Benchmarking photon number resolving detectors

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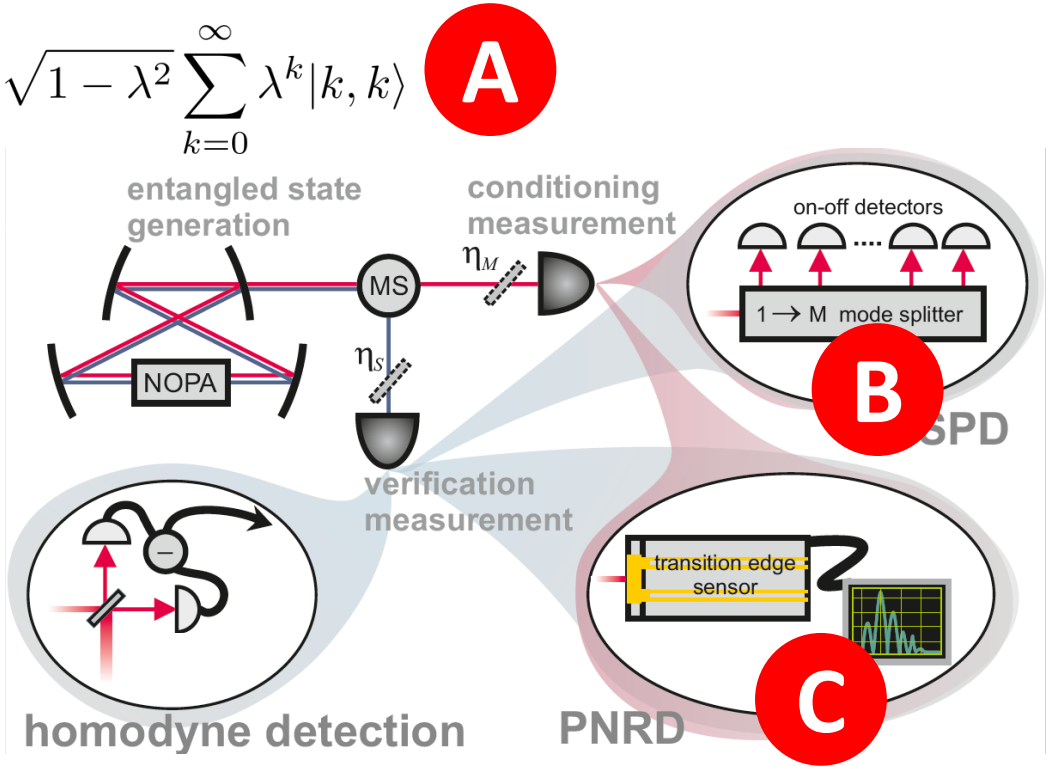

How to decide whether a photon number resolving detector (PNRD) is good?

PNRD (B) can be used to prepare Fock states! Better the detector, better the state!

Array of M on-off detectors can be used too. Higher the M, better the state!

Compare and profit!

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Photon number resolving detectors

