XY-stage for alignment of optical elements in MOEMS

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ABSTRACT

The alignment of optical elements in a Micro-Opto-Electro-Mechanical System (MOEMS), is of prime importance in order to realize a reliable and low loss system. Fabrication errors or temperature changes deteriorate the alignment accuracy. These errors can be compensated with the aid of an active alignment system. The aim of the paper is to investigate an active system in order to align microlenses and fibers.

A high lateral precision is required for single mode fiber injection, typically better than 1 μm. The alignment along the optical axis is less critical. Our system consists of a microlens placed between one input fiber and one output fiber. The fibers are held in V-grooves and the microlens is mounted on an XY-stage. The lens is fabricated by melting resist technology and subsequent etching in quartz. The mechanical parts are realized by wire electro-discharge machining (wire-EDM). Two piezo-electrical actuators move the flexible bearings of the stage in the X and Y direction. We will present the results obtained with this system and we will discuss its potential.

Keywords: MOEM, Microlens, Telecommunication, Optical switch, Fiber, Alignment.

1. INTRODUCTION

Micro-optical and micro-electro-mechanical technologies have been highlighted during the last few years. Thanks to their potential of batch processing and cheap replication, these technologies are merging to create a new and broader class of micro-opto-electro-mechanical (MOEM) devices.

New concepts of photonic networking are being developed to increase dramatically the data capacity of optical fiber communication networks. A prototype system based on the wavelength division multiplexing (WDM) principle is developed at the IBM Zürich Research Laboratory. It makes possible to transmit multiple data channels simultaneously at different wavelengths over a single fiber. Optical switches bring reconfigurability for transmitters and receivers as well as easy bypassing nodes by using just one redundant fiber (see Fig. 1). Opto-mechanical switches will enhance the versatility of the prototype significantly.

Optical switches are an attractive alternative to electrical switches in electro-optical systems, because of their low weight and immunity to electromagnetic interference, and because they eliminate the need for optical-to-electrical and electrical-to-optical conversion at the switch. Some non integrated switches are already commercialised, but all use big mechanical systems for fiber positioning and are extremely expensive. Optical switches that utilize micromechanical switching elements are best suited for integration (low price mass production); they can provide high contrast, large bandwidth and have multiple wavelength compatibility. The aim of our work is to develop a fiber optical switch to be used in telecommunication ring networks. In order to have a reliable and low loss switch, the optical elements (lens, fiber) have to be aligned with a high accuracy. Two different approaches are mentioned in the current MOEMS literature: passive alignment and active alignment of the components. The passive alignment is realized once, generally during the fabrication process.

The active alignment process is more complicated as the adjustment of the optical elements is realized in real time, looking always for the best position. Nevertheless, active alignment helps to considerably reduce the system tolerances (fabrication errors, stability). The aim of this paper is to investigate an active system in order to align microlenses and fibers.

For that purpose, we investigated an XY-stage which holds all elements of the system.

