Temporal Intensity Interferometry

Peng Kian Tan[1]

[1]Centre for Quantum Technologies

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Abstract

Working in experimental quantum optics with focus on instrumentation for temporal intensity interferometry. Have successfully measured and resolved the temporal photon bunching effect from Sunlight in Singapore despite the tropical, humid, and urban environment. Our lab measurements have successfully identified the presence of coherent laser light even when embedded in a blackbody radiation background. Measurements also differentiated coherent laser light from thermal light that are both narrowband emission lines which could otherwise be mis-identified.

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Tan Peng Kian[1] and Christian Kurtsiefer[1,2]

[1]Centre for Quantum Technologies, National University of Singapore, Singapore 117543
[2]Department of Physics, National University of Singapore, Singapore 117542

Motivation

Stellar objects emitting both blackbody radiation and very narrow spectral emission lines in the non-visible bands are known and natural lasers may provide a possible mechanism to explain these narrow linewidths [1]. However, stellar laser candidates in the visible spectrum are expected to have linewidths in the tens of MHz, with optical emission lines that cannot be resolved by existing astronomical spectrographs as yet, although they are suspected in energetic stars like η Car and Wolf-Rayet stars including γ^2 Vel [2].

Simulated Stellar Laser Source

A defining characteristic of coherent laser light from blackbody radiation is the second order correlation $g^{(2)}(\tau)$. Blackbody radiation exhibits a photon bunching behaviour [3], with a characteristic timescale τ_c, given by [4]

$$g^{(2)}(\tau) = 1 + e^{-2|\tau|/\tau_c}. \qquad (1)$$

In contrast, coherent laser light without Doppler broadening obeys Poissonian timing statistics such that $g^{(2)}(\tau) = 1$.

