Fiber Bragg Grating Sensors for Temperature Monitoring during Radio Frequency Thermal Ablation (RFTA) Treatment on *Ex-Vivo* Organs

Giovanna Palumbo, Agostino Iadicicco, and Stefania Campopiano
Dept. of Engineering, University of Naples "Parthenope"
Naples, Italy
email: giovanna.palumbo@uniparthenope.it, iadicicco@uniparthenope.it, campopiano@uniparthenope.it

Paolo Verze, Nicola Carlomagno, Vincenzo Tammaro, and Juliet Ippolito
Dept. of Urology and Dept. of General Surgery
University of Naples "Federico II"
Naples, Italy
email: p.verze@gmail.com, nicola.anita@tiscali.it, vincenzo.tammaro@unina.it, juliet@unina.it

Paola Saccomandi
Institute of Image-Guided Surgery of Strasbourg
Strasbourg, France
email: p.saccomandi@unicampus.it

Elena De Vita, Carlo Massaroni and Emiliano Schena
Università Campus Bio-Medico di Roma,
Rome, Italy
email: devita.ele@gmail.com, c.massaroni@unicampus.it, e.schena@unicampus.it

Daniele Tosi
School of Engineering, Nazarbayev University,
Astana, Republic of Kazakhstan
email: daniele.tosi@nu.edu.kz

***Abstract*—In this work, we report on the use of fiber Bragg gratings (FBGs) sensor for real-time in-situ temperature monitoring during Radio Frequency Thermal Ablation (RFTA) tumor treatment. In order to create a thermal multi-point measurement of the area to be treated, a proper sensing configuration was developed by instrumenting the RF commercial probe with more than 30 FBG sensors. The experiments were conducted on ex-vivo animal liver and kidney tissues and results confirm that the proposed setup is able to conduct a multi-point measurement and to distinguish between different and consecutive RF discharges with a temperature resolution of 0.1 °C and a minimum spatial resolution of 1 mm.**

Keywords-Fiber Bragg Gratings (FBGs); Radio Frequency Thermal Ablation (RFTA); temperature monitoring.

I. INTRODUCTION

RFTA is a local treatment of small tumors that, by using RF current released by electrodes connected to a RF generator, locally induces a rapid temperature increase in the tissue affected by the tumor with resulting immediate necrosis of diseased tissues [1]. Real-time temperature monitoring during the treatment is essential in enabling surgeons to adapt RFTA parameters to the tumor size during surgery and consequently preserve as much healthy tissue as possible. Due to their small size, non-toxicity, chemical inertness, biocompatibility, flexibility and low cost, Fiber Bragg Gratings seems to be a good solution to monitor the temperature during the RF treatments [2].

In Section II, a novel setup to temperature monitoring during RFTA treatment is proposed and the results of a RF discharge on ex vivo animal liver are shown, while in Section III the conclusion is reported.

II. EXPERIMENTAL SETUP AND RESULTS

The experimental setup is illustrated in Figure 1. In particular, in the blue box, the RFTA instrumentation is reported: the RF probe is powered by a 500 kHz generator (RITA 1500X®) producing up to 250 W of power. The laparoscopic bipolar RF device Habib 4x® was used, consisting of two pair of opposing electrodes with active ends of 6 cm in length. In the red box, it is also reported the optical interrogation of the FBGs' sensor used to measure the reflected signal. This device consists of a commercial FBG interrogator in the range of 1500-1600 nm with a resolution of 1 pm and maximum sampling frequency of 1 Sample/s. Several commercial FBGs 1 mm long have been used. In order to correctly measure the temperature during the RF discharges, the FBGs were inserted in carbon fiber needles and properly fixed to the RF probe, as shown in Figure 2. Several measurements of the spatial temperature profile during multi-step RFTA discharges and the monitoring of the heat propagation on animal liver and kidney organs have been carried out confirming that the proposed setup is able to conduct a multi-point measurement and to distinguish between different and consecutive RF discharges with a temperature resolution of 0.1 °C and a minimum spatial resolution of 1 mm. For example, in Figure 3, the temperature is reported by a color map versus spatial sensor position along the axis parallel and perpendicular to the electrodes respectively (vertical axis in the graph) and time (horizontal axis).

