

FEMTOSECOND LASER WRITTEN WAVEGUIDES FOR FLUORESCENCE-SENSING DURING MICROCHIP CAPILLARY ELECTROPHORESIS

C. Dongre¹, R. Dekker¹, H. J. W. M. Hoekstra¹, D. Nolli², R. Martinez-Vazquez², R. Osellame², P. Laporta², G. Cerullo², G. A. J. Besselink³, R. van Weeghel⁴, and M. Pollnau¹

¹*Integrated Optical MicroSystems, MESA⁺ Institute for Nanotechnology, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands*

²*Dipartimento di Fisica and Istituto di Fotonica e Nanotecnologie del CNR, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milan 20133, Italy*

³*Capilix B. V., PO Box 455, 7500 AL Enschede, The Netherlands*

⁴*Zebra Bioscience B. V., Weth. Beversstraat 185, 7543 BK Enschede, The Netherlands*

C.Dongre@ewi.utwente.nl

Introduction

The substitution of conventional bench-top instrumentation by fully integrated lab-on-chip systems continues to be a challenge. The integration of microfluidics and integrated optics in glass is an important step towards this goal, forming the focus of this work [1]. In particular, excitation and detection of fluorescence emitted by labeled biomolecules flowing through a microfluidic channel is considered. Excitation occurs at specific wavelengths by means of waveguides inscribed with femtosecond laser pulses in a commercial, glass lab-on-chip. A widely known diagnostic application that will exploit this sensing scheme is the monitoring of microchip capillary electrophoresis (MCE) leading to separation of DNA fragments of different lengths, labeled with fluorescent dye molecules. In order to meet the resolution demands of MCE separation and to achieve multi-point sensing, we envision a device consisting of on-chip integrated optical splitters written coplanar with the microfluidic channel along which MCE separation takes place (Figure 1).

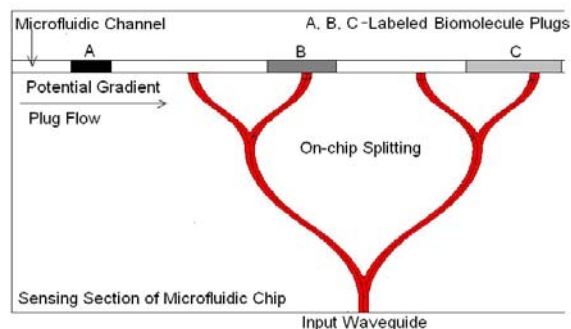


Figure 1 - Schematic picture of the aimed multi-point fluorescence sensing device

Analyte flow and MCE separation through a gel-matrix

During MCE, application of appropriate voltages at microfluidic reservoirs creates a potential gradient along the microfluidic separation channel, along which a plug with analyte molecules is ejected and split into different constituent plugs owing to differences in mobility. In order to enhance the quality of the spatial separation during MCE, different gel-matrices (e. g. Hydroxyethylcellulose, Hydroxypropylcellulose etc) and buffers (e. g. TRIS-Borate-Acetate, MES-TRIS etc) were prepared, experimentally tested, and optimized with respect to viscosity (to be able to fill microfluidic channels with dimensions $50\ \mu\text{m} \times 12\ \mu\text{m}$) [2]. The formation of a well-defined 30 picoliter plug consisting of Fluorescein and Rhodamine-6G, its flow through a gel-matrix, and consequent MCE separation is shown (Figure 2). Furthermore diffusion-induced plug-broadening effects have been quantitatively studied.



Figure 2 - Formation, propagation, diffusion-induced broadening, and MCE separation of a 30 picoliter plug of Fluorescein and Rhodamine-6G through a gel-matrix in a microfluidic channel

Optical waveguide writing and characterization

Straight-channel waveguides with a circular cross-section (diameter $\sim 10\ \mu\text{m}$) were inscribed in a commercial microfluidic chip made of fused silica. The waveguiding properties are created due to refractive-index changes as a result of irradiation with a Ti:Sapphire femtosecond pulsed laser source, at a pulse repetition rate of 1 kHz, with pulse energies of $1\ \mu\text{J}$. The following optical properties considered critical for the sensing applications were characterized.

- Mode profile
- Cross-sectional refractive-index profile from the near-field mode profile using a back-calculation algorithm [3]
- Propagation losses from the decay of color-center-induced photoluminescence along the waveguide length
- Bend losses as a function of bend radius and refractive-index contrast

Concluding remarks

The waveguide characterization results showed that they are indeed suitable as building-blocks of the envisioned fluorescence-sensing device. Corresponding test structures are being designed and tested. The latest experimental results thereof will be presented during the conference.

Acknowledgements

This work was supported by the European Union within the contract IST-2005-034562 (Hybrid Integrated Biophotonic Sensors Created by Ultrafast laser Systems - HIBISCUS).

References

- [1] R. Osellame et al, Appl. Phys. Lett. 90, 231118, 2007
- [2] J. P. Landers et al, Anal. Chem. 75, pp. 986-994, 2003
- [3] M. L. von Bibra et al, IEEE J. Lightwave Technol. 15 (9), pp. 1695-1699, 1997