EXPERIMENTS WITH CORRELATED PHOTONS

Centre for Quantum Technologies

Lijiong Shen, Jianwei Lee, Mathias A. Seidler, Brenda Chng,
Hou Shun Poh, Peng Kian Tan, Alessandro Cerè, Christian Kurtsiefer

NUS National University of Singapore

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Many-pairs non-locality

collaborators: Jean-Daniel Bancal[1], Yu Cai, Nicolas Sangouard[1], and Valerio Scarani.

We consider a scenario where n identical entangled pairs are prepared and measured collectively. A many-pairs Bell inequality can be violated in this scenario using two binning strategies: majority vote and parity. The maximal number of pairs for which a violation can be observed quantifies the high quality of the pair source. We find a violation up to 41 pairs in the presence of majority voting and up to 12 pairs in the presence of parity binning [1].

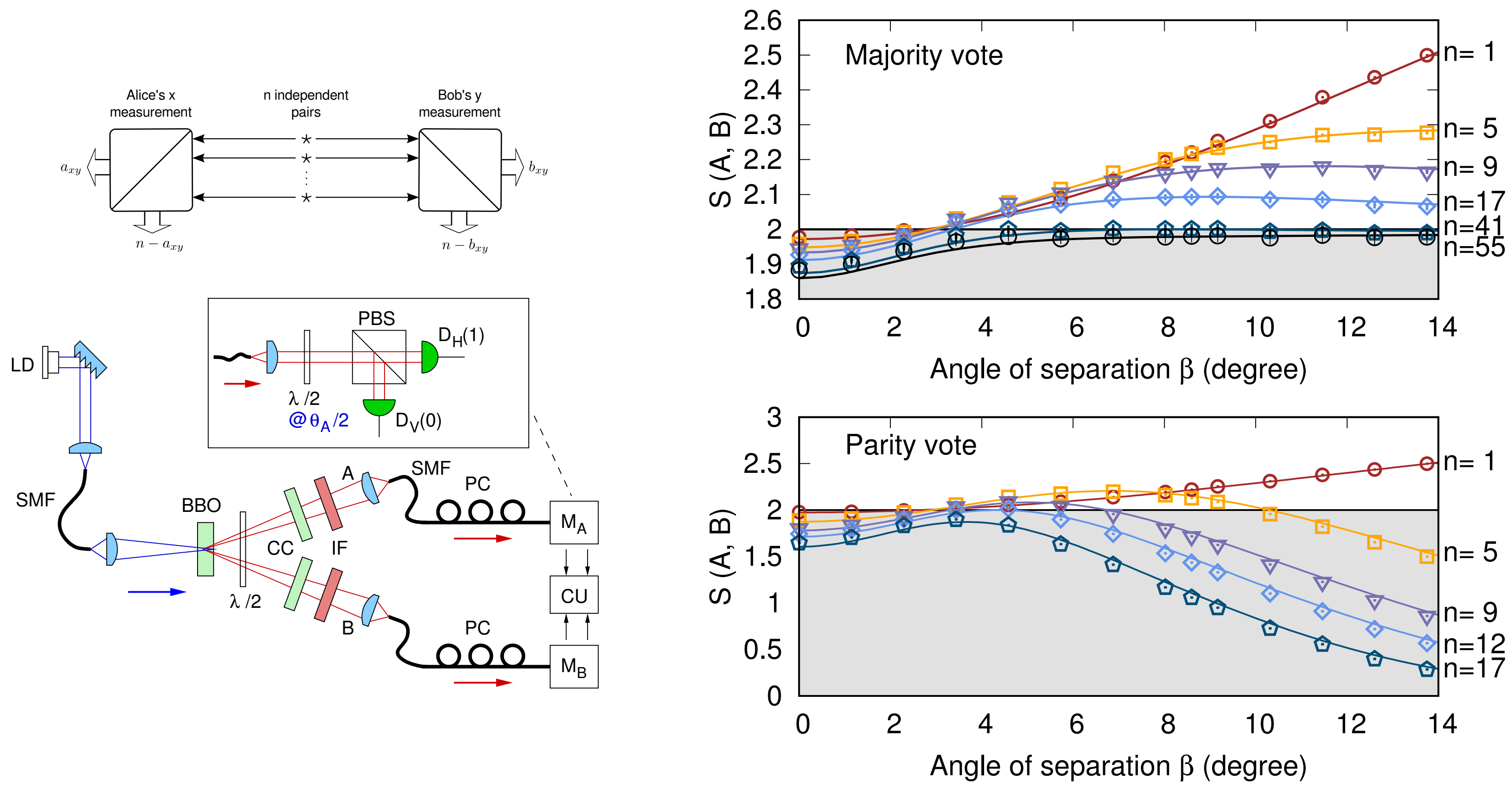

FIGURE 1: Top left: Many-pairs scenario. Bottom left: experimental setup: high purity non-collinear SPDC source of near-IR polarization entangles photon pairs. Right: CHSH parameter S as function of the separation angle between measurement basis for majority voting (top) and parity binning (bottom).