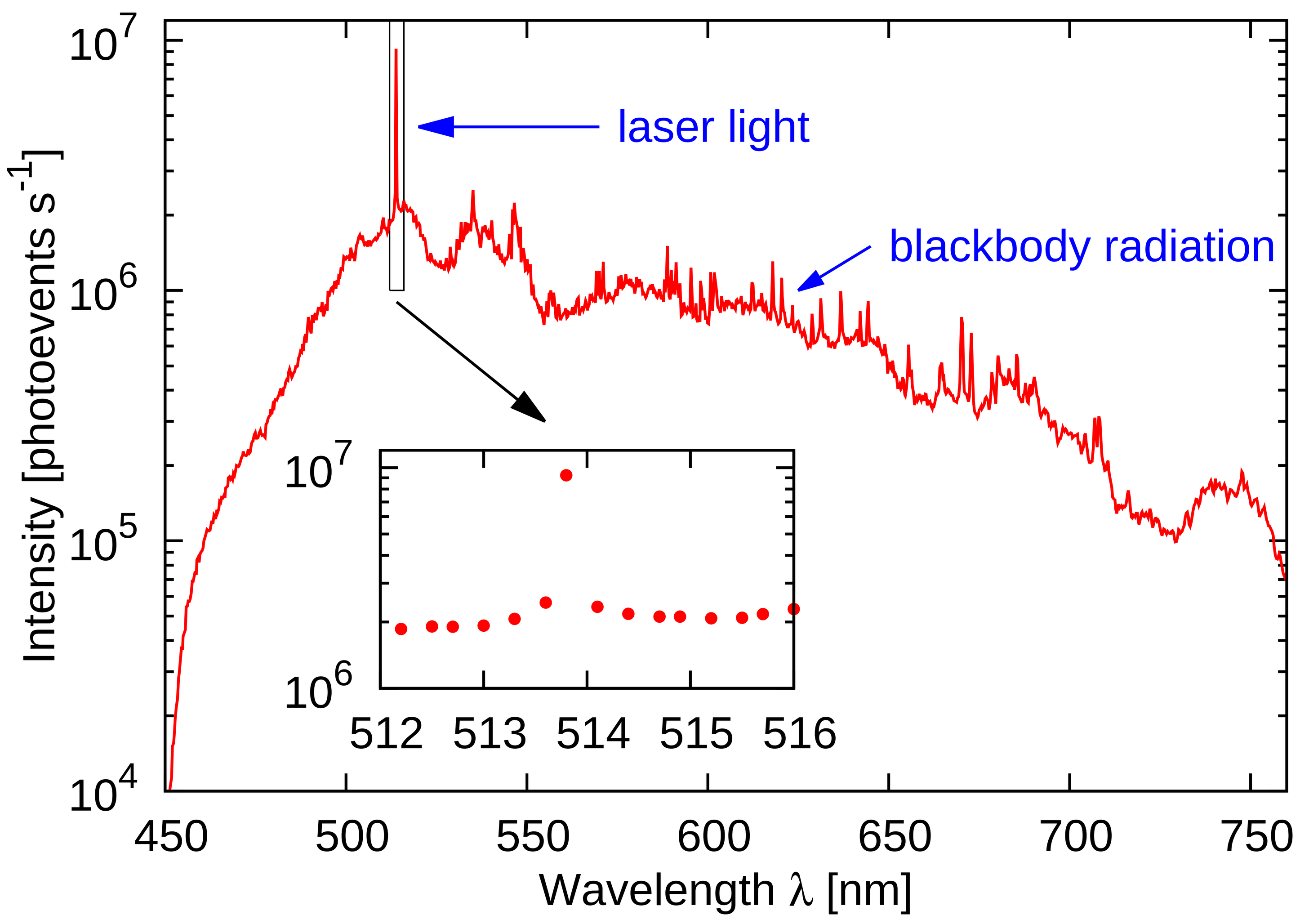

FIGURE 1: Spectrum of the simulated light source without the Doppler broadening. The broad background over the whole visible range resembles blackbody radiation at an effective temperature $T = 6000$ K, while the inset shows the unresolved spectrum around the laser line.

