SASQS Executive Summary

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
TRL	Technology Readiness Level

1 Executive Summary

Current implementations of entangled-photon sources for space are at the verge of reaching very high TRLs. Today we are at a point where laboratory demonstrators routinely achieve performances that mark the transition of the technology from scientific experiments to versatile tools for both fundamental research and commercial applications. The next development step to further raise the TRL of high-performing quantum sources for space is to develop stable and reliable industry-grade implementations that perform consistently. However, this step is currently hampered by the fact that the lab prototypes still need a considerable amount of tinkering, debugging, and experimental optimization to reach their maximum performance, while compact industry prototypes that are derived from them suffer from limited performance.

A key obstacle for obtaining a higher TRL today is that the strategy of using established industrial assembly processes for the production of entangled-photon-source flight models turned out not to be effective. We see the main reason for this difficulty in the fact that state-of-the-art industrial precision optical alignment processes focus on the implementation of classical optics systems and, in general, do not take into account the specific alignment requirements of quantum sources. Entangled photon source alignment requires the monitoring of specific feedback signals that are obtained by quantum measurements as well as parallel manipulation of a number of key degrees of freedom. A systematic approach to bring the integration and alignment procedures for quantum sources from the laboratory to industrial manufacturing is currently missing.

In the SASQS activity, we developed such an assembly and alignment process that enables the manufacturing of high performing entangled photon sources for space applications. We identified the technological requirements to produce space-qualifiable entangled photon sources and developed a step-by-step protocol for their manufacturing. Following an assessment of state-of-the-art assembly and bonding technologies, we quantified the manufacturing tolerances of a reference quantum source. This included the “standard” optical tolerancing of components using ZEMAX as well as quantum mechanical simulations to establish a quantitative connection between optical imperfections/misalignment and entangled photon source performance parameters.

Building on these results, we performed a quantitative comparison of assembly methods. To this end, we simulated various alternative ways to assemble the quantum source, i.e., which component to align and bond before which other component and with what precision. The results allowed us to identify the assembly strategy that leads to the best achievable quantum source performance while being feasible with state-of-the-art bonding and measurement techniques. Based on this optimized strategy, we derived a step-by-step assembly procedure along with the manufacturing precision required for each optical element of the quantum source.