Optical distribution board for atom quantum experiments in space

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ABSTRACT

With the arrival on satellites of LIDAR, optical communication, laser ranging, and most importantly quantum technologies, the required optical complexity has increased enormously. In many cases this can be handled by in-fiber devices, however, often the requirements exceed what can be achieved in single mode waveguide devices. If frequency shifting (acousto-optic modulators) or very high extinction ratios are needed, the light has to be coupled out of the fiber onto a free-space breadboard and back into the fiber. The single mode nature of the fibers results in very stringent requirements for the optical breadboard and its components. The PHARAO mission was forced to use active stabilization of many optical components. For LISA Pathfinder the optical components were attached to the breadboard using optical bonding, where alignment errors had to be corrected by re-machining the optical components. These solutions are very costly and/or complex to become commonplace in space.

We report a novel scheme, that allows precise beam-steering for fiber-free space-fiber systems on a Zerodur breadboard with the use of optical wedges and plates. The wedges control the angle and the flat the position of the beam. The key advantage of this method is that the wedgeangle and the plate thickness determine the maximum deviation of the beam and thus the resolution of the adjustment. A resolution of 0.1% is achieved in the Coupling Efficiency (CE) during the alignment process. The cost of the optical breadboards is reduced by a) reducing the complexity of the sensitive components b) simplifying the alignment procedure c) move to a more the more flexible UV adhesive system (compared to hydroxyl bonding). A relaxation of the manufacturing requirements of the mechanical components is achieved by separating the beam steering into coarse and a fine part, thus reducing the number of degrees of freedom required for the beam couplers, mirrors and beamsplitters. This scheme yields highly robust, small optical breadboards for use in space missions, meeting very high stability requirements whilst reducing the complexity of the fiber couplers in terms of manufacturing and assembling the different parts that consist them.

The manufacturing - assembling process of a Zerodur prototype breadboard will be presented and the performance in the presence of temperature fluctuations will be discussed. Thermal cycling tests at a temperature range from 10-40 oC show mean CE of 88% and fluctuations of less than 2% RMS, with only 0.5% stemming from alignment errors. Fluctuations at stable temperature are smaller than 0.2% over 15-30h with mean CE of 89.8%. Large temperature changes and mechanical shocks did not result in any measurable non-elastic changes to the coupling efficiency