DEVELOPMENT AND TESTING OF PAT SYSTEM FOR FREE-SPACE QKD

Adrián Llanos, CSIC
C. de Serrano, 144, Madrid, Spain
+34674802448, adrian.llanos@csic.es
Pablo Arteaga, CSIC
Verónica Fernández, CSIC

Quantum Key Distribution (QKD) is a cryptographic protocol that leverages quantum mechanics principles to unconditionally and securely distribute cryptographic keys between distant parties. In Free Space, the transmission of quantum states occurs through open air rather than optical fibers. This set of techniques is particularly suitable for satellite-based global key distribution, secure communication in remote or mobile settings (UAVs like drones), and short-distance urban applications. However, Free Space QKD faces significant challenges, such as atmospheric turbulence or alignment issues between the terminals, which can negatively impact the transmission and reception of quantum states. Notably, a critical component in overcoming these challenges is the Pointing, Acquisition, and Tracking (PAT) system [1] [2] [3]. The PAT system ensures precise alignment and stable communication links by continuously adjusting the position and orientation of the transmitter and receiver. Control electronics are crucial for its performance, managing real-time feedback and control loops to maintain alignment despite environmental disturbances.

Due to its pivotal role, we have developed and tested PAT system for a QKD link. This system is divided into two control stages, coarse alignment (outer loop) and fine alignment (inner loop). During the coarse alignment stage, a motorized 2-axis gimbal platform, an IMU, and a CMOS-type camera are used. A closed-loop electronic control is responsible for both searching for the opposite beacon and centering it on the necessary camera point (pointing and acquisition). This loop allows for a general approximation of the desired target through broad and rapid movements. The fine control loop is subsequently activated, which steers the beam via the FSM-PSD control loop. Once both loops have been executed, the nodes are perfectly aligned, and will be continuously monitored to detect deviations and correct them (tracking). Upon testing its performance integrated with the QKD modules in a real field transmission (300 m link), it has been observed that the PAT system has not only enabled and enhanced QKD transmission but have also significantly contributed to the robust operation of the overall system, achieving an average pointing time of 120 seconds and a beam stabilization accuracy of about 50 µrad.

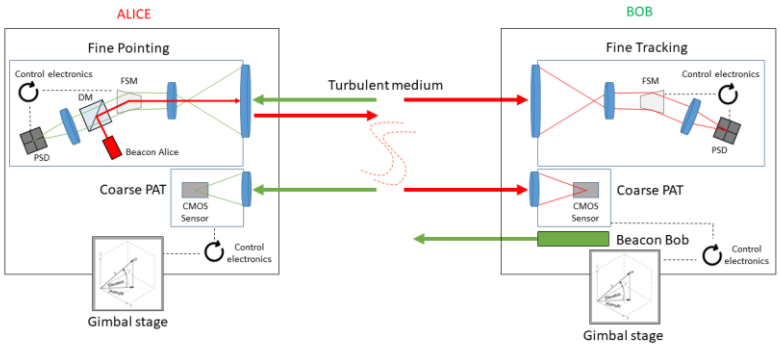

Figure 1 - Scheme of PAT System. PSD: position sensitive device, DM: dichroic mirror, FSM: fast steering mirror, CMOS Complementary Metal-Oxide-Semiconductor.

References

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