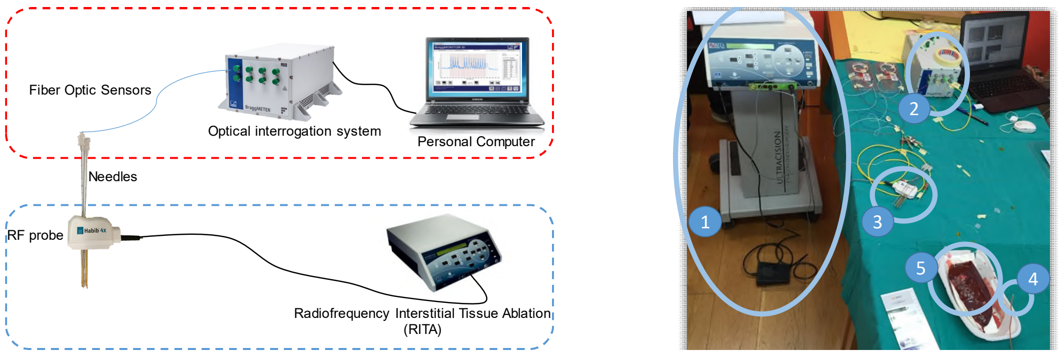

Figure 1. Left: Schematic of the experimental measurement setup. Right: Picture of the experimental setup where 1) the RF generator RITA; 2) the optical interrogation system FS22; 3) the modified RF probe; 4) thermocouple used as a reference; 5) the organ sample.

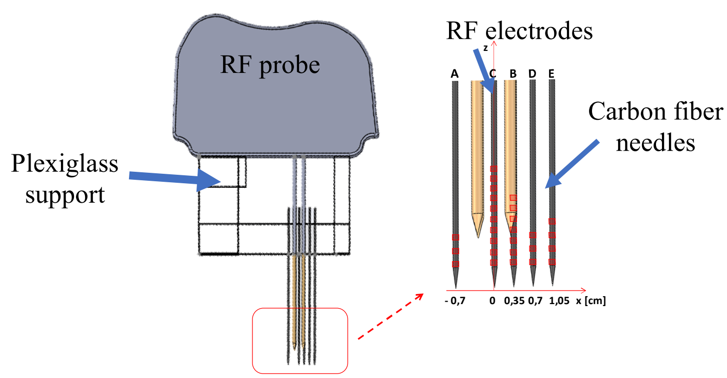

Figure 2. Schematic of the RF probe instrumented with FBGs inserted in carbon fiber needles fixed to the probe.

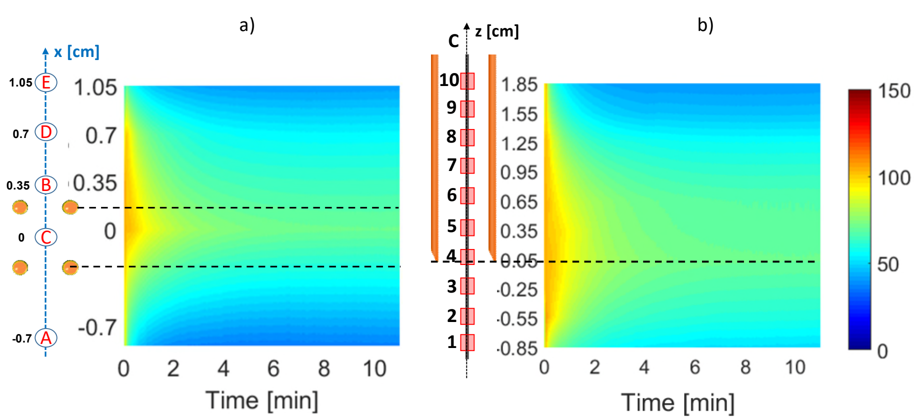

Figure 3. (a) Temperature profile of the FBGs at the end of electrodes. (b) Temperature profile of the 10 FBG sensors of the array C tip.

III. CONCLUSION

Thanks to the FBG's fast response time and small size, we were able to monitor temperature with a resolution of 0.1 °C during RF discharges. This mapping of the tissue temperature allowed the monitoring of the thermal dose delivered to the patient in real time and, at the same time, to avoid potentially adverse effects to the tissue adjacent to the target region.

REFERENCES

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