Time resolution of TES for CW sources

collaborators: Thomas Gerrits[2], Adriana E. Lita[2], Sae Woo Nam[2]

Transition edge sensors (TES) can be highly efficient single photon detectors. For continuous wave (CW) sources with large mean photon number their energy resolving ability and timing accuracy is compromised by the slow recovery time on the order of microseconds. We developed a technique to assign arrival times to overlapping detection events. For this, a two-level discriminator coarsely locates pulses in time, while the exact timing of individual photoevents is obtained by fitting to a heuristic detector response function. This allows to measure the second-order time correlation of a coherent source in a single spatial mode using a single TES.

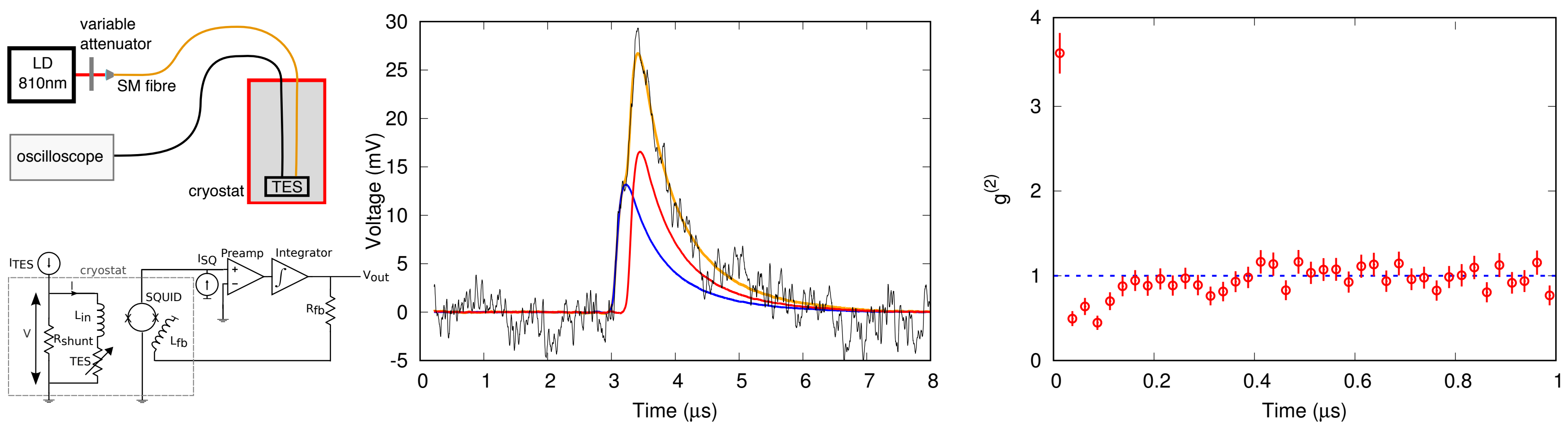

FIGURE 2: Top left: experimental setup: a CW laser diode centered at 810 nm with a variable attenuator to control the average photon number. Bottom right: TES signal detection and amplification. Center: overlapping pulses, corresponding to two photon detection events, with fit to the heuristic model based on average single photon response. Right: second order autocorrelation of the laser light obtained with the TES.