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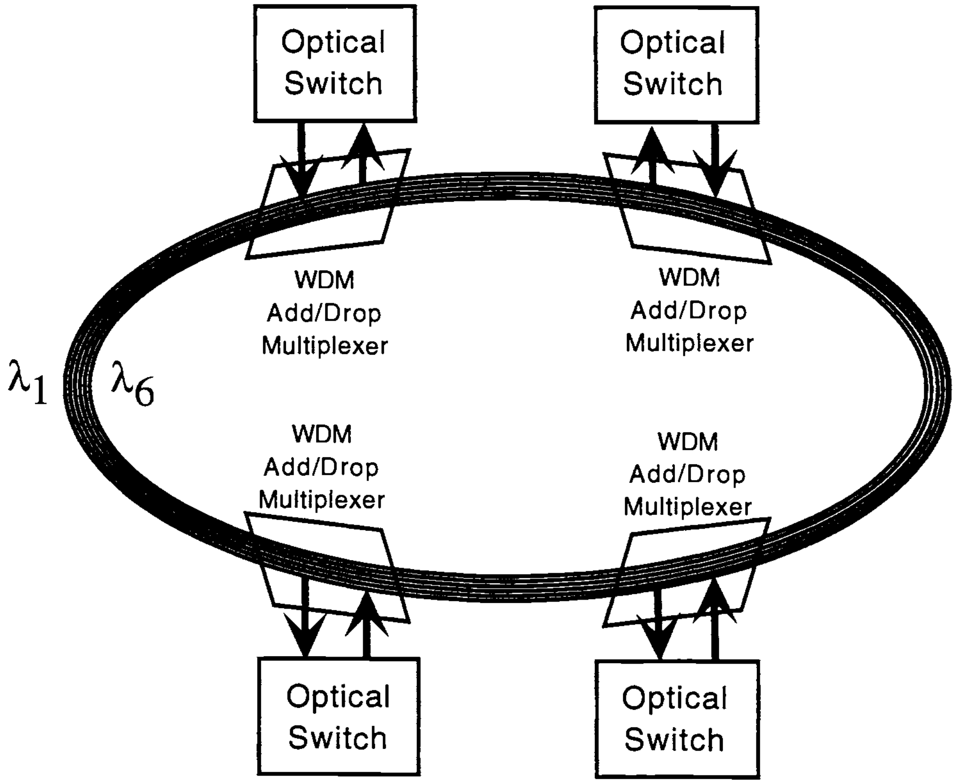

Figure 1. WDM ring network.

2. XY-STAGE

The XY-stage is realized in one steel block 10x20x28 mm^3 by wire electro-discharge machining (wire-EDM).[1] Figure 2 shows the stage with the flexible bearings. The bearings allow displacements of 100μm in the X and Y directions. The flexion is continuous and has a very good repeatability.

3. EXPERIMENTAL SETUP

We realized the experiments at a wavelength of λ=633nm. Our system consists of a microlens placed between one input fiber and one output fiber. The distance between fiber and lens is twice the focal length (2f) in order to have a 1x1 imaging (see Fig.3).

The fibers are single mode fibers with a core diameter of 5μm. The fibers are held in V-grooves with a small cylindrical magnet (see Fig. 4). The microlens are fabricated by melting resist technology and transferred into quartz by plasma etching.[2] Their diameter is 245 μm. Two different focal length were fabricated: f_1=410 μm (height h_1=41.5 μm) and f_2=885 μm (height h_2=19 μm). The quartz substrate is mounted on the XY-stage as shown in Fig. 4. Two piezo-electrical actuators move the flexible bearings of the stage in the vertical and lateral directions by 60 μm and 90μm, respectively.
The fibers are mounted on a translation stage (Fig. 5) for the longitudinal adjustment along the optical axis.

4. RESULTS

A high lateral precision is required for single mode fiber injection, typically better than 1 μm. The alignment along the optical axis is less critical. Figure 6 and 7 show the laser beam (near the image plane) after passing the microlens. In Fig.6 the position of the fiber along the optical axis is adjusted. In Fig. 7 the lateral position of the microlens is

