Computational modeling and printing optimization in fiber-based laser-assisted bioprinting

Ahad Mohammadi[1,2,3], Jesto Raju[1,2,3], Jennyfer Zapata-Farfan[4], Michel Meunier[4], Christos Boutopoulos[1,2,3] *

[1] Department of Ophthalmology, Faculty of Medicine, University of Montreal, Montréal, Canada
[2] Centre de Recherche Hôpital Maisonneuve-Rosemont, Montréal, Canada
[3] Institute of Biomedical Engineering, University of Montreal, Montreal, Quebec, Canada
[4]Engineering Physics Department, Polytechnique Montreal, Montreal, QC, Canada
*Corresponding author email: christos.boutopoulos@umontreal.ca

Bioprinting technologies represent a transformative approach to tissue engineering, aiming to fabricate biomimetic constructs that closely resemble natural