Phased array antenna for lasercom: experimental results

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Abstract— **The demonstrator of a 16-aperture receive telescope array, suitable for coherent free-space laser communications, has been implemented and tested. Despite it's large collecting area, the system is able to accurately track an optical source located within the field of view of a single subtelescope. The tracking bandwidth amounts to some 1.4kHz.**

INTRODUCTION

Space borne laser communication requires optical antennas in the form of telescopes. The extremely high gain associated with such telescopes asks for pointing accuracies in the sub-microradian domain. As a result, pointing in free-space laser communication links turns out to be of equal or of even more importance than the task of data transmission and signal detection itself.

For the telescope realization, so far mainly single ("monolithic") telescopes with mechanical fine-pointing mechanisms have been considered [1], [2]. However, arranging several subtelescopes in close proximity and coherently superimposing the subsignals offer many fundamental advantages, such as smaller diameter of optical elements, reduced structural length, inherent modularity, and capability of inertia-free fine pointing [3].

Under contract of the European Space Agency (ESA) we have designed, manufactured, and tested an engineering demonstrator of a phased telescope array to be used in the receive branch of a coherent intersatellite laser communication link. In the following we describe our experimental setup and give a summary of the most important measurement results.

DEMONSTRATOR SETUP

Fig. 1 shows the block diagram of the engineering demonstrator. Sixteen refractive subtelescopes, each having a clear-aperture diameter of $25mm$, collect the incident optical radiation centered at $\lambda = 1064nm$ and couple it into 16 polarization-maintaining single-mode fibers. The subtelescope axes are arranged on a 4×4 Cartesian grid (see Fig. 2). Piezo-electric fiber stretchers allow to introduce phase shifts. Then the subbeams are superimposed by a beam combiner, i.e. a binary tree of 15 symmetric, polarization-maintaining directional couplers manufacured in fiber technology. Both input ports of each coupler carry substantially equal powers. The signal output port nominally carries the total optical input power. The optical power in the control output port of each directional coupler is measured by a power sensor and actively minimized via a control loop driving the pertinent phase shifters. A single polarization-maintaining fiber constitutes the array output interface which can be attached to a coherent optical receiver. Simultaneous minimization of the optical powers within the 15 control output ports of the beam combiner — achieved by a dither algorithm implemented on an ADSP-21020 digital signal processor — gives the maximum optical power at the array output. The total optical power available from the subtelescopes is added coherently and directed to the subsequent receiver. As a result, the array's main lobe automatically follows the direction of the incident wavefront within a single subtelescope's field of view.

MEASUREMENT RESULTS

As optical source simulating a transmitting terminal in the array's far field, we used a fiber-coupled collimator with a clear-aperture diameter of $194mm$. To achieve fast steering of the test beam, the fiber end located in the focal plane of the collimating lens was moved by piezo-electric actuators.

Fig. 3 shows both theoretical and experimental results of the receive characteristic and the instantaneous characteristic. The *receive characteristic* is defined as normalized output power versus angle of incidence in case the angular variations can be compensated by phase control, thus representing the normal mode of operation. In theory it is identical with the characteristic of a single subtelescope. The *instantaneous characteristic* is defined as power versus angle in case the array's mainlobe is fixed, i.e. angular variations are not compensated by phase control. For both characteristics, a very good correspondence between theory and experiment was achieved.

The agility of the array's adaptive tracking has been tested by sinusoidally varying the angle of incidence and measuring the mainlobe axis variation as a function of frequency. The $-3dB$ tracking bandwidth, i.e. the frequency where the amplitude of the mainlobe axis variation is 70% of the excitation, amounts to $1.4kHz$.

The phasing efficiency, i.e. the mean output power reduction factor due to electronics noise within the control loops, remains above 99% for optical input powers as low as $50nW$.

