $\bar{n}$ =**0.005**.

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