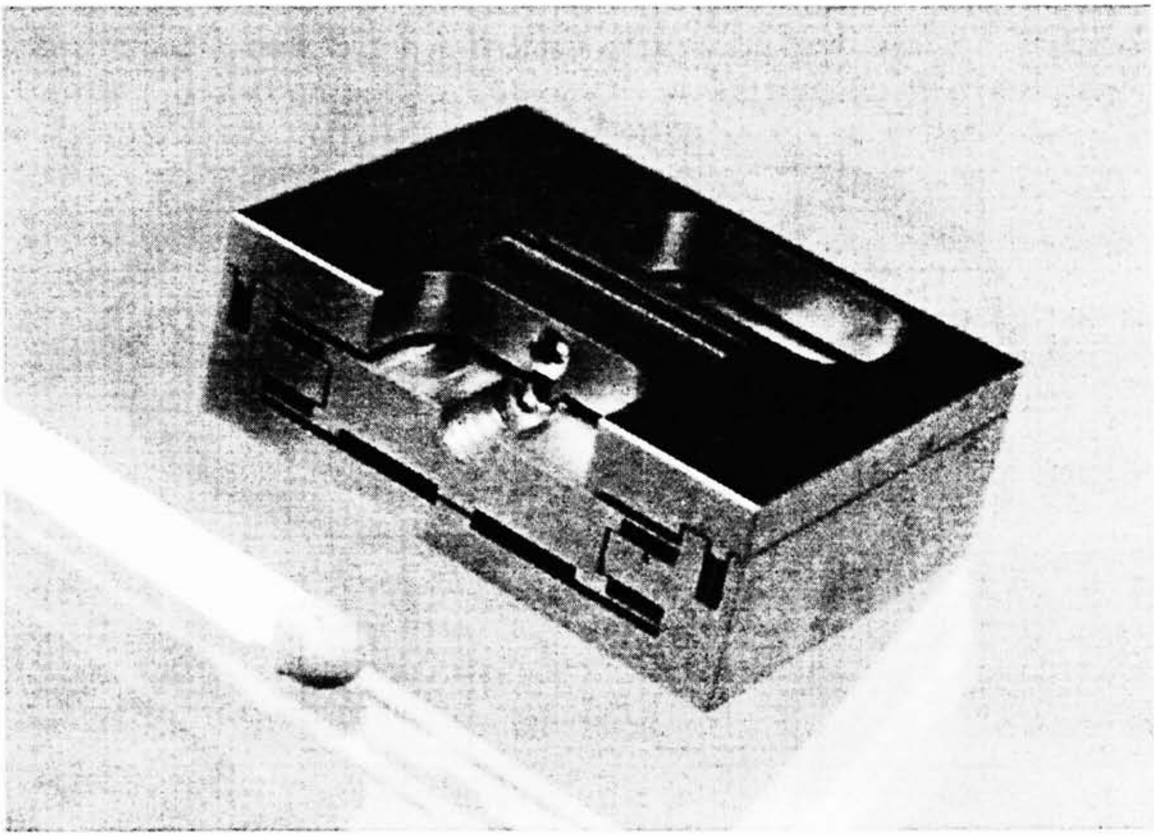

Figure 2. XY-stage fabricated by wire electro-discharge machining (wire-EDM).

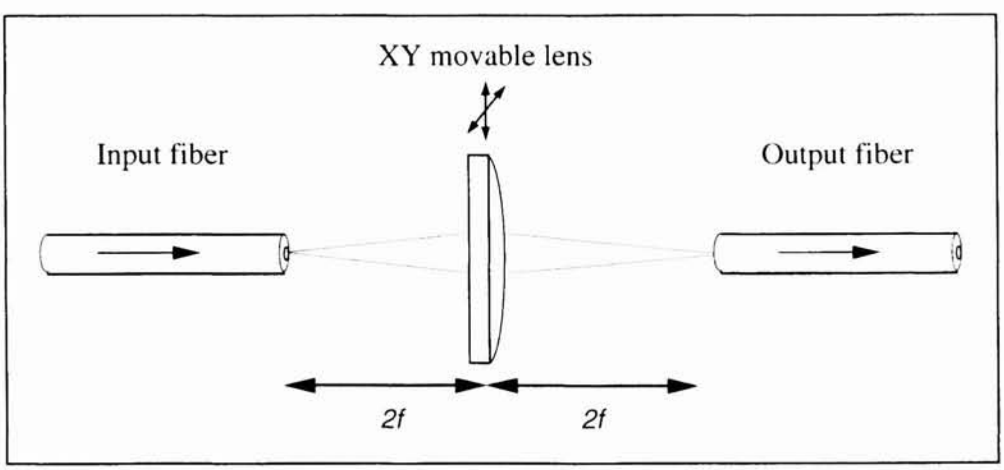

Figure 3. Setup of the coupling system. The lens can be shifted in x and y direction.

adjusted. 77% of the light passes through the lens. The main losses are due to reflections at the interfaces and to the lens aperture.

The deflection angle showed in Fig.7 is ± 6°.

After the re-injection into the output fiber, we measured an efficiency of 33% (input fiber-microlens-output fiber).

