Novel Automatic Alignment of Specialty Optical Fibers

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ABSTRACT

This paper presents the development of an automatic alignment system for specialty optical fibers. Based on a XY coordinates system, the alignment is achieved by the control of stepping motors through displacement algorithms. A hexagonal shape arrangement of SMF´s fibers generates a map location of the spot light. This photo-detection system enables to analyze the launching of the beam into the fiber. Through an USB based PC interface and software to automate the alignment process the device's performance has been improved in time and in optical coupling efficiency. The results obtained are 2 or 3 seconds in the alignment process and roughly 80% coupling efficiency.

Keywords: Optomechatronics, automatic alignment, fiber optics.

1. INTRODUCTION

Automatic alignment systems play an important role in various areas of technology development. In the field of research and development, mainly in the field of optics, high precision mounts are required for alignment of experimental arrangements with micrometric displacements or even nanometric [1,4]. The process of alignment of optical systems require a considerable time even for skilled personnel. Moreover, the implementation of these systems is useful for applications in diverse areas such as laser materials processing [2,3], industry, military, medical operations for high precision optical recording systems, etc. Automatic alignment systems require, in one hand, sensors that detect the signal and a system that process it, in order to align at the right position [5]. In our system, the sensing is replaced by reading signals through an arrangement of single mode fibers to locate the spot and optimize the performance of our whole device. This automation system brings a fast, economic and flexible way to improve the alignment process than commercial solution based systems.

2. THE ALIGNMENT

The alignment system comes from the need of optimization in the process of launching of a laser beam into an optical fiber. It is considered the alignment of a laser beam into a specialty optical fiber. The process starts by a 2-axis-dimension scanning of a system of fiber based photo-detection which search and find signal intensity in at least one of the fibers and through a location analysis, it will align the fiber to the right beam axis.

2.1 The Alignment System

The system consists of a CPU that through one computer software sent commands to an electronic control device via USB link as is seen in Fig. 1. The control device handles two stepping motors assembled to a XY positioning mechanical commercial system over which is mounted a hexagonal shape arrangement of fibers to photo-detect the light. The USB interface after reading the signal can control the translate mechanism by computing the reading data. Subsequently, the system was tested to align an incident laser beam.

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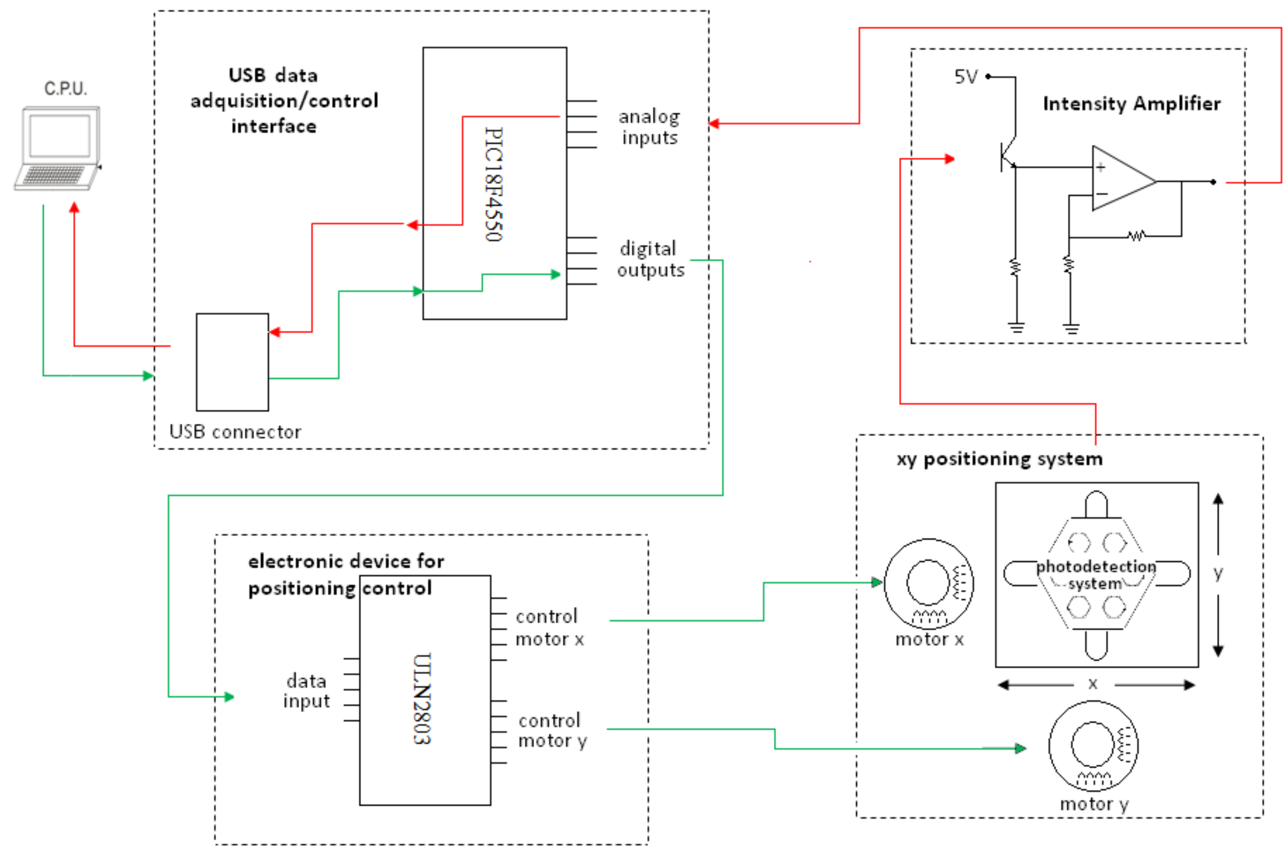

