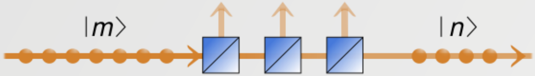
Feedforward-enhanced Fock state conversion with linear optics



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Engineering quantum states of light is a crucial task in a large scale of quantum technology. We propose a generic scheme for Fock state conversion from an arbitrary m-photon to n-photon state by subtraction of m-n photons at feedforward-controlled beam splitters. To maximize the total probability of photon subtraction, we adaptively adjust the splitting ratio for each particular task depending on the outcomes of all preceding subtraction tasks. Our approach is fully achievable with present technology as we demonstrate by an experimental realization of $2 \rightarrow 1$ conversion.

Related publication:

V. Švarc *et al*, Opt. Express 28, 11634-11644 (2020)

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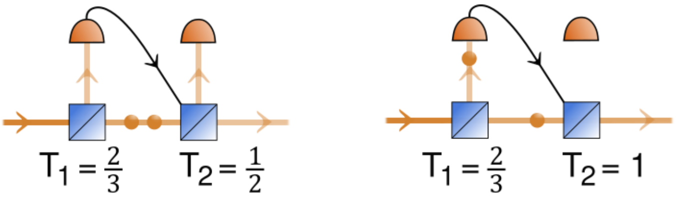
Motivation and approach

Why to convert between Fock states?

- to generate highly non-classical states
- to realize optical quantum gates and operation
- to perform probab. noiseless quantum amplification
- to distill continuous-variable entanglement
- to probe fundamental quantum properties

The principle explained on two-stage $|2\rangle \rightarrow |1\rangle$

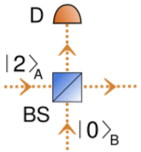


feedforward off | feedforward on

How to do that?

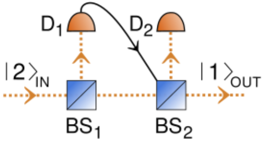
- Probabilistic conversion is possible with a single beam splitter.

P_{succ} = 50%



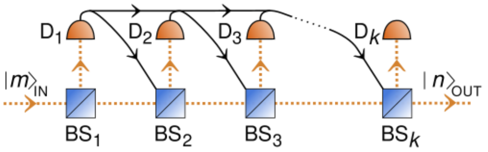
- Better performance is achieved using an additional feedforward-controlled beam splitter.

P_{succ} = 66%



- Cascading this approach leads to the asymptotically deterministic conversion.

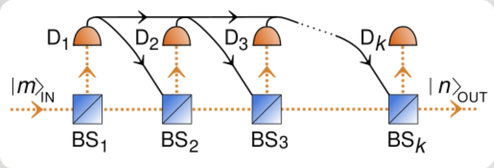
$P_{succ} \rightarrow$ 100%



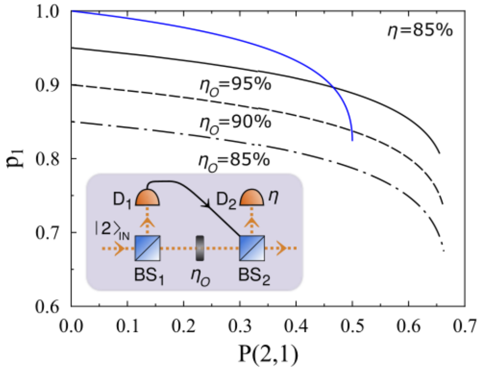
requirements:

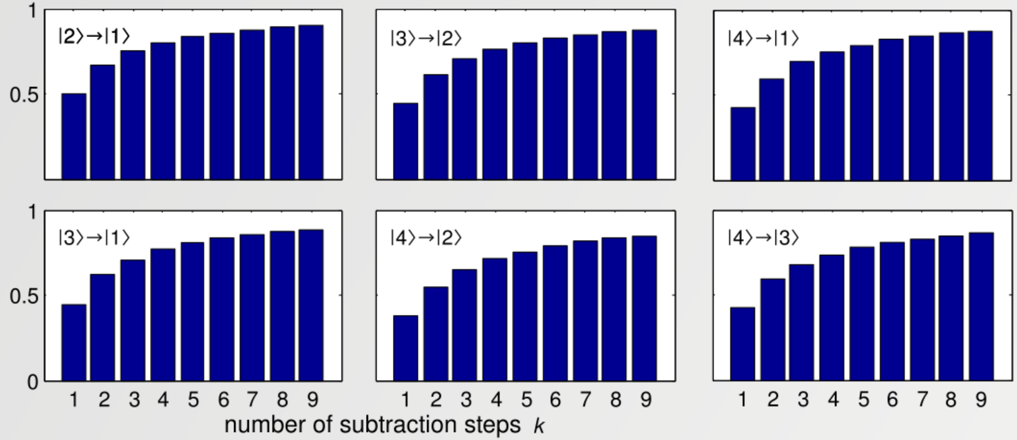
- fast opertation
- low loss
- high detect. eff.

Theoretical results



The scheme remains beneficial even with a certain amount of optical loss.

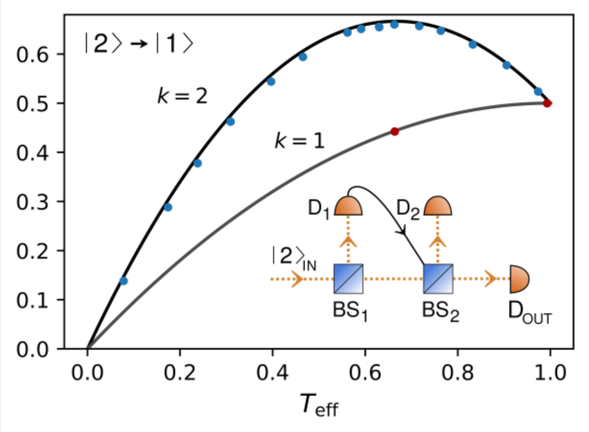


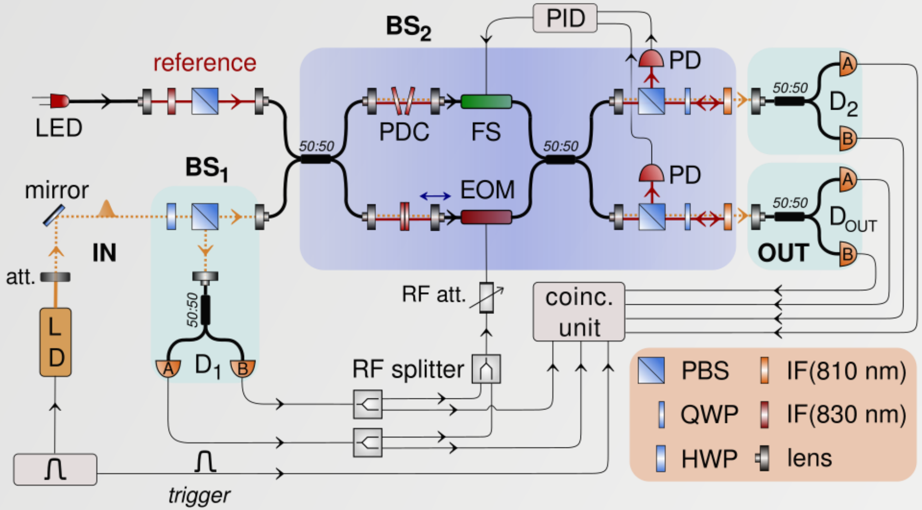


Conversion probabilities obtained after recursive evaluation and maximization of the following equation:

$$P(m,n|k) = \sum_{j=0}^{m-n} \binom{m}{j} T_1^{m-j} (1-T_1)^j P_{\max}(m-j,n|k-1).$$

Experimental results





We demonstrate the potential advantage of feedforward-enhanced conversion (k=2). This configuration provides 66% success that is significantly higher than 50% success of the passive conversion using a single beam splitter (k=1).

Experimental setup for two-stage $|2\rangle \rightarrow |1\rangle$ conversion. The feedforward-controlled beam splitter is implemented as a phase-switchable Mach-Zehnder interferometer. To avoid spontaneous phase drift, the interferometer is actively locked via an auxiliary light beam acting as a phase reference. Our measurements are performed in two-fold coincidence basis to overcome imperfections caused by a light source, losses, and detectors.