5. CONCLUSIONS

We investigated an active alignment system to be used in a micro-opto-mechanical system. This system showed promising for a single mode fiber coupling. The actual system contains all elements for a self-aligning system, but the system is not yet independent of a user. Thus, the next step will be to realize an automatic system using a feed-back loop. Afterwards, we will extend the system to a 1x3 monomode fiber switch (Fig. 8).

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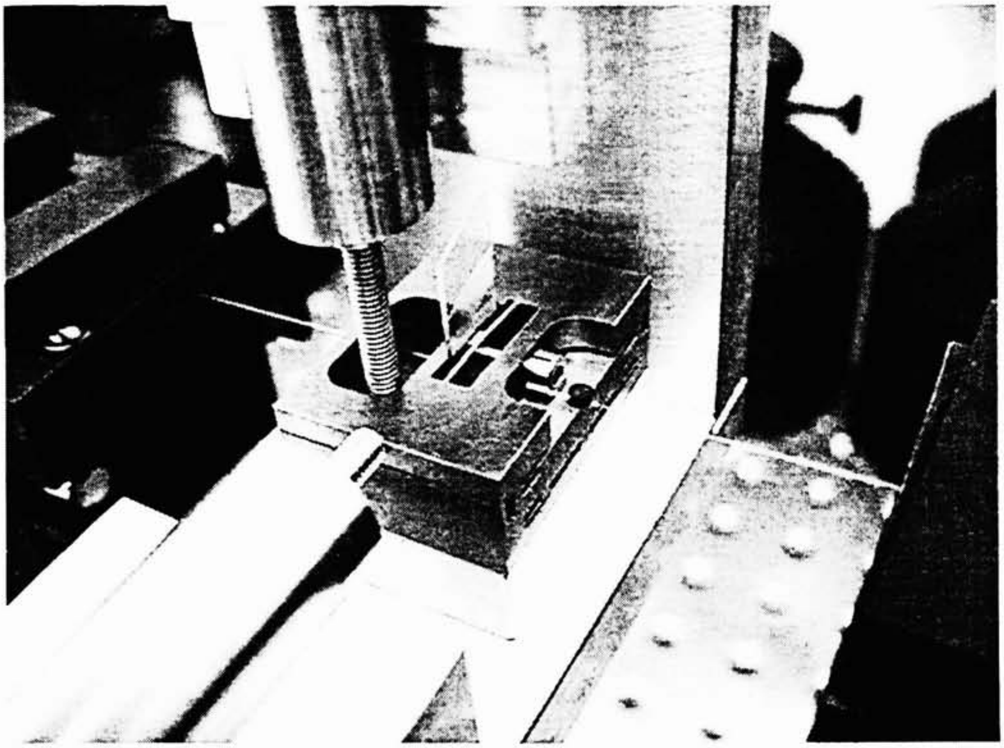

Figure 4. Detailed view of the experimental setup with the input fiber and the output fiber, the two actuators and the quartz substrate of the microlens.