Fig 1. Description of alignment system's device.

Photodetection system

The system is based on a hexagonal geometric shape arrangement of SMF´s fibers as illustrated in Fig. 2. As it can be seen, the target fiber is located at the center. The hexagonal arrangement allows a bigger area for the light detection and a more precise location of the axis of the spot.

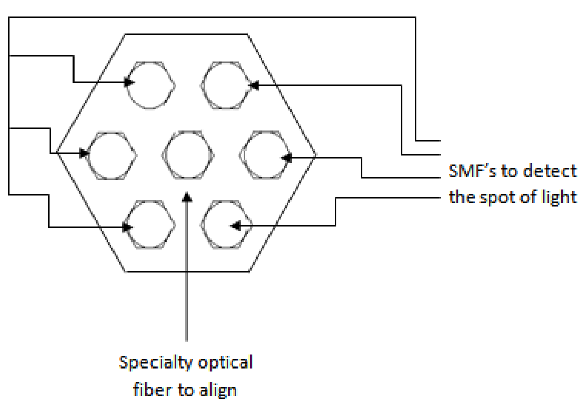

Fig 2. The fiber based photo-detection system

The fiber arrangement is connected to the measuring device that read the power intensities of each fiber. When a signal is detected in any fiber, the intensity information is sent to the CPU together with the coordinates of the receiving fiber. This information enables to micro-stepping movements to realign the whole fiber system and to get the maximum power intensity in this desired fiber. Table 1 illustrates the mapping in power of a laser beam.

Fiber No	coordinates	intensity
A	(x_A,y_A)	I_A
B	(x_B,y_B)	I_B
C	(x_C,y_C)	I_C

Table 1. Expected response of each fiber

The measurement of intensity in the arrays of fibers allows better localization of the axis of the light's beam through the hypothesis of a Gaussian distribution profile as it is well know that for a Gaussian beam has a maximum localized.

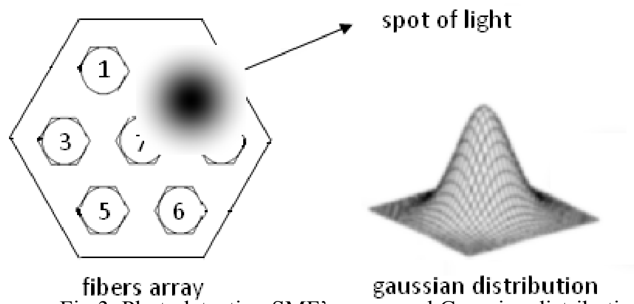

Fig 3. Photodetection SMF's array and Gaussian distribution

Intensity amplifier

Together with the photo-detection system, this feedback device is used to measure the intensity from each fiber and sends the data to the acquisition/control card. This device works through 2 internal stages: in the first stage, it takes measurements of intensities from each fiber using an array of photo-transistors. The second stage consists in the signal processing. Here, the signal is amplified from the photo-transistors and adjusted to be processed with the acquisition/control interface.

The software

The software was built to run Linux operating system, additional this program brings the user a manual control of the alignment process through a mouse scroll wheel interface, where every single wheel click moves the fiber array platform. This software program generates plots of the measured intensity of each fiber and decides how many steps the micro-motor must do. It brings a more precise control on maximizing the insertion of light in an optimum time.

3. EXPERIMENTAL SET UP AND RESULTS

Fig. 4 shows the experimental set up which consists of a 630 nm He-Ne laser used as pump, a fiber array, a specialty optical fiber, two stepping motors, and one interface.

