DEVELOPMENT OF MULTIMODE INTERFERENCE BASED MULTICHANNEL INTEGRATED LAB-ON-A-CHIP BIOSENSOR

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Introduction

In recent years the use of biosensors has had a big impact on the successful investigation of any research field and almost the entire biomedical analysis nowadays is performed by employing bioassays or biosensors. Biosensors are used to detect and measure the presence of a specific analyte by means of a recognition system which translates information from analyte concentration into a chemical or physical output signal. They offer an accurate measurement and can be easily integrated within microprocessor electronic circuits, thus allowing an easy computation of signals. In this paper is presented a new design and realization of a multichannel integrated optical interferometer biosensor device based on Multimode Interference (MMI) waveguides. This biosensor posseses the right features to be a successful one, such as high sensitivity toward the analyte to be analyzed, stable, robust, accurate, easy-to-use, cost-effective, fast etc.

Design and realization

The original biosensor on which this research is based was developed by Ph.DAurel Ymeti et al. at MESA+ Institute for Nanotechnology at the University of Twente. It is based on Young's Interferometer (YI) and combines the optical output from four channels to form interference fringes on a detector screen [1], such a CCD camera, as shown in figure 1.

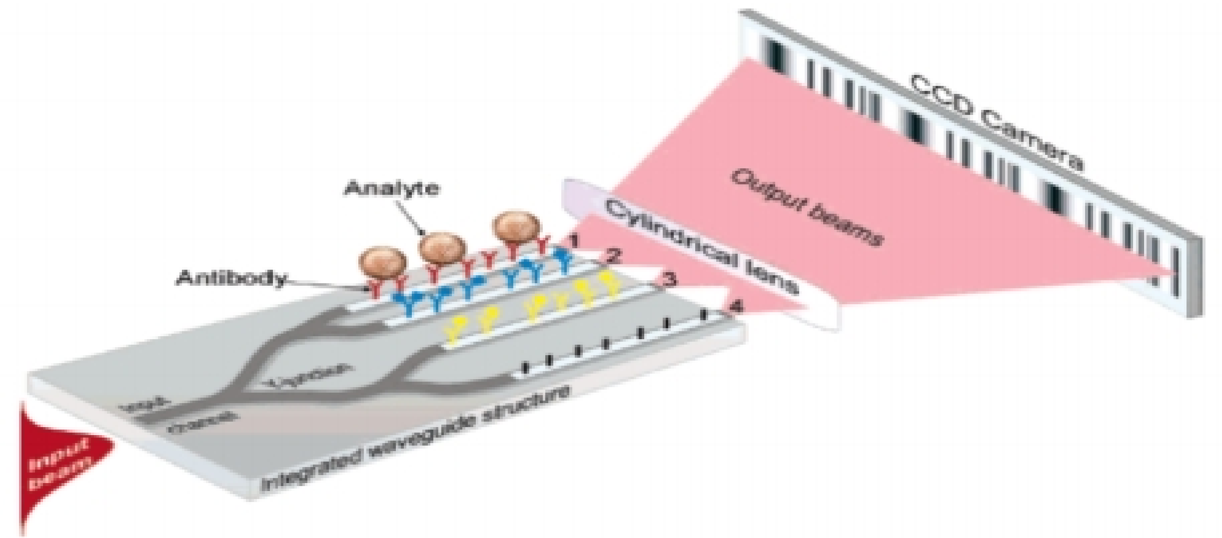

Figure 1. *Schematic representation of the four-channel integrated optical YI biosensor:* ***1, 2*** *and* ***3*** *indicate the measuring channels, and* ***4*** *is the reference channel.*

This biosensor uses three Y-junctions to split the input light into four output channels. First three of the output channels act as measuring channels and the fourth is used as a reference channel. Sensing is accomplished by measuring the shift in phase of the output beams due to the changes in the binding surface (e.g., through antibody-antigen binding). So this biosensor can make three measurements simultaneously and independently from each other.

In the new design of this biosensor the input light splits by using symmetric interference [2] effect at the first MMI waveguide. This effect offers equal splitting of the input light in a shorter distance compared to the Y-junctions.