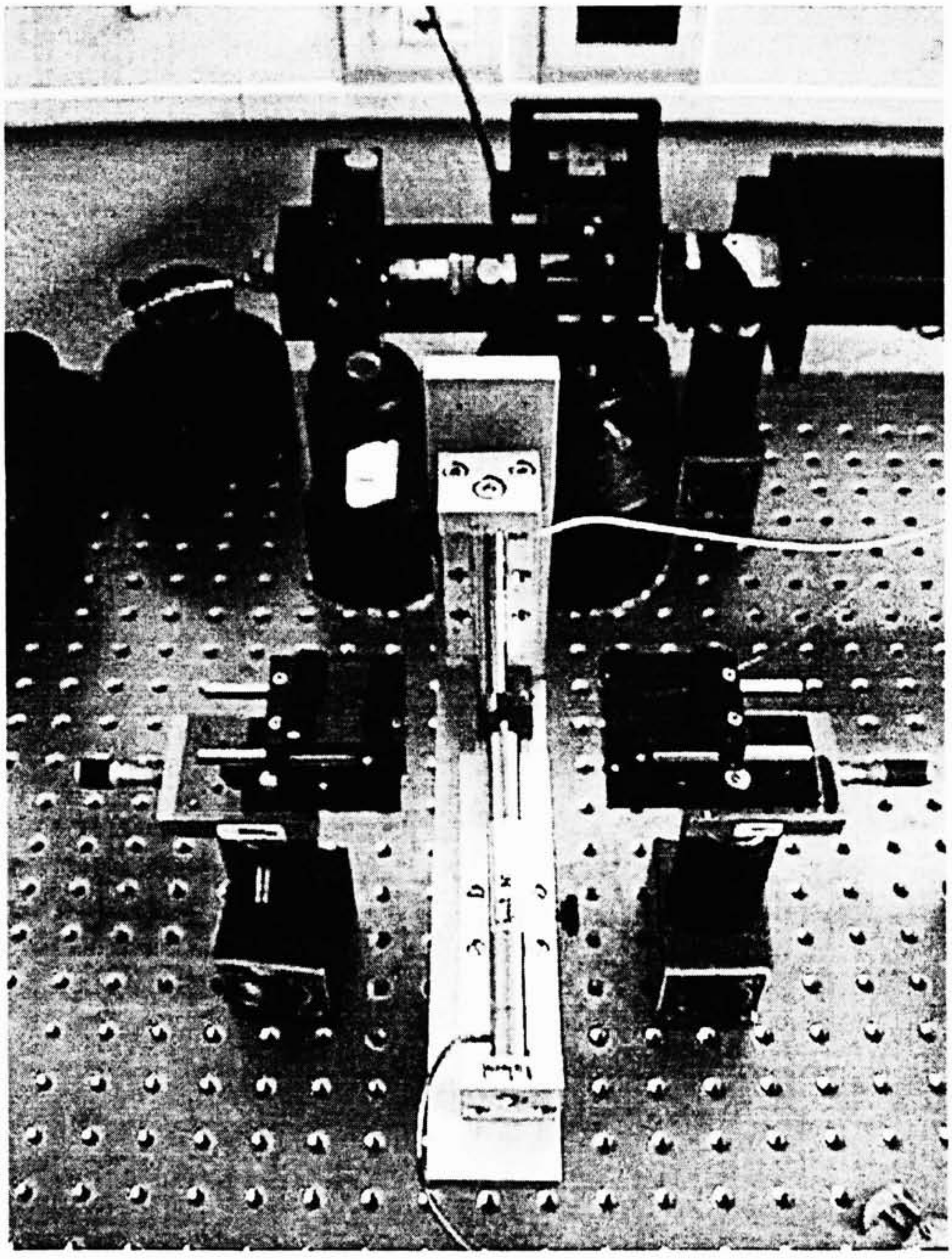

Figure 5. View of the XY-stage with the two piezo-electrical actuators and the two translation stages for the fibers.