Photocorrelation spectroscopy

Photocorrelation spectroscopy can help determining very narrow spectral lines found in some stellar objects. We are able to determine the line width of a 20 MHz wide spectral line on a thermal blackbody background, an distinguish laser-like emission from pseudo-thermal light. This may help to identify optical stellar lasers in the visible range [2].

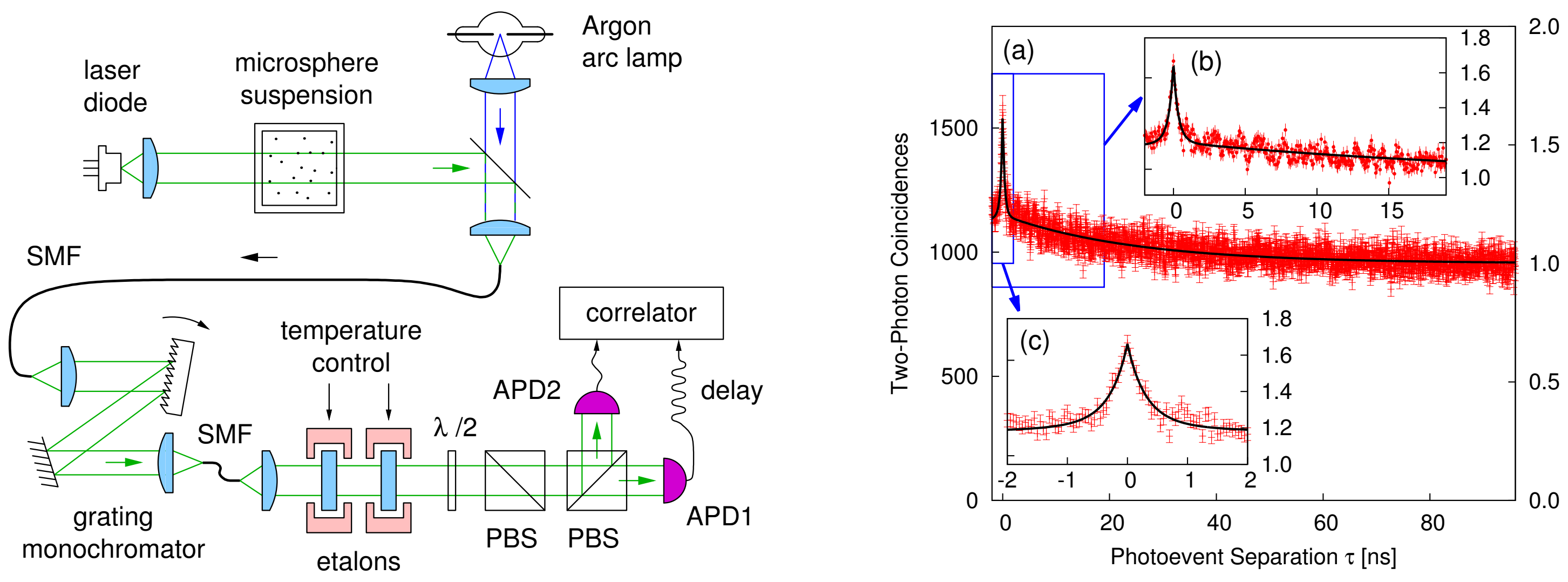

FIGURE 3: Left: preparation of a Doppler-widened laser line on top of a thermal background. Right: resultant photopair correlation, revealing a long tail in $g^{(2)}(\tau)$ corresponding to a narrow spectral line on top of a thermal photon bunching signature.

Bell tests & Randomness generation without detection loophole

collaborators: Thomas Gerrits[2], Adriana E. Lita[2], Sae Woo Nam[2], Thinh Le Phuc,
Jean-Daniel Bancal[1], Valerio Scarani.

