Project acronym: HIBISCUS
Project full title: Hybrid Integrated BIophotonic Sensors Created by Ultrafast laser Systems
Proposal/Contract no: IST-2005-034562
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Project Summary

In this project we propose the development of a new technology, based on **high-intensity femtosecond laser pulses**, providing an integrated platform for the fabrication of microfluidic Lab-On-Chips (LOCs) with integrated photonic functionalities. Such technology makes it possible to include **on the same glass chip microfluidic channels**, for transport and manipulation of biological matter, and **femtosecond written optical waveguides** for sensing of biomolecules. The waveguides will be arranged in different configurations exploiting the **unique three-dimensional capabilities of the femtosecond writing technique**.

The integrated approach to optical sensing proposed in this project has many advantages over the traditional free-space configurations. **The waveguides are precisely aligned to the channels during fabrication**, resulting in stable setups with enhanced sensitivity; parallel excitation at multiple points of the microfluidic flow can be performed, enabling to follow a chemical reaction in real time; novel sensor concepts can be implemented, exploiting the three-dimensional capabilities of the technique. By pigtailing the waveguides to optical fibers, one can obtain a robust device and easily change the excitation and detection wavelengths. A significant advantage of the femtosecond laser writing approach over today's integrated optical sensor technology is the fact that it does not require any clean-room environment, thereby greatly reducing fabrication costs.

An additional goal of our project is the use of the **femtosecond laser** technology also **for the direct writing of the microfluidic channels**. To reach this objective, two techniques will be investigated: selective femtosecond laser sensitisation followed by wet etching and direct femtosecond ablation. Even if at present channels with the characteristics (length, symmetry, surface roughness) required for this application have not yet been demonstrated using femtosecond laser machining, the success of this technique would revolutionize the field of LOCs, by greatly simplifying the manufacturing procedures and enabling true three-dimensional geometries also for the microfluidic channels.

If both goals are achieved, we can envisage a single production line for the biophotonic LOCs, based on an high-power femtosecond laser, that can manufacture **both the microfluidic channels and the optical waveguides.**

Achievement of the goals of this project critically depends on the **availability of innovative femtosecond laser sources** with suitable characteristics in terms of wavelength, pulse energy, average power and repetition rate. In addition these laser sources need to be sufficiently **compact, reliable and user-friendly** to enable **industrial application in a microfabrication line**. Therefore, an important intermediate goal of this project will be the development of

advanced diode-pumped femtosecond laser sources, with average power higher than currently available. Expected parameters are: repetition rate of 1 MHz, pulse energy of 10 µJ, pulse duration <500 fs. This will represent a significant advance in the state-of-the-art of femtosecond lasers, with applications beyond the goals of this project.

The **unique integration of photonics and microfluidics**, offered by the inscription of optical waveguides on the LOCs, will enable to implement a wealth of novel functionalities. In this project we will concentrate on two prototypical devices:

i) *Microreactors for chemical synthesis of polypeptides and proteins:* such devices offer, thanks to the small reaction volumes and high surface-to-volume ratios, a level of reaction control that is not attainable in conventional bench-top reactors, resulting in higher product yield and selectivity. Integration of optical waveguides on the microreactor chip will enable direct *in-situ* monitoring of the reaction products, thereby greatly simplifying the measurement and improving its sensitivity.

ii) *Analysis of biomolecules separated by capillary electrophoresis:* capillary electrophoresis (CE) is a powerful technique for the separation of a variety of biomolecules CE can be easily integrated on a LOC, greatly increasing the analysis speed and sensitivity. We propose to integrate the optical waveguides with the microfluidic channels in a CE setup, to sensitively detect *in situ* the separated biomolecules, after suitable fluorescence labelling.