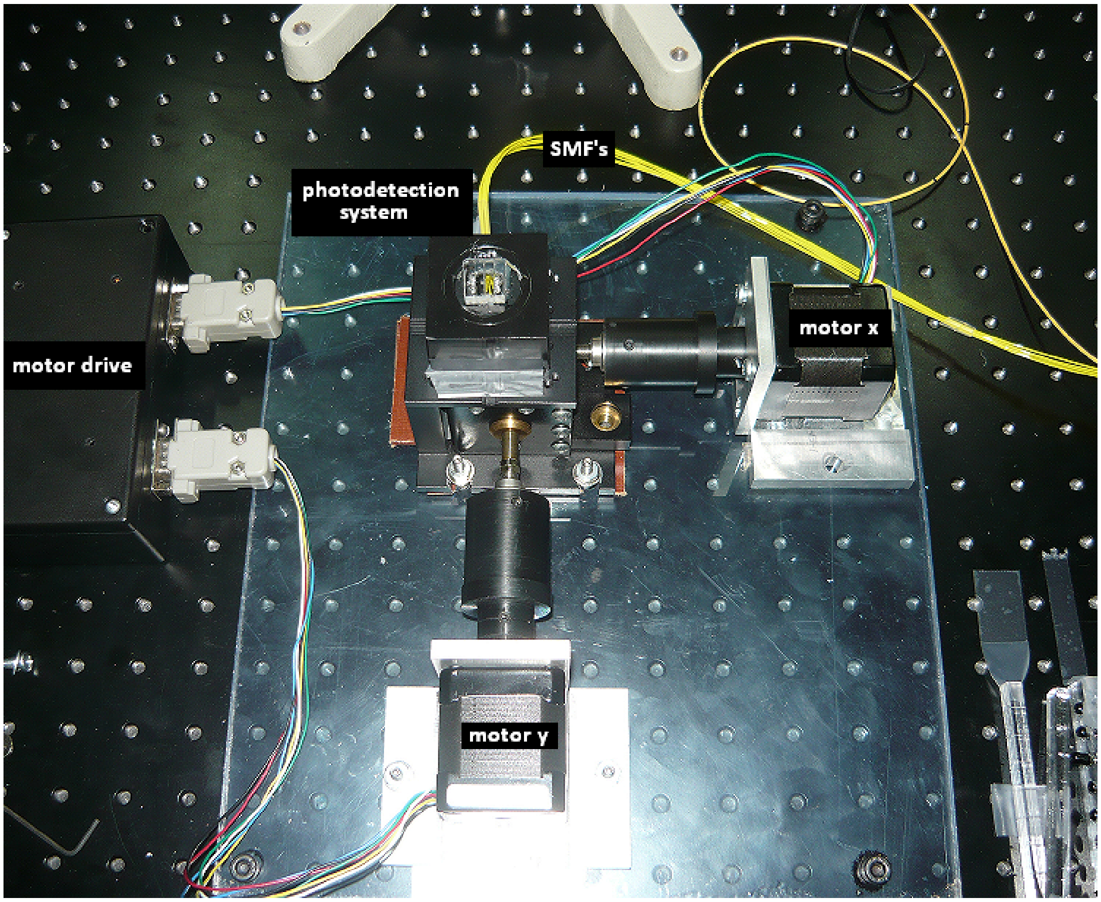

Fig 4. Experimental set up.

3.1 Procedure and results

We align manually the axes of the laser light and the fiber in order to maximize the percentage of light coupled. Afterwards, the system was tested in automatic mode by measuring the achieved alignment and its working time. These results of automatic alignment were compared with manual mode. Although the coupling efficiency in the manual mode is slightly higher, the average time for the process is significantly short. The target fibers can be any of type, such as, double clad fibers, multimode fibers, polarized fiber, highly nonlinear fibers, etc. Comparing with commercial devices for automatically aligned, it was found that the materials used in our proposed are considerably low. The system results to be robust, replicate and reliable. By including extra axes in our system, it will allow us expanding its functions to 3 or more axes.

Operating mode	**Average intensity (V)**	**Relative alignment (I_n/I_{max})**	**Average time (s)**
Manual	I_{max}	0.95	560
Automatic	I_1	0.8	2

Table 2. Experimental Results (coupling efficiency and time of alignment)

3.2 Conclusions

It was proved the efficiency of our system by the alignment process and enable us times that runs from 2 to 3 seconds for an optical power coupling efficiency of 80%. The cost for the whole systems is low when compare with a conventional automatic alignment system. The reliability of our system permits to accelerate the process of our research, focusing all the efforts only in the analysis of the phenomena to study. It is intended to optimize our system and expand its functions to 3 axis alignment.

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