Experimental Setup

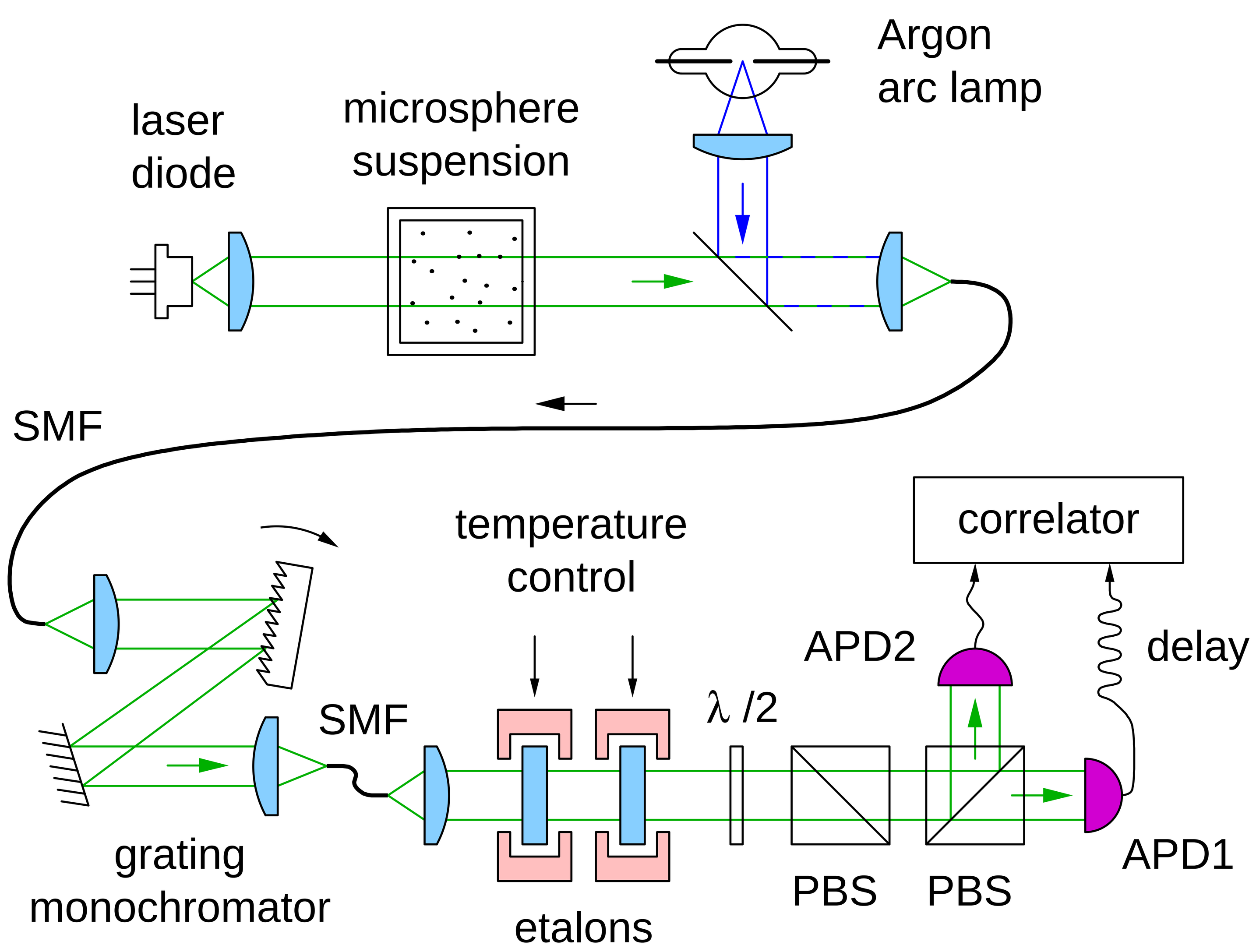

FIGURE 2: Experimental schematic for narrowband spectral filtering [5].

Light from a 513.8 nm laser diode ($\lambda = 513.8$ nm) is Doppler-broadened by passing through a suspension of microspheres (0.2 μm diameter), combined with light from an Argon arc lamp on a microscope slide, and coupled into a single mode optical fiber (SMF). The bottom part shows the analysis system, consisting of a grating monochromator and a temperature-tuned etalon pair to select a 2 GHz wide spectral window around 513.8 nm from the light mixture. Temporal photon pair correlations are recorded to identify different light contributions. PBS: polarizing beam splitter, $\lambda/2$: half wave plate, APD: single photon avalanche photodetectors.