Quantum physics can provide randomness that can be certified as being uncorrelated to any outside process or variable, thus provide private randomness, based on a violation of a Bell inequality [3]. With advancements in high efficiency infrared photon detectors [4] in combination with a high efficiency pair source, a loophole free experimental violation of the Bell inequality becomes feasible, which can be engineered into a source of certified randomness.

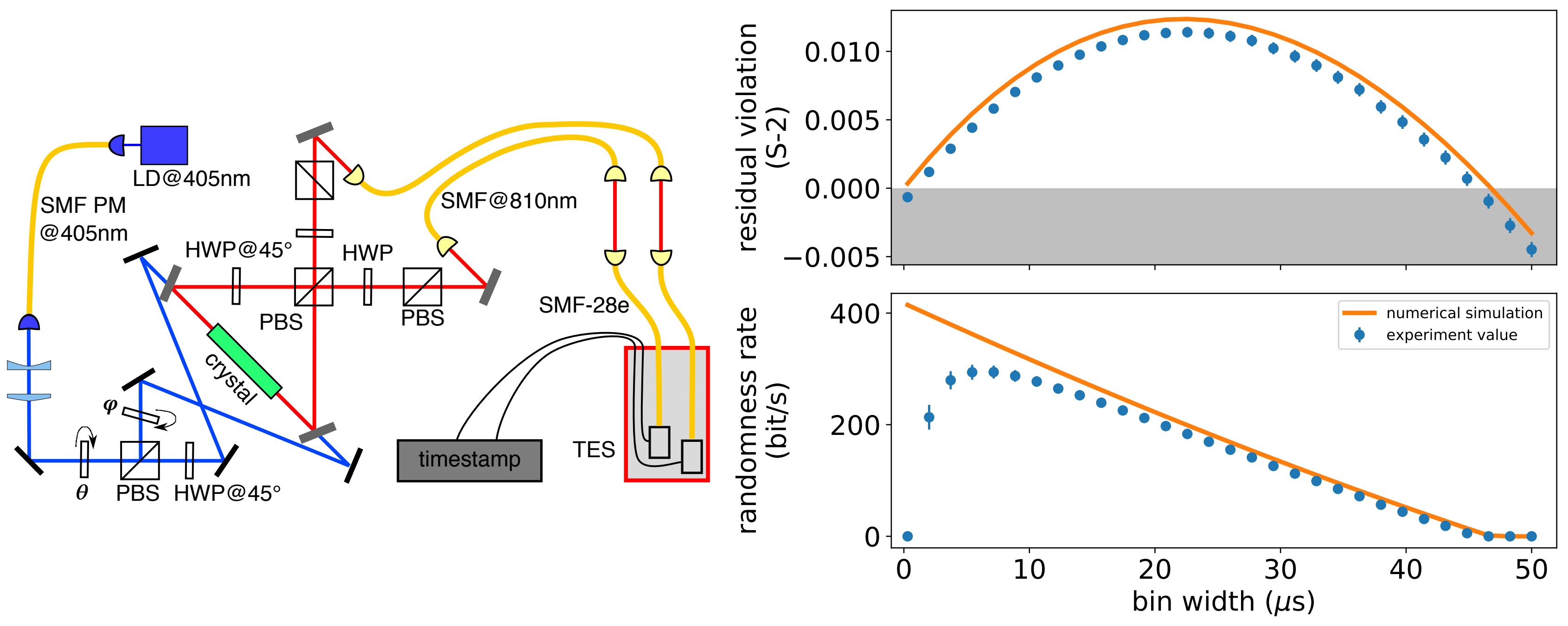

FIGURE 4: Left: Efficient polarization-entangled pair source and detection scheme involving superconducting transition edge sensors (TES). Top right: Violation of CHSH inequality observed as a function of the time bin width. Bottom right: Rate of random bits that can be extracted as a function of the time bin width.

