Dual Wavelength Optical System for Multiple Quantum Communication Transmitters in Cubesat Platform

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Abstract

Quantum Key Distribution (QKD) systems will play an important role in future networks for secure data communication, especially with the help of satellite-based nodes. In the scope of the project "QUBE"[1], DLR builds a system of a laser terminal and a fibre-based wavelength combiner which serves as a downlink platform for multiple QKD sources. A previously developed 1/3 U CubeSat laser-communication terminal is adapted for the use of C/L-band wavelength and 850nm[2].

Design Considerations

For a precise beam steering to the optical ground station (OGS), the residual body pointing error is compensated by a fine pointing assembly (FPA) This induces angular displacements to the beam paths inside the optical terminal and therefore can also cause wave-front aberrations as well as angular offsets between the polychromatic transmitted beams. Three scenarios of this are illustrated in Figure 1: An ideal aberration-free system in which the beams have lowest possible divergence and no angular offset (a), a more realistic system in which the divergence is optimised, but the beams point in different directions (b), and a system in which the divergences are adapted to the angular offset (c).

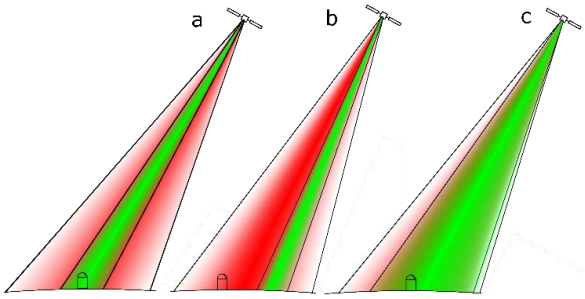

Figure 1: Pointing scenarios for different wavelengths: a) optimal divergences and no angular offset; b) optimal divergences, but angular offset; c) compromise between angular offset and divergence.

Optical Design

Referring to Figure 2, the optical system of a transmitter- (Tx-) and a receiver- (Rx-) system, both using partly a combined beam path, which is separated by a beam splitter (BS). The blue rays indicate the beam path inside the Tx-system: Light from all three payloads is coupled from a fibre into free space and collimated by an achromatic doublet (L1&L2). In the combined path, the beam is steered with a fast steering mirror (FSM) and magnified by a lens system of two achromatic doublets (L3-L6) forming a Keplerian telescope. In the Rx-system, an incident beam pointing from an OGS to the satellite is demagnified, reflected by the FSM and passed through the BS and projected by the lens L7 to a four-quadrant detector(4QD). Between L7 and the 4QD, a prism is used to fold the beam and a filter (FLT) reduces the amount of stray light incident onto the 4QD. This detector is used in a closed loop control together with the FSM for a precise pointing to the OGS during a downlink. Due to the heritage of the laser terminal, the mechanical dimensions for the lens system were constraint and causes the focal lengths of the lenses to be varied only in a small range. Occurring aberrations could be mitigated by the use of aspherical surfaces and the combination of lenses made of a chalcogenide glass with lenses made a heavy flint glass. The optimisation of the overall lenses led to a system with a pointing behaviour comparable to the one shown in Figure 1c.

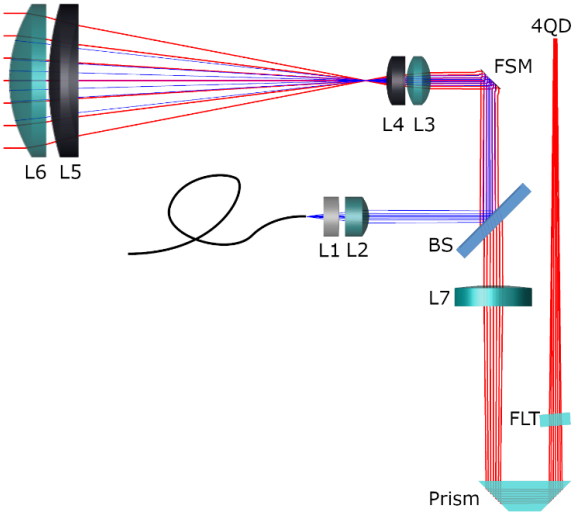

Figure 2: Cross-sectional view of the laser terminal's optical system. The blue and red rays indicate the beam paths of the Tx- and Rx-system, respectivly.

Wavelength Combiner

In addition to the laser terminal, a wavelength division multiplexer (WDM) was specified for the combination of the signals from the two QKD-payloads and the laser communication terminal. For the sake of integrability and complexity of alignment between the payloads, a fibre-based WDM was preferred to a free space system. Figure 3 shows a functional diagram of the WDM. It consists of two cascaded WDMs, each equipped with a microoptical assembly for coupling light from two input fibre into one output fibre by using an interference beam-splitter.

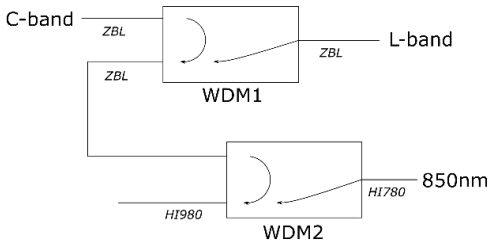

Figure 3: Functional diagram of the WDM with indicated input wavelengths and used fibre types.

Acknowledgements

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References

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