Measured $g^{(2)}(\tau)$ of Narrowband Light

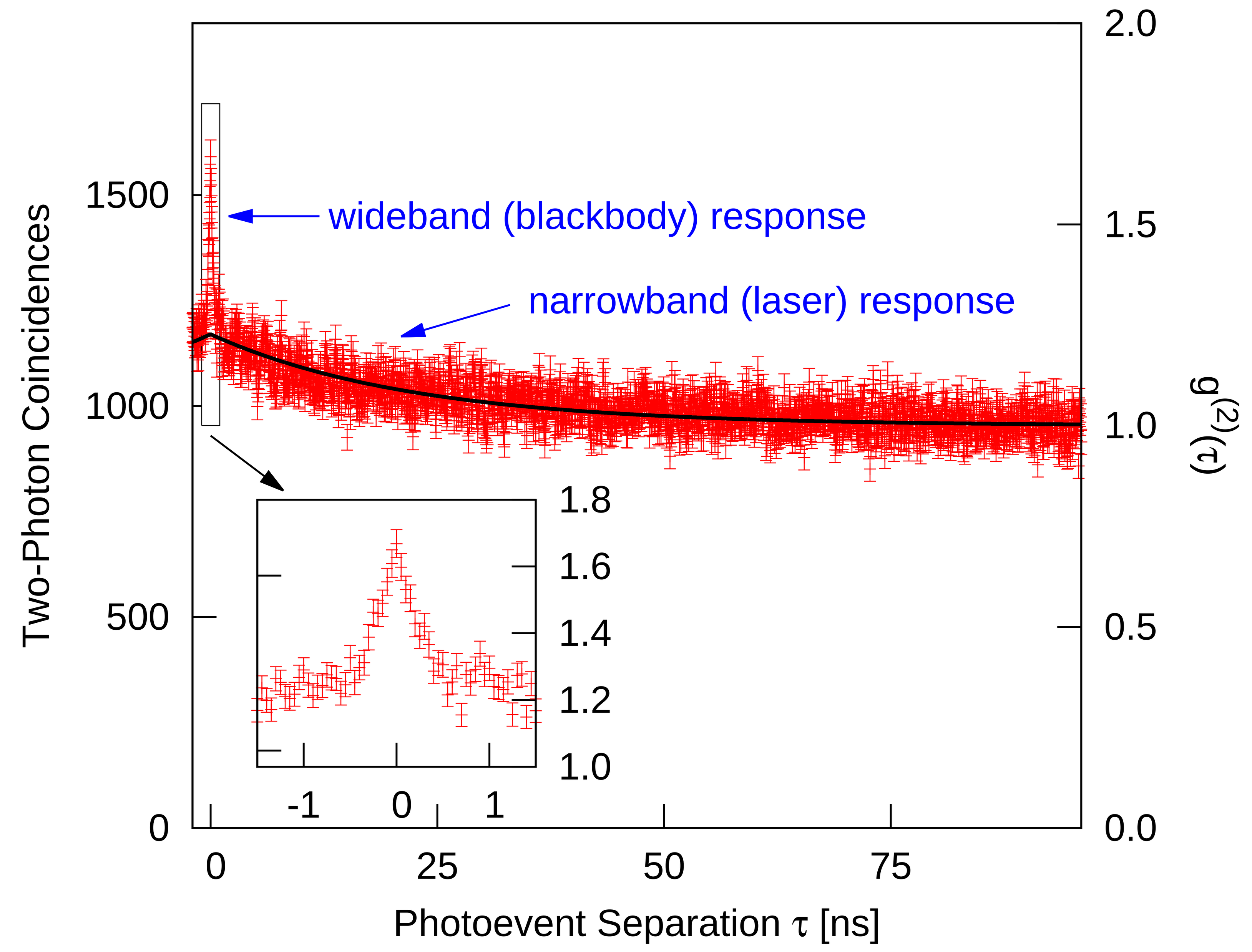

FIGURE 3: Two-photoevent coincidence histogram from the mixing of filtered blackbody radiation from an Argon arc lamp (wideband response) with Doppler broadened laser light contribution at 513.8 nm (narrowband response), both at similar intensity levels of contributions around 2×10^4 photoevents per second. A total of 2×10^6 coincidences were recorded to accommodate the lowered laser light intensity after Doppler broadening. The long coherence time corresponds to a linewidth of ≈ 20 MHz.