Our pair source can reliably prepare non-maximally entangled states with a high fidelity. In combination with TES, we regularly find system efficiencies >80%. This permits to test a version of CHSH inequality that with a continuous source of photon pairs, with events defined by dividing the measurement time in discrete time bins of fixed length. Numerical simulation and initial experimental results support the intuition that this approach can generate randomness with an efficiency exceeding that of systems based on pulsed pair sources.

Six-wave mixing in cold atoms for narrowband triplets of photons

Extending earlier results in with four wave mixing [5], three-photon states from a cold atomic ensembles can be generated with six wave mixing. The photon wavelength and bandwidth will be compatible with other atomic systems, and the possibility of heralding a photon pairs could improve the scaling of quantum protocols based on light-atom interactions.

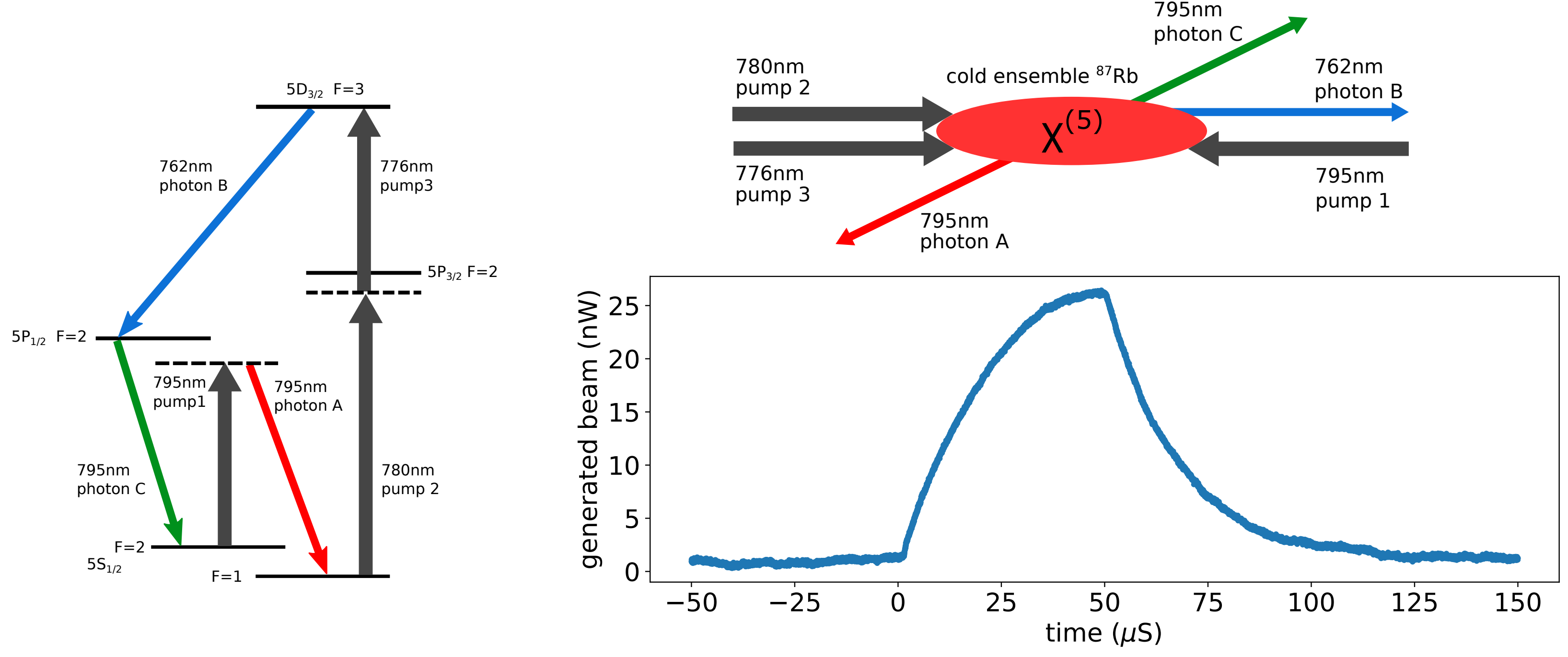

FIGURE 5: Left: schematic of the energy levels of ^{87}Rb for the six-wave mixing. Top right: phase matching scheme. Non-collinear phase-matching allows for geometrical separation of modes only few hundreds of MHz away. Bottom right: we confirm phase matching by parametrically amplifying a seed laser beam at 795 ns (corresponding to photon C) in a five-beam configuration, and observing the concurrent generation of light at 762 nm as a signature of the six-wave mixing process.

