Evaluation of the manuscript by Monica E. Mycroft for the defence of her PhD thesis

The thesis manuscript of Monica E. Mycroft details her investigations on the employ of multi-photon quantum interferometry for applications in quantum communication and quantum metrology. The topic is timely, as it provides valuable contribution to a field under intense development towards real-world applications.

The manuscript is organised in 5 chapters:

Chapter 1 is a brief introduction, mostly sketching the research field of quantum information and then narrowing the theme to quantum photonics. It is probably terse with respect to the standard, but this is a matter of personal tastes.

Chapter 2 introduces quantum photonics more in depth, insisting on current devices, which is quite peculiar and commendable in a theoretical investigation. Again, this is a concise presentation, however it suits the needs of the presentation. Concerning specific comments:

- pg 7: in 2.2 it is not clear whether the demultiplexing refers to the use of a single source;
- pg 9: I would not say that the "JSA is a measure of the modal purity", since it is a function rather than a parameter, thus probably stating "JSA bear signatures of the modal purity" is more fitting'. Also, multiple uses of the same symbol f should be avoided in the equation $f(\omega_s, \omega_i) = f(\omega_s)f(\omega_i)$;
- pg 10: waveguides need not being 'crystallographic structures" as they can also be build in glass;
- pg 11: the presentation of the angle theta is too terse, and, in the end, not that necessary. Probably, this can be presented as the phase of the pair with respect to the pump.

Chapter 3 presents the mathematical tools used throughout the thesis. A comment I have is that the derivation leading from the initial state (3.13) to the amplitudes (3.40), while substantially correct, makes an unusual usage of both Schroedinger and Heisenberg pictures, as both the operators and the initial state is evolved. Probably, one can simply take the general vacuum as the initial state and use Heisenberg's picture only. Concerning specific comments:

- pg 15: beware of a typo in (3.3) ($n/2$ should be $N/2$);
- pg 26: the treatment of loss is correct, but it should be stated explicitly that $\eta = 1 - r^2$ — this result will be used extensively later on;
- pg 27: in the figure the relative phase between the two arms is always zero, unless one has $\theta/2$ on one arm and $-\theta/2$ on the other;

Chapter 4 addresses the first set of original results in the thesis, in particular those on entanglement distribution. The state of the art is very concise, if not laconic, but, in the end, it is effective in presenting what the challenges are. The analysis of the effects of loss on entanglement is thorough and inspects parameters relevant to satellite distribution, which has seldom being considered for multi-photon states. This is certainly an original and substantial contribution. Concerning specific comments:

- pg 30: when presenting the protocol it could be helpful to mention entanglement swapping, which is ultimately what is taking place here.

Chapter 5 discusses the application of the states introduced in Chapter 4 for phase estimation. The focus is on the theoretical aspects, but, quite interestingly, experimental results from collaborators are also included. The results are very relevant for the building of quantum phase sensors with a palpable quantum advantage. Concerning specific comments:

- pg 74: the discussion of the data analysis states that the values of the Fisher information are obtained by means of ‘a model fitted to the measured rates’. It should be clarified if this is derived directly from the theory in Chapter 4, or whether ad hoc procedures have been used and, if so, which ones;
- pg 75: a brief mention is given about global phase estimation. Unfortunately, the advantages of the generalised HB states are not as clear cut as they are mentioned, since there is an inherent ambiguity by multiples of 2π, which demands a more involve treatment that is not part of this thesis. That sentence needs being amended accordingly.
- pg 76: the caption of Fig. 5.8 mentions ‘former’ and ‘latter’ cases with no context; it is clear these refer to a condition with and without quantum interference, but the reader should not be left to guess.

In conclusion M.E. Mycroft has been able to collect and discuss interesting results from her research, and present them with enough clarity and detail. I can then recommend that she can defend her thesis in the *viva voce* examination.

In faith,

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