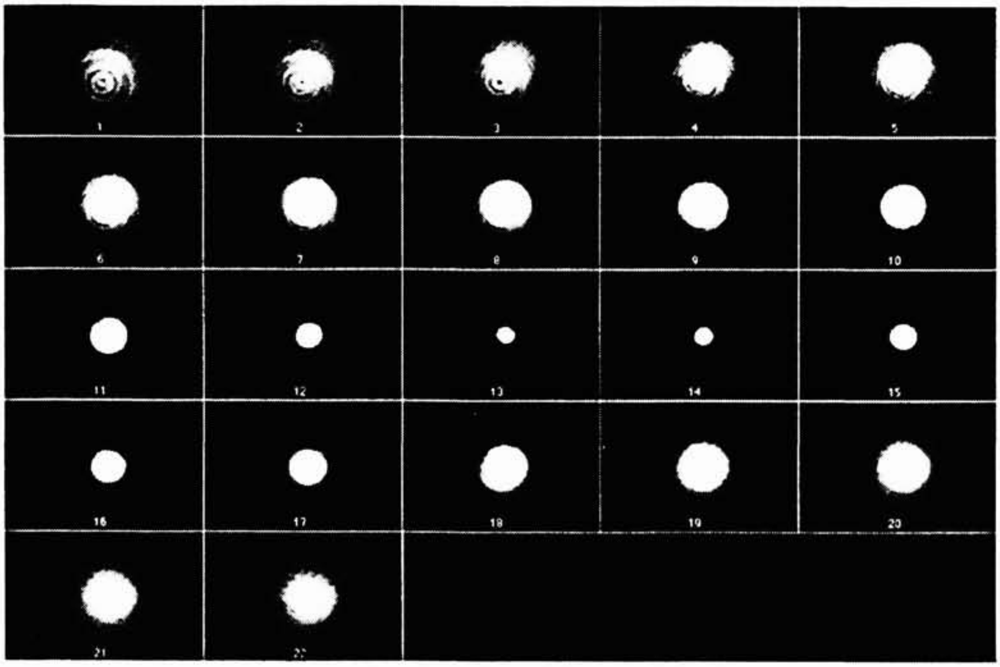

Figure 6. Image spot while adjusting the longitudinal position of the fiber.

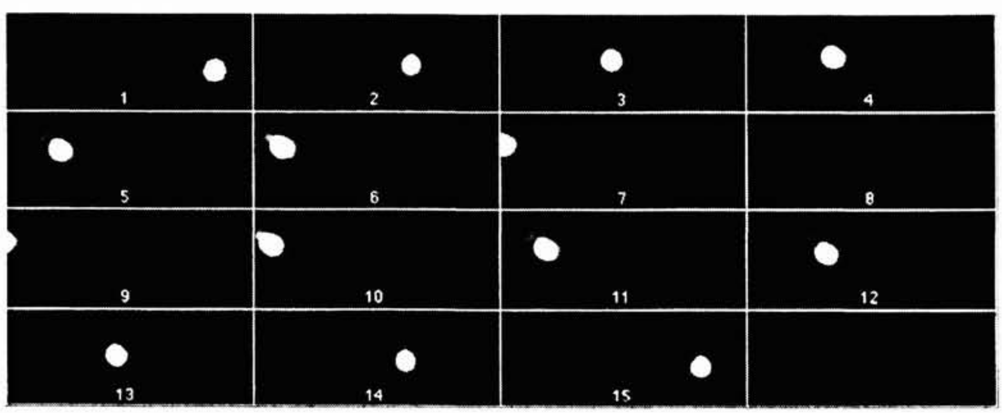

Figure 7. Image spot while adjusting the lateral (left-right-left) position of the lens.

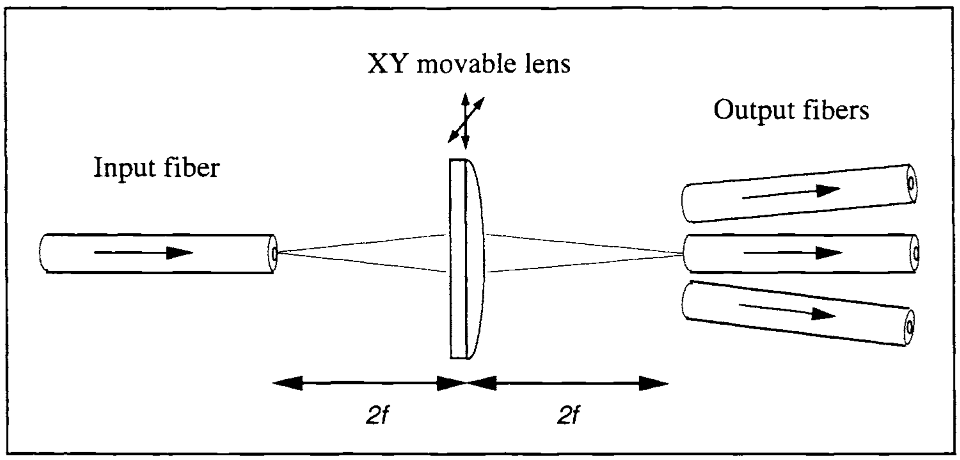

Figure 8. Setup of a 1x3 switch.