Toward an heralded quantum memory for single photons

collaborators: Zhang Zhiqiang, Ravi Kumar, Kyle Arnold, Murray Barrett.

Quantum memories promise the scalability of quantum communication protocols. A memory that confirms the effective storage of an excitation could enhance this scalability even further. We investigate a scheme based on the interaction between a cold atomic ensemble and a cavity, and test it with narrowband heralded single photons.

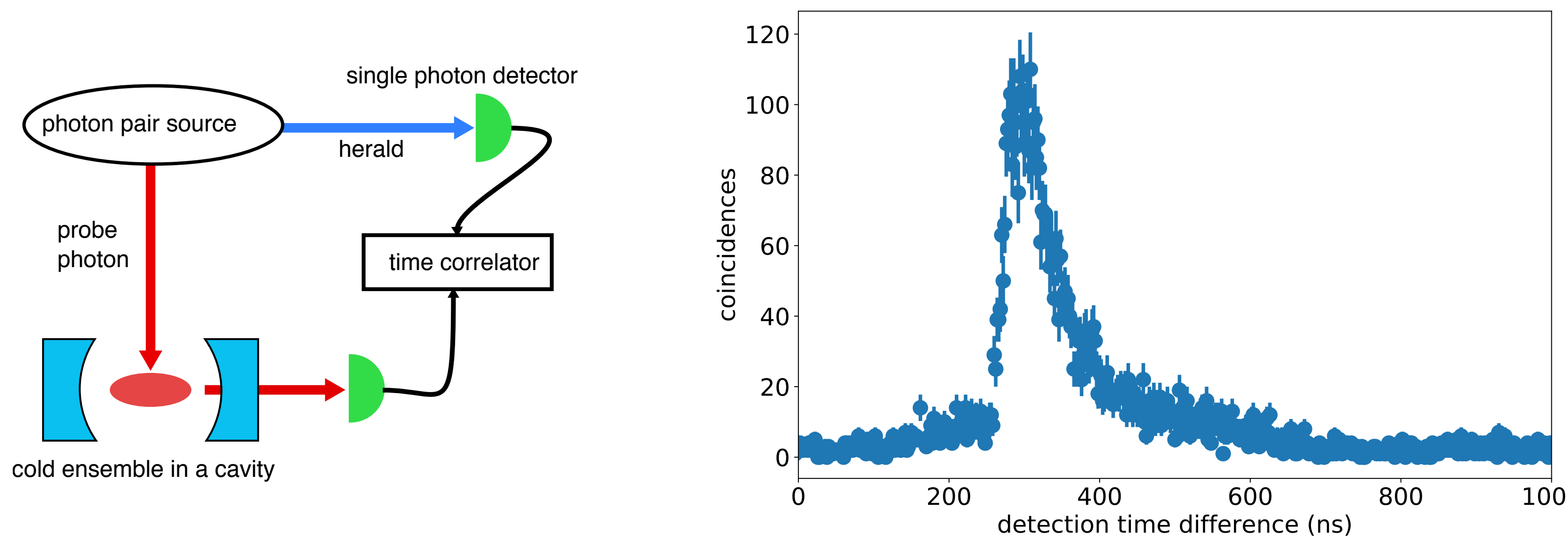

FIGURE 6: Left: schematic of the experiment. Four-wave mixing in a cold cloud of ^{87}Rb generates heralded single photons (probe) wich are sent to a second cold atomic ensemble interacting with an optical cavity. Left: time correlation between heralding events and detections at the output of the cavity.

References

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Affiliations

[1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland
[2]National Institute of Standards and Technology (NIST), 325 Broadway, Boulder, Colorado 80305, USA

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