PhD subject - Sujet de thèse (2023-26)

Title: **Laser scanning out of multi-core optical fiber for tumor treatment**

Titre : **Balayage laser en bout de fibre optique multicœur pour le traitement de tumeur**

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Host Unit/ Unité d'accueil : ICube Laboratory (D-ESSP Department)
IPP team (Photonics Instrumentation and Processes)

Affiliate institution: INSA of Strasbourg

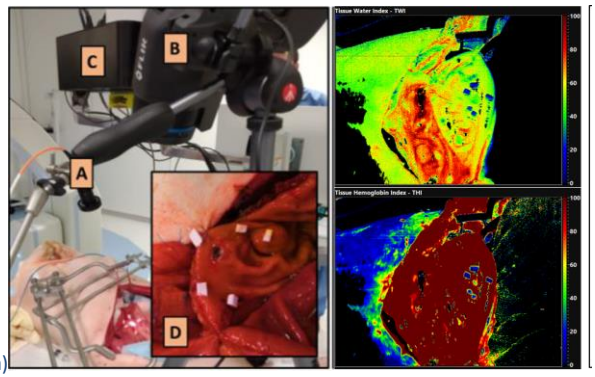
Collaboration(s) (if applicable): IRCAD

Attachment to a program (if applicable):

Summary:

Cancers of the digestive tract are all among the 10 most frequently diagnosed cancers (Ferlay, 2012) with more than 2,670,000 new cases/year. Their treatment is a major societal issue that requires early detection and appropriate surgical techniques. M. Diana, surgeon at IRCAD, uses modulated laser sources to obtain a complete ablation of the entire mucosa and submucosa[1-4]. Lasers are precise, compatible with a mini-invasive surgery and can be used in endoscopy. However, the control of the laser position inside the body is still an issue due to the low mechanical accuracy of the endoscopes.

The aim of the PhD project is to make possible the tumor laser scanning without any mechanical system. Computer Generated Hologram (CGH) will be used. In this case the laser spot results of the interferences of N coherent laser sources controlling their relative phase differences. These CGH can be computed numerically and implemented dynamically using Spatial Light Modulators (SLM). Our team has the expertise of CGH computation and SLM. The objective is to implement this solution through multicore fiber for endoscopic use. N laser beams will be guided in N cores independently. The microlens for optical fiber, we developed[5,6], will be used to increase scanning range. Controlling the phase with a SLM at the fiber entrance[7], a CGH will be obtained at the distal end, inside the body to generate the laser spot at the wanted position for tumor ablation.

(a) 

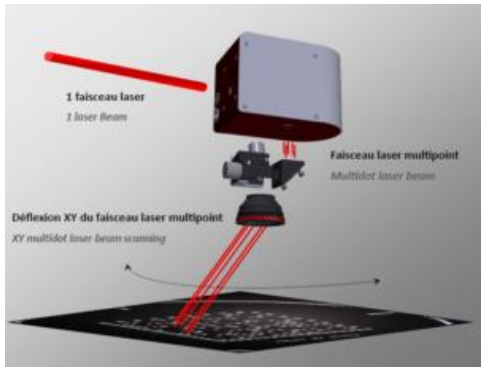
(b) 

Fig.1 : (a) Current laser setup for surgery (M. Diana) for in vivo direct laser ablation. A: laser collimator, B : camera iR, C : hyperspectral camera, D : zoom on stomach. (b) Spatial Light Modulator (Qiova system) use to control the phase at the multcore fiber entrance.

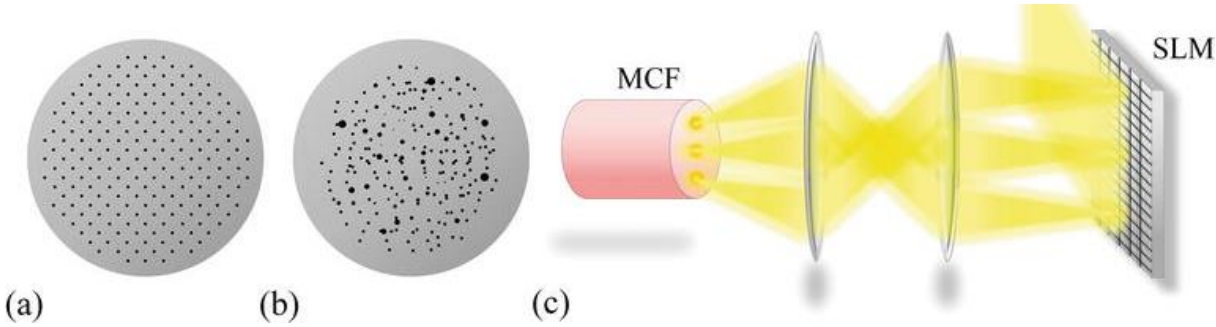


Fig.2 : (a) regular and (b) non regular multicore fibers and the possibility to control the phase using SLM at the entrance [5].

Planned timetable

1-First Year

Taking into account the state of the art, the PhD student will make the relation with the Michele Diana requirement and the multicore fiber characteristic. It will implement the Gerchberg-Saxton algorithm to compute Cumputed Generated Holograms and will begin to use the spatial light modulator for light fiber injection. Then the objective will be to **control the phase at the output of each fiber core**. Direct **laser ablations of biological tissue will be achieved in parallel** to validate the laser choice and focusing requirement. The methods to characterize the burned tissues will be tests (Thermography in IRM, diffuse imaging, OCT,…).

The possibility to control a high-power laser beam out of a multicore fiber will the subject of a first paper.

2-Second Year

The PhD student will implement the phase control at the multicore fiber entrance, test it experimentally and will evaluate the phase perturbation due to the fiber deformation. **Tests through an endoscope** will be achieved. The number of used fiber-cores will be progressively increased. The possibility to **increase the number of micro-lenses deposited in parallel on the multicore fiber** will be studied with possible adaptation of the technique described in our patent.

In parallel a specific setup will be designed to be used in real surgical condition.

The possibility to increase the range of laser scanning using an array of micro-lenses on a multicore fiber will be the subject on a second paper.

3-Third Year

The scanning system will be coupled to the automatic system developed by **Florent Nageotte (ICube-RDH)** to control the laser spot positioning using flexible endoscope movements. Tissue, ablations will be tested in real condition. The probe protection will be considered. The aim will be to reach a preclinical test.

The PhD manuscript will be written.

The non-mechanical laser scanning for mini-invasive surgery will the the subject of a third scientific paper.

References

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[5] D. Bouaziz, S. Perrin, T. Hajj, G. Chabrol, A. Guessoum, N-E. Demagh, and . Lecler, Direct imaging of a photonic jet at shaped fiber tips, Opt. Lett. 46, 5125-5128 (2021)
[6] A. Guessoum, T. Hajj, D. Bouaziz, G. Chabrol, P. Pfeiffer, N-E. Demagh, and S. Lecler, Molded high curvature core-aligned micro-lenses for single-mode fibers, Appl. Opt. 61, 7741-7747 (2022)
[7] A. M. Ortiz, and R. L. Sáez, Multi-Core Optical Fibers: Theory, Applications and Opportunities, in Selected Topics on Optical Fiber Technologies and Applications. IntechOpen, 2017. https://www.intechopen.com/chapters/58243 doi: 10.5772/intechopen.72458