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Integrated Microprisms Matrix for Coupling a Laser Beam in Microfluidic Systems †

Aleksandra Pokrzywnicka * and Rafał Walczak

Department of Microsystem Electronics and Photonics, Wroclaw University of Science and Technology, 50-370 Wroclaw, Poland; rafal.walczak@pwr.edu.pl

* Correspondence: aleksandra.pokrzywnicka@pwr.edu.pl; Tel.: +48-320-49-94

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Abstract: It is still a challenge to integrate the optoelectronic technology in microfluidic analytical systems, due to the complex alignment of the optical components within the microchip, or expensive and complicated methods of their fabrication. In this paper, inexpensive, glass microprisms matrix, with high quality surface and precise 54.7° reflection angle is presented. Fabrication and integration of optical components into the substrate is done using conventional microfabrication techniques such as soft lithography and anode bonding. The results of beam intensity measurements propagating within the glass substrate are presented, showing the possibility of controlled coupling of the beam into the substrate using integrated glass optical structures for microfluidic systems.

Keywords: integrated optical microstructures; microprisms matrix; microengineering

1. Introduction

The optical detection techniques have been integrated in microfluidic systems for analyte analyses, among others, due to non-invasive nature of measurements [1,2]. Introduction of the laser beam by edge coupling using the waveguides requires unambiguous and precise alignment of optical fiber within the structure and with respect to the edges of the microfluidic channels. The optical coupling components such as prisms and microlenses can be integrated into microchip by relatively expensive femtosecond laser ablation, although with the surface roughness of structures. There is still a need for low-cost fabricated and integrated with a lab-on-a-chip optical detection mechanism. In this paper, for the first time, an integrated matrix of glass microprisms allowing the coupling of the laser beam to the glass substrate is presented.

2. Materials and Methods

The microprisms matrixes were fabricated in two main stages: the first involves the formation of silicon replica of microprisms and the second concerns fabrication of the appropriate glass microprisms by bonding the glass substrate with silicon wafer with anode bonding in a vacuum, then forming optical structures under the effect of annealing and revealing microprisms by selective etching of silicon substrate in KOH solution. The series of matrix configurations, with high quality of the edges, were fabricated to determine the optimal geometry of the optical structures for coupling the laser beam into the glass substrate (Figure 1).

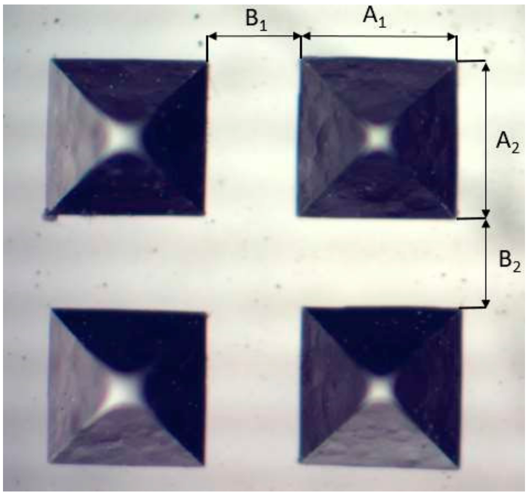


Figure 1. The microscopic photo of the glass microprisms with determined geometric dimensions (A_1, A_2, B_1, B_2).

The dimensions of the base sides of the structures (A_1 and A_2) and the distances between the prisms (B_1 and B_2) were taken into account. Within matrix configurations two different heights of the microprisms were taken into account 350 and 250 μm (Table 1).

Table 1. Various geometrical configurations of the glass microprisms matrix.

Matrix Configuration	Height [μm]	$A_{1,2}$ [μm]	$B_{1,2}$ [μm]
A	350 ± 15	500 ± 10	250 ± 10
B			300 ± 10
C			350 ± 10
D			400 ± 10
E	250 ± 15	350 ± 10	150 ± 10
F			200 ± 10
G			250 ± 10
H			300 ± 10

3. Results

A series of measurements of the intensity of the laser beam propagating through microprisms and glass structure to its edge was carried out for different angle of incident ranging from 15° to 90°. A reflective filter with optical density 1.0 was placed after the laser diode with a wavelength of 635 nm. Intensity of the beam propagating through the glass substrate was measured at the edge of the substrate using miniature spectrometer (Ocean Optics). The tip of the optical fiber has been permanently positioned perpendicular to the substrate surface. (Figure 2). Reference measurements were also performed for the glass substrate without a matrix microprisms. The intensity of the beam propagating through the reference glass substrate were below 5000, regardless of the incident angle of the beam.