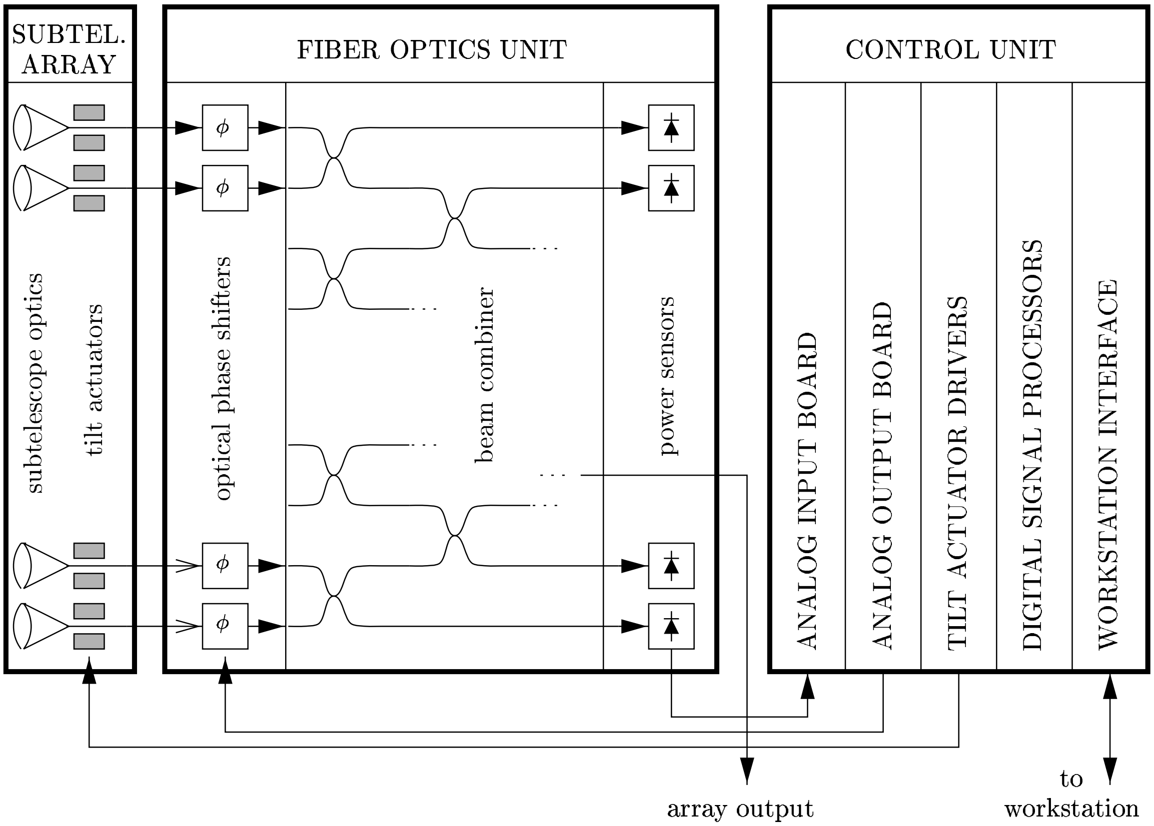

Fig. 1. Block diagram of the experimental 16-aperture receive telescope array

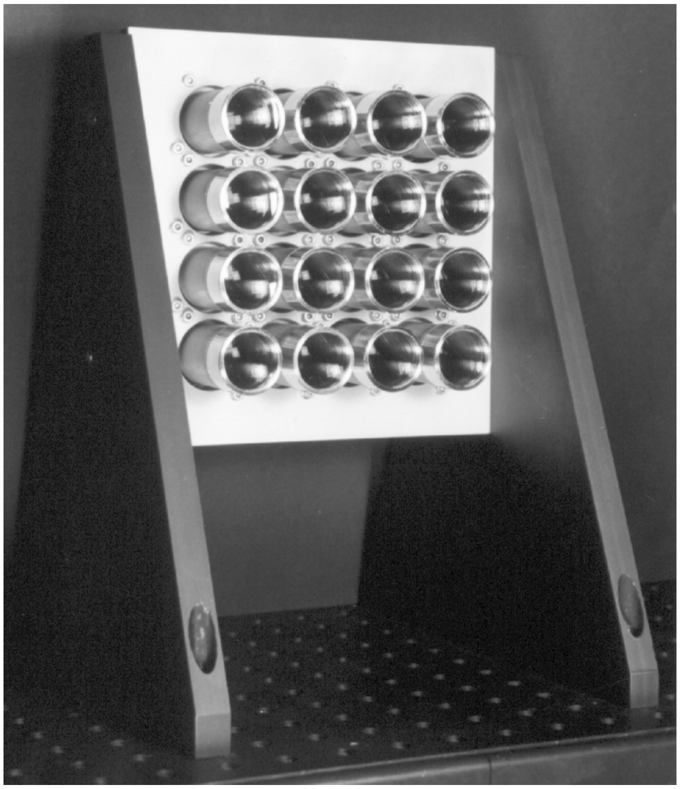

Fig. 2. Subtelescope array

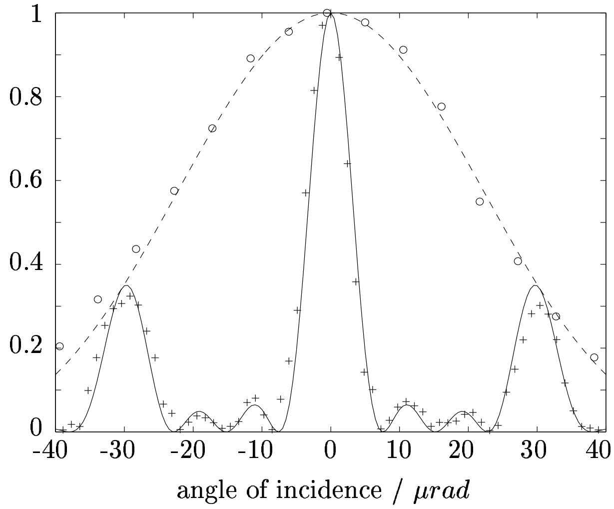

Fig. 3. Vertical cross-section of the receive characteristic (dashed line. . . theory, circles. . . measurement) and of the array characteristic (solid line. . . theory, crosses. . . measurement)

References

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