- Ideal - the perfect way of detecting light

$$\Pi(n) = |n\rangle\langle n|$$

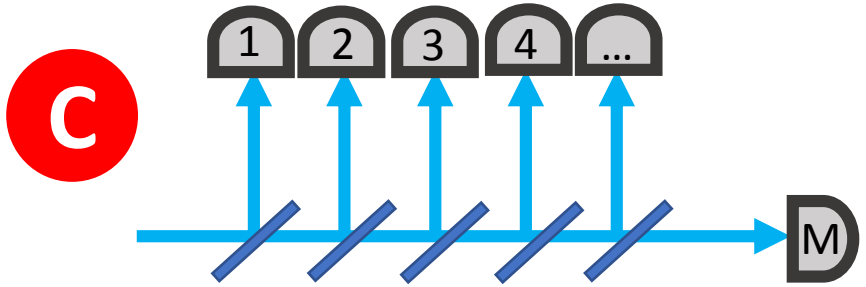
A

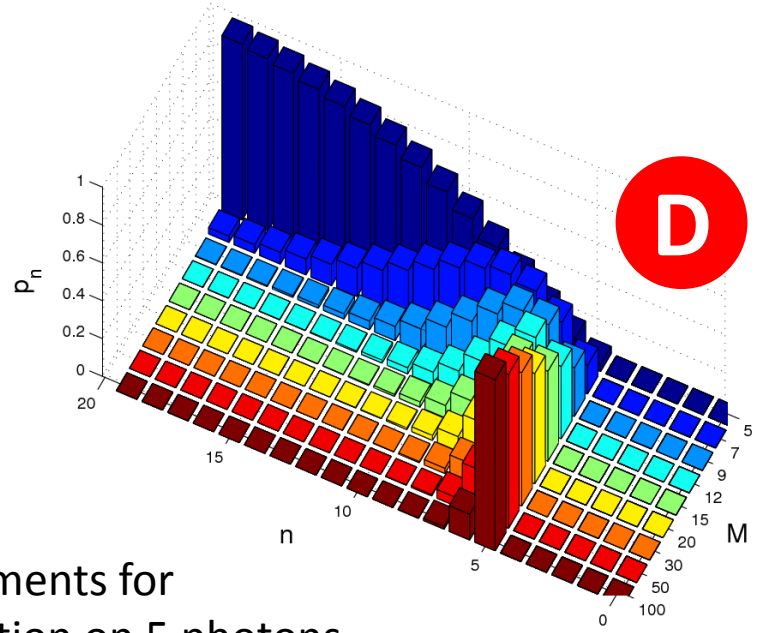
- Approximate - any realistic detector with imperfections

$$\Pi(n) = \sum_{n=0}^{\infty} p_n |n\rangle\langle n|$$

B

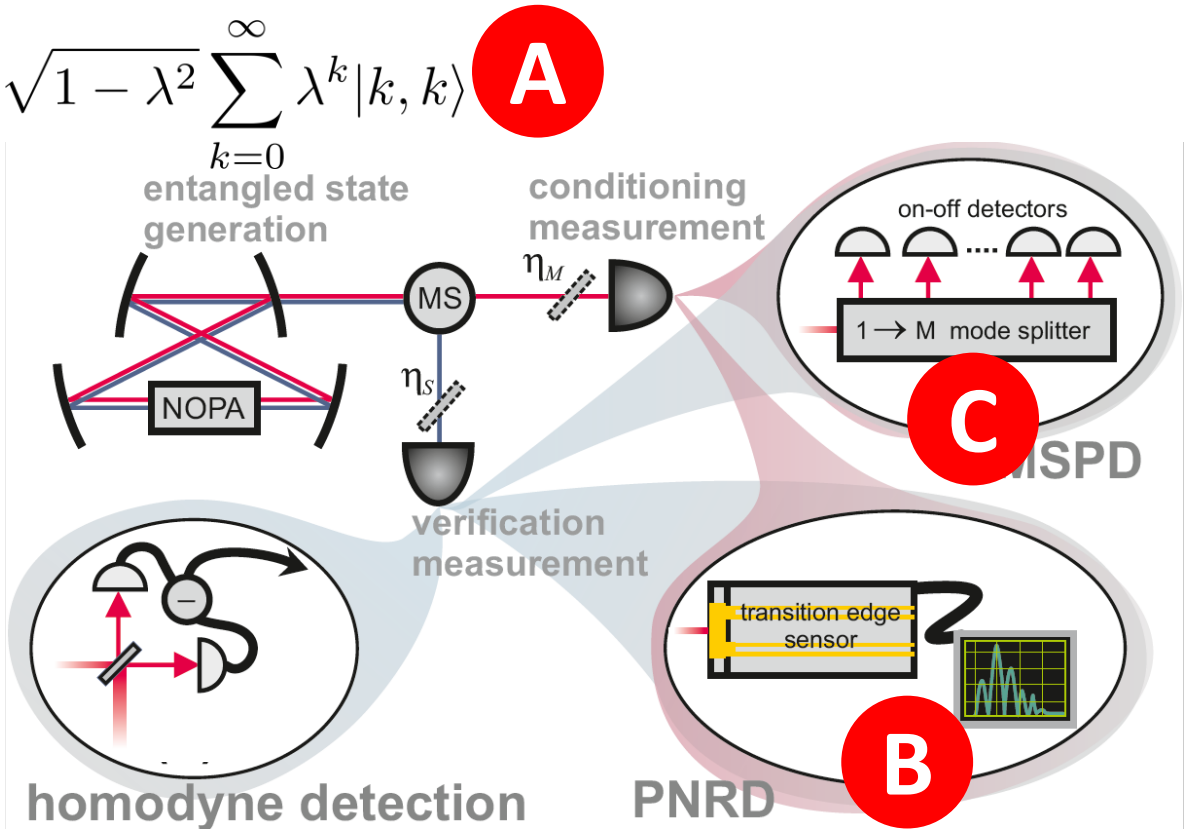
- MSPD - approximation by an array of on-off detectors (see C)
  - limited by M (see D)