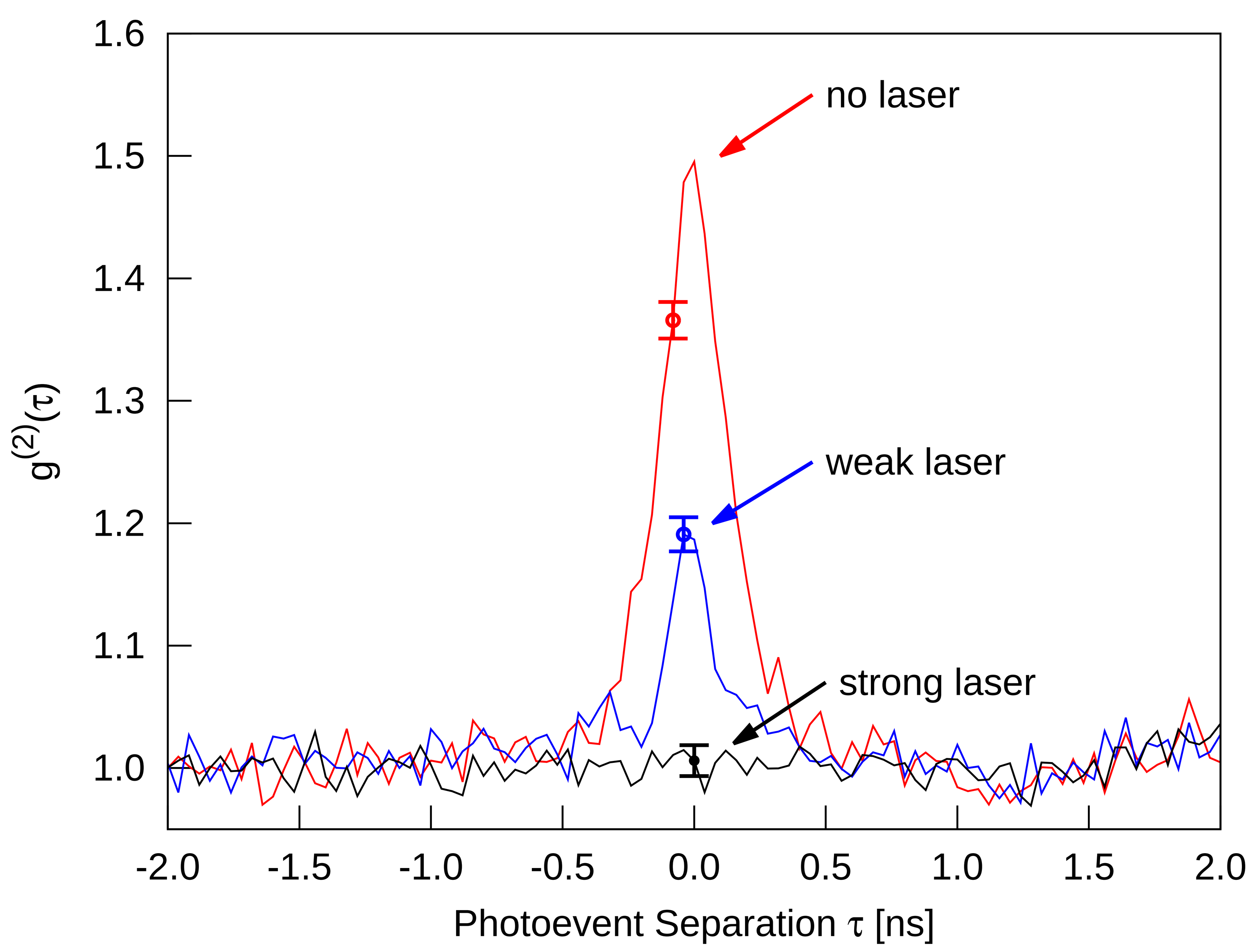

FIGURE 4: Temporal photodetection correlations for different mixing ratios: all measurements have a blackbody contribution from the Argon arc lamp of approximately 3×10^4 photoevents/sec. For the "strong laser" trace, there was a contribution of $r_l = 6 \times 10^6$ photoevents/sec of laser light, for the "weak laser" trace, $r_l = 3 \times 10^4$ photoevents/sec, comparable with the blackbody contribution level. For reference, the photodetection correlations without any laser light admixture is shown. The measurements all accumulated 10^6 coincidence photoevents with -3.1 ns$< \tau < 3.3$ ns to allow for an easy direct comparison of the resulting histograms.

References

[1] P.K.Tan et al, ApJL **789**, L10 (2014)
[2] D. Dravins and C. Germanà, in High Time Resolution Astrophysics, ed. D. Phelan, O. Ryan and A. Shearer (USA: AIP) (2008)
[3] R. Hanbury-Brown and R.Q. Twiss, Nature **178**, 1046-1048 (1956)
[4] R.J. Glauber, Physical Review **130**, 2529 (1963)
[5] P.K. Tan and C. Kurtsiefer, MNRAS **469**, 1617-1621 (2017)