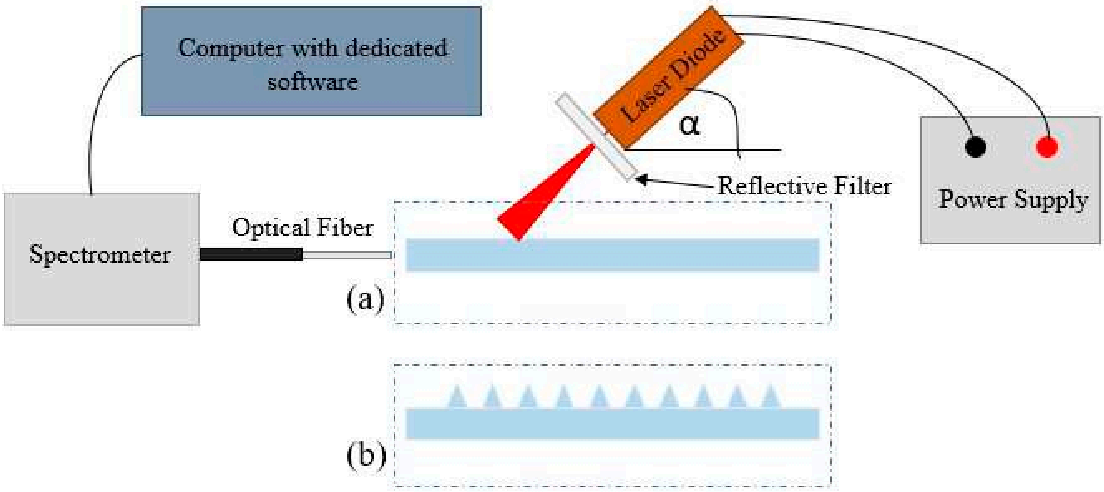
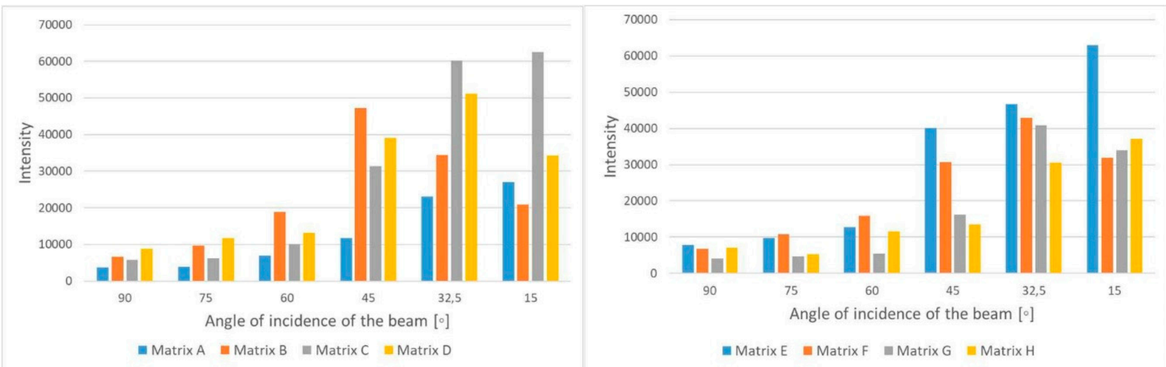


Figure 2. Scheme of the measuring station for testing the quality of the laser beam coupling: (**a**) in the reference glass substrate, and (**b**) glass substrate with integrated microprisms matrix.

It was noticed that by alternating the matrix configurations and the angle incidence of the laser beam, it is possible to control the intensity of the beam propagating through glass substrate. The highest intensity values, irrespective of the geometry, were obtained when the beam fell approximately at right angle to the surface of the microprisms inclined by 54, 7°, i.e., when the beam was inclined to the ground by 45, 32.5 and 15 degrees (Figure 3).



(**a**) (**b**)

Figure 3. Dependence of the light beam intensity measured at the edges of the substrate for different angles of incidence (α) of the beam on the glass surface for various configuration of prisms' matrix (**a**) of height 350 µm and (**b**) 250 µm.

4. Discussion

It is possible to couple the laser beam in glass substrate with integrated microprisms matrix without the need for a precise waveguide set-up or expensive and complex fabrication techniques such as femtosecond laser ablation. Such microstructures can be used in microfluidic systems for optical detection technologies such as fluorescence detection of cells or other biosensing applications.

Author Contributions: R.W. conceived and designed the experiments, A.P. fabricated all microstructures, performed experiments, both authors analyzed the data, and A.P. wrote the paper.

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Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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