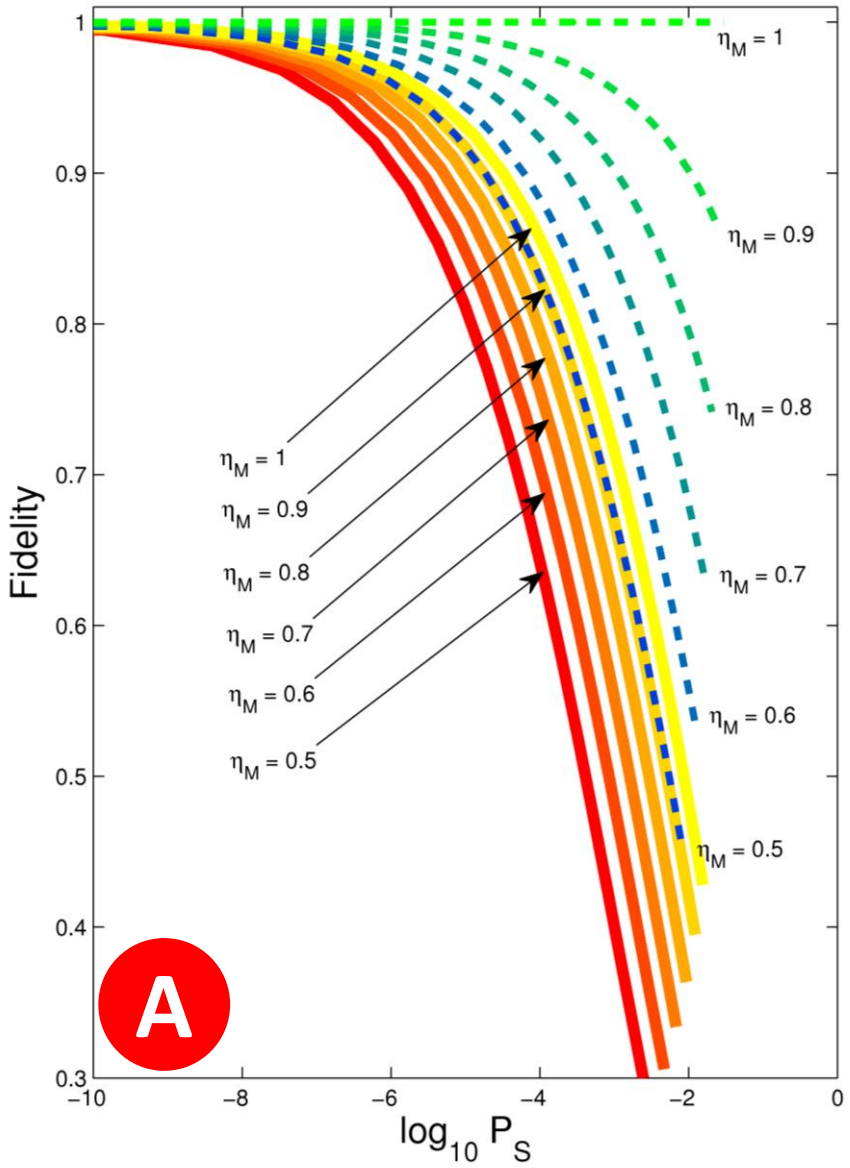
p_n elements for Projection on 5 photons, MSPD with various M

Conditional preparation of the Fock state



- Entangled state with photon number correlations (A)
- One arm measured by a PNRD detector (B or C) and projected on a single result
- Fock state prepared in the other arm
- Quality and Success probability of the operation depend on entanglement and on quality of the detectors

