ICFO

PhD THESIS DEFENSE: Narrowband Photon Pairs for Atoms: High Resolution Spectral Engineering and Characterisation

VINDHIYA PRAKASH

December 16, 2021

10:00 to 13:00

ICFO Auditorium and Online (Teams)

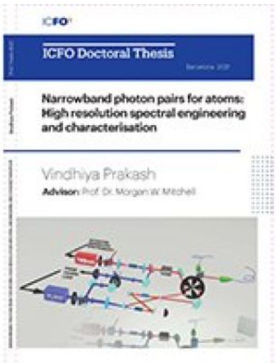
This thesis describes experimental work to generate and characterise single photons and photon pairs, with frequency content suitable for controlled interaction with cold rubidium atoms. We describe a photon-pair source, consisting of a cavity-enhanced spontaneous parametric down-conversion (CE-SPDC) system, followed by Fabry-Perot interferometer (FPI) filters, that produces narrowband photon pairs that have a bandwidth of ? 5 MHz. Both photons from the photon-pair source are matched to the D1 line in atomic rubidium. Type-II phase matching, a tuneable-birefringence resonator and MHz-resolution pump tuning are used to achieve independent frequency control over each photon in the pair with MHz precision, enabling them to excite different hyperfine transitions in rubidium. We have designed and implemented tuneable FPI, also with ~ MHz control over their resonance frequencies, to isolate a single frequency mode-pair from the CE-SPDC source. The filters have ~ 90 % on-resonance transmission and extinguish unwanted frequency components by over 20 dB. The thesis includes predictions of the two-photon spectra at the output of the CE-SPDC source, and also after the filters, based on existing theoretical models of CE-SPDC. We measure the two-photon linewidth, the number of modes in an emission cluster and the spacing between clusters, the second-order cross-correlation and heralded autocorrelation functions, and find good agreement with predictions. We demonstrate independent tuneability of the signal and idler frequencies by atomic absorption spectroscopy with the filtered CE-SPDC output as the light source.

We also report a technique to resolve narrow frequency differences between photons with a high frequency resolution. The technique, which we call autoheterodyne characterisation, can measure the photon-pair joint spectra by detecting the time-correlation beat-note when nondegenerate photon-pairs interfere at a beamsplitter. It implements a temporal analog of the Ghosh-Mandel effect with one photon counter and a time-resolved Hong-Ou-Mandel interference with two. We provide a complete theoretical description of the process and show how the distribution of sum and difference frequencies in the photon-pair spectrum can be obtained from measured correlation functions. Through a power spectral analysis of the correlation measurements, the strengths, linewidths and relative frequencies of the spectral content in the two-photon state is obtained. With this, it is possible to quantify the contribution of undesired frequency modes when a single mode output is required. We analyse the application of this technique to photon-pairs that are produced by narrowband pumping and are strongly anti-correlated in frequency, and to pairs with reduced frequency correlations produced by broadband pumping. Experimentally, we demonstrate this technique using photon-pairs from the filtered CE-SPDC source described in the previous paragraph, that have a frequency separation of ~ 200 MHz. From the results, we quantify the performance of the filters and verify the accuracy of our model for the two-photon joint spectra from this source.

Thursday, December 16, 2021, 10:00. ICFO Auditorium and Online (Teams)

Thesis Director: Prof Dr. Morgan Mitchell

Hosted by: Prof Dr. Morgan Mitchell



Vindhiya Prakash's Thesi Cover