Optical fiber switch using a deformable mirror for a large number of interconnects.

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1 Introduction

The rapid expansion of fiber optic telecommunications networks requires complex optical switch matrix systems [1]. Simple switches of 1x2 or 2x2 have low losses, because of small size and good passive alignment [2]. For a large number of output fibers (1x1024), the losses are high because of misalignment and aberrations of the optical elements, such as lenses and mirrors. We propose and demonstrate a switch concept with alignment and aberration corrections which has the potential of a 1x546 optical switch with 3 dB insertion loss and less than -30 dB crosstalk. Each switching configuration is optimized once. The parameters are memorized and each connection can then be addressed with its proper corrections.

2 Experimental setup

The concept of the micro-optic fiber switch, using a lens to switch from one fiber to another and a membrane mirror to correct the aberrations, is shown in Fig. 1. A V-groove array of fibers is placed in the front focal plane of the lens, whereas the deformable mirror is placed in the back focal plane. Switching from one fiber to another is possible by moving the lens laterally. The deformable membrane mirror provides adaptive correction of the aberrations and optimization of the coupling efficiency, individually for each position.

We use a commercially available silicon V-groove array with 8 singlemode fibers (λ = 633nm, NA=0.11, ϕ_{core} =3.8μm). The distance between adjacent fiber cores is 250 μm $\pm$ 0.5 μm and the fibers are parallel within 0.1 deg. The lens is an achromat with a focal length of 40 mm. The lateral position of the lens is controlled with a precision x-y stage. The deformable mirror, fabricated at TU-Delft [3], is a silicon membrane (ϕ=15mm) covered with aluminum (see Fig. 2). An array of 37 electrodes placed underneath allows to modify electrostatically the shape of the membrane.

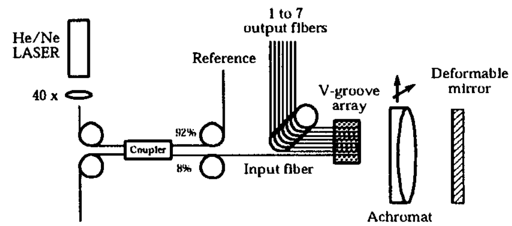

Figure 1: Setup for the investigation of the switching system.

3 Results

First, we used a flat mirror in the back focal plane of the lens and optimized the coupling efficiency by moving the lens laterally and adjusting the distance between the fiber holder and the lens for every connection. The coupling efficiency obtained for each output fiber is shown in Fig. 3. Considering 2 interfaces between the output fiber and air, with 4 % Fresnel losses each, and a reflectivity of 92 % for the mirror, the maximum theoretical coupling efficiency is 85 %. We see in Fig. 3 a clear decrease in the coupling efficiency with increasing distance between the input fiber and the output fibers. This shows the limit for such an optical switch without aberration correction.

One way to overcome this limit is to use a better lens than an achromat [1], and another is to use a deformable mirror which corrects the aberrations. We aimed our investigations at the use of a deformable mirror which can correct not only the aberrations, but also misalignment due to temperature fluctuations and vibrations. A genetic algorithm [4] with a feedback loop optimizes the shape of the mirror. Figure 4 shows a typical optimization curve, measured on the 7th output fiber. Figure 5 shows the reconstruction of the mirror surface after optimization. The main corrections are defocus and tilt. Defocusing is due to the initial deformation of the membrane (bias) and tilt is due to the switch configuration. We obtained coupling efficiencies as good as 73 % (1.4 dB insertion loss) for the 7th fiber and crosstalk of less than -30 dB. Considering the Fresnel losses and the 87 % reflectivity of the deformable mirror, the maximum theoretical efficiency is 80 %.

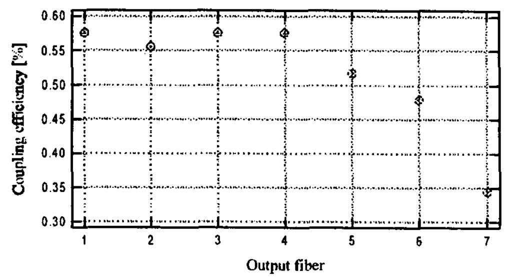

Figure 3: Coupling efficiency using a flat mirror.

4 Outlook

We have demonstrated a 1D asymmetric (Fig. 1) 1x7 optical fiber switch with 1.4 dB insertion loss. A similar system with a 2D-hexagonal fiber bundle can address 168 output fibers. If we arrange the fibers in the hexagonal 2D bundle with 130 μm pitch, instead of 250 μm, the results presented here make a 1x546 optical switch possible.

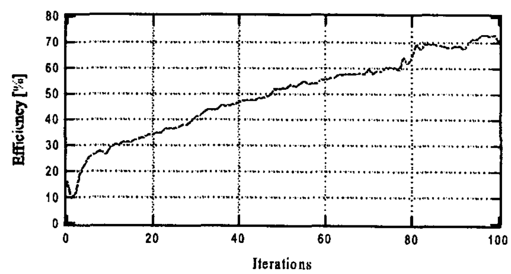

Figure 4: Optimization of the coupling efficiency on the 7th output fiber.

References

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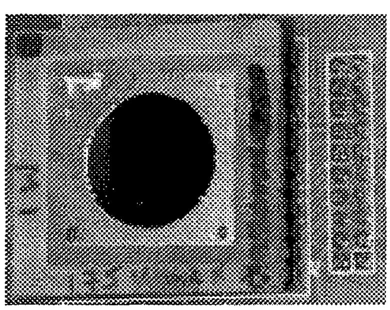

Figure 2: Picture of the deformable mirror.

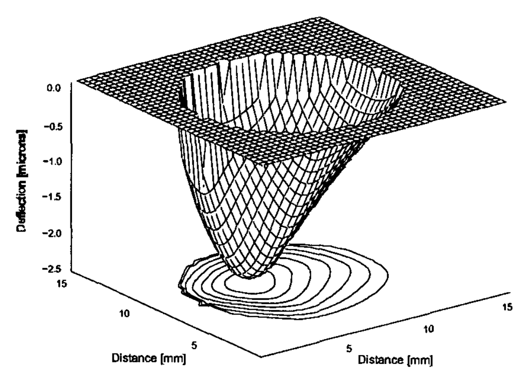

Figure 5: Reconstructed shape of the mirror for optimum coupling.