Fidelity and rate when preparing state $|3\rangle$



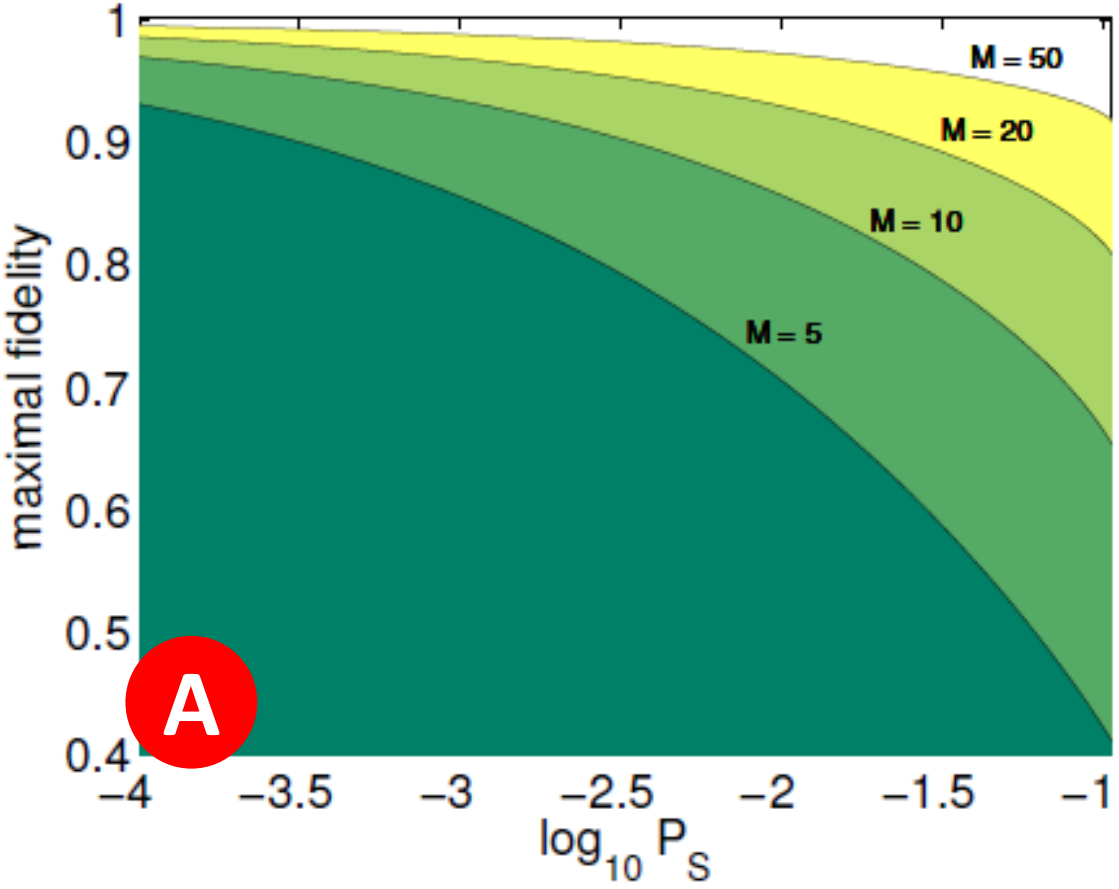
- Green - ideal PNRD with quantum efficiency
- Red - multiplex of M = 3 APD detectors with quantum efficiency
- trade-off between Fidelity and success probability given by the entanglement
- Ideal PNRD with low efficiency operate on the level of MSPD with high efficiency

- Imperfect PNRD can be replaced by perfect MSPD with some M

Effective M

- single parameter quantifying quality of a PNRD
- number of ideal on-off detectors forming an MSPD with the same fidelity-success probability trade-off for preparation of a Fock state
- incorporates construction of the detector as well as detector inefficiency

MSPD benchmarks for fidelity-rate trade-off when preparing state $|3\rangle$



Conclusion

- Conditional preparation of photon number states can be used for benchmarking photon number resolving detectors
- Trade-off between quality and success probability of the prepared state depends on the detector
- Quality of the benchmarked detector can be given as the number of ideal on-off detectors required for comparable performance

- J. Provazník et al., *Benchmarking photon number resolving detectors*, Optics Express 28, 14839 (2020)