In order to gain a full insight understanding of the multimode interference effect and the self-imaging phenomena in multimode waveguides, a full-modal propagation analysis will be used. This method decomposes the input field into all guided mode fields, propagates each of these modes independently, and calculates the output field by recombining the propagated mode fields.

The central structure of an MMI device is a waveguide designed to support a large number of modes, as shown in figure 2.

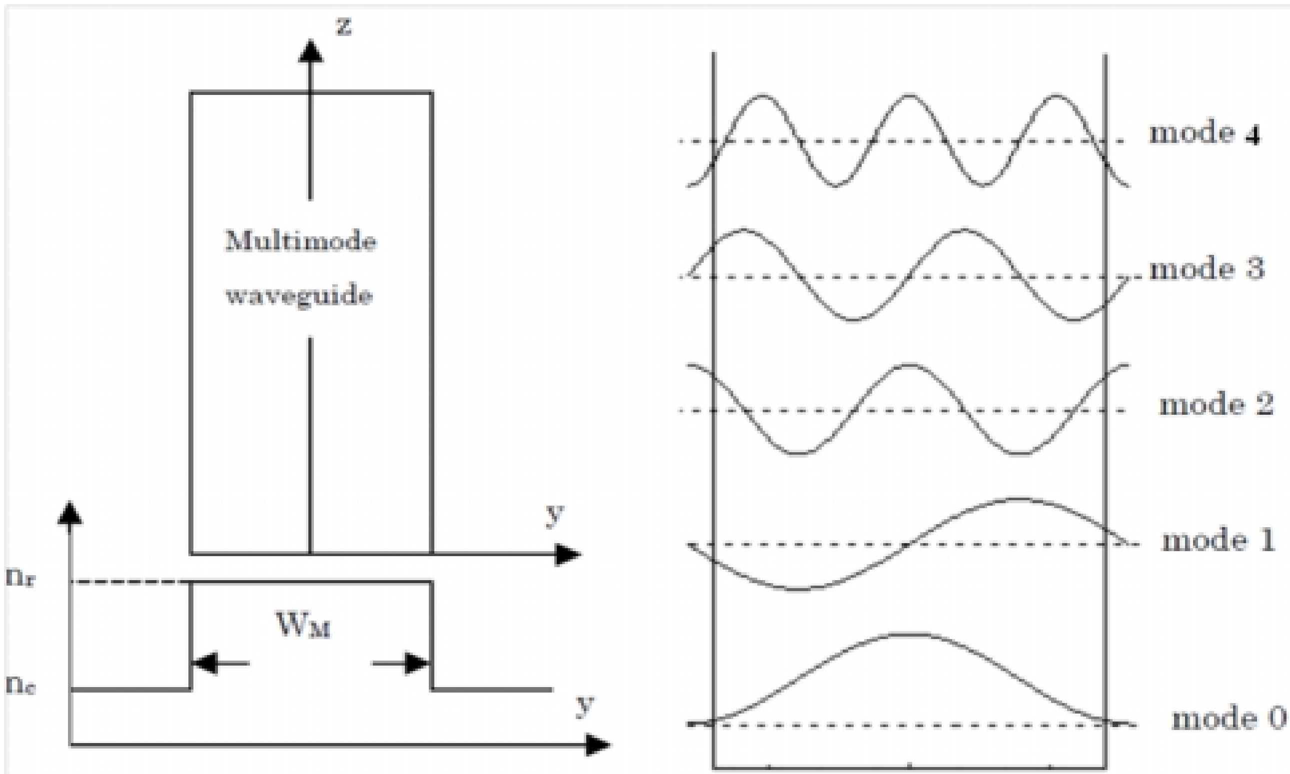

Figure 2 *Step-index multimode waveguide, refractive index distribution and lateral field profiles of the first 5-guided modes of the multimode waveguide*

Using self-imaging effects by symmetric interference, splitters 1xN can be produced, having very good optical parameters, where the branching of the input field is realized over a very small area of a few hundred μm [3].

The new biosensor is composed of two MMI waveguides one after another, as shown in figure 3.1. In order to have symmetric interference input light is launched at the center of the first MMI device. By using *symmetric interference* the splitting of the input light is done in a shorter distance compared to the use of Y-junctions. The parameters of the first MMI waveguide are defined in order to take five replicas in the output waveguides. In each of the output channels a sensing window will be created. In this way we will have 4 measuring channels and one reference channel, thus increasing the throughput of the system. The design and all the parameters for this biosensor are shown below.

Design

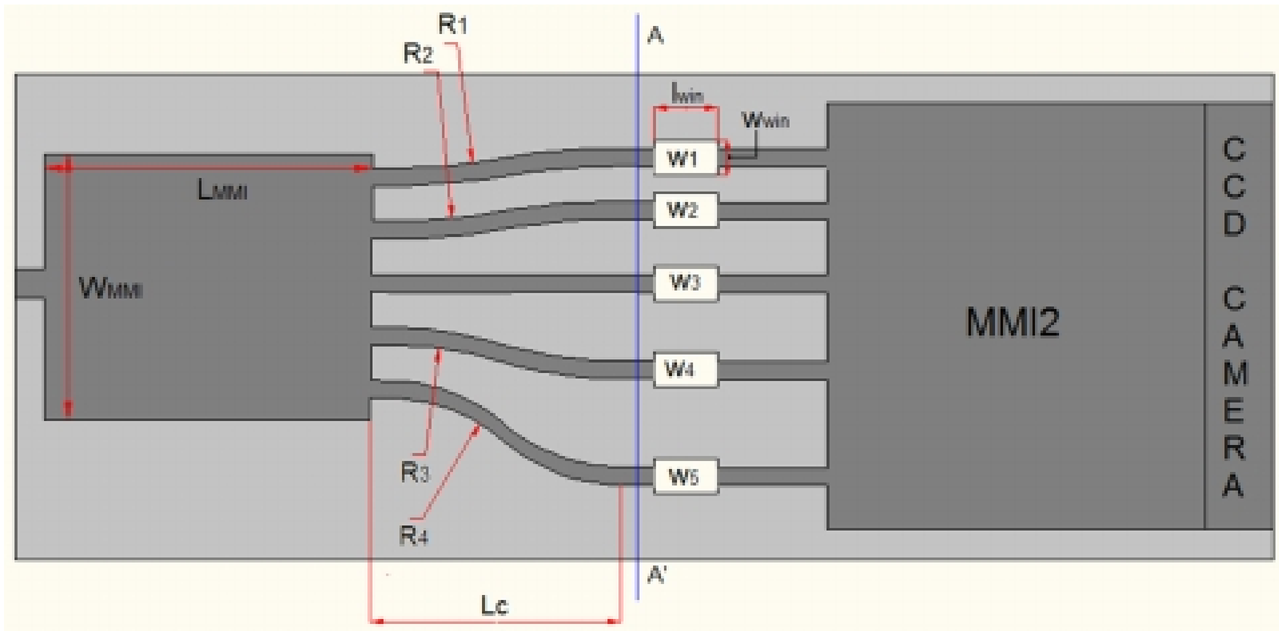

Figure 3.1 *Schematic top-view of MMI biosensor*

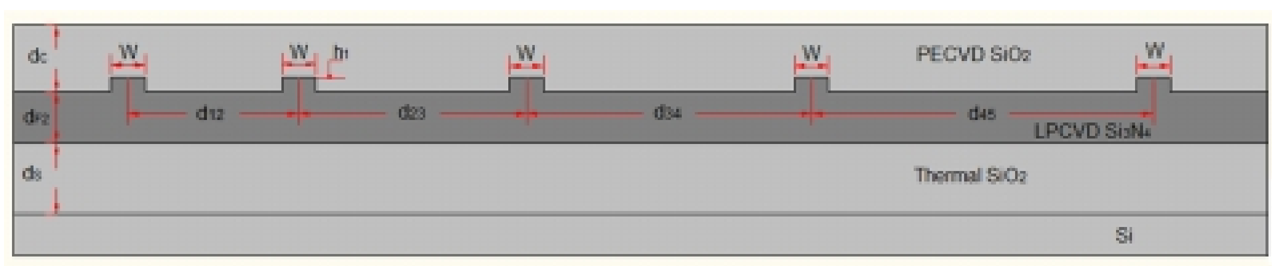

Figure 3.2 *Transverse cutting of AA' section*

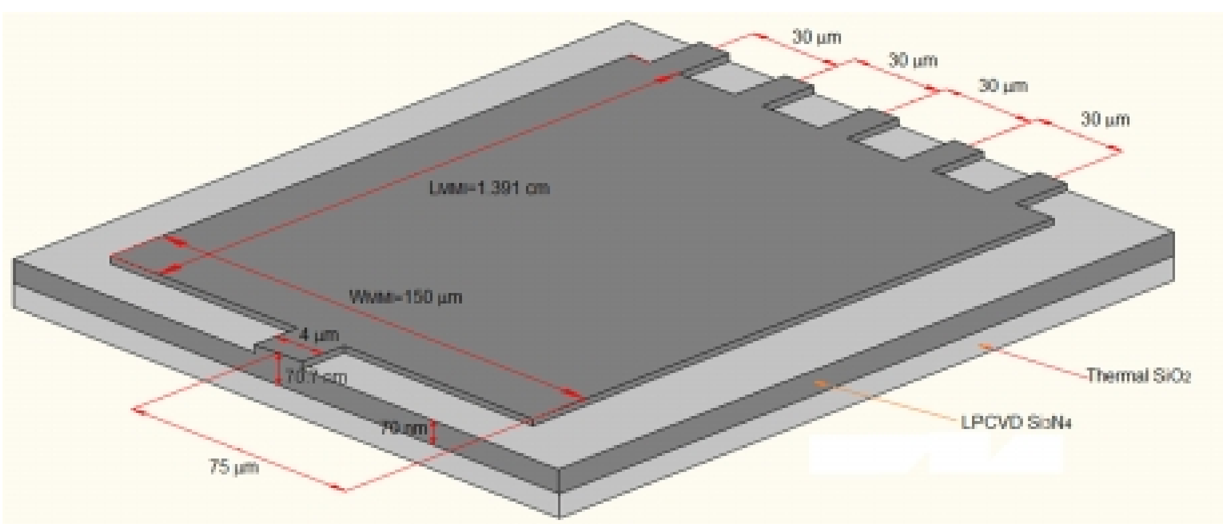

Figure 3.3 *Schematic 3D view of the first MMI*

Table 1 Biosensor parameters

Name	Symbol	Value	Dimension
Width of first MMI	W_{MMI}	150	μm
Length of first MMI	L_{MMI}	1.391	cm
Thickness of the core layer	d_{F2}	70	nm
Height of the channel ridge	h_1	0.7	nm
Thickness of the SiO_2 subs layer	d_S	1.25	μm
Thickness of the SiO_2 cover layer	d_C	1.5	μm
Channel width	W	4	μm
Radius of first output channel	R_1	373	μm
Radius of second output channel	R_2	373	μm
Radius of third output channel	R_3	219.6	μm
Radius of fourth output channel	R_4	100	μm
Length of sensing windows	l_{win}	8	mm
Width of sensing window	W_{win}	100	μm
Window Interdistance	l_{int}	3	mm
Linear length of output channel	L_C	141.4	μm
Distance between channels	d_{12}	30	μm
	d_{23}	40	μm
	d_{34}	50	μm
	d_{45}	60	μm

Conclusion

In this paper is demonstrated the design of a multichannel integrated optical biosensor based on symmetric MMI effect. This biosensor is composed of two MMI waveguides that are positioned one after another. Symmetric interference offers the equal splitting of the input light in a shorter distance compared to the Y-junctions. The parameters of the first MMI waveguide are defined in order to split the light in 5 channels, consisting of four measurement channels and one reference channel. In this way it will be possible to monitor up to four binding events. Features such as small size, high sensitivity and ease of fabrication make this biosensor design highly attractive to be applied in areas such as medical diagnostics, food and beverage industry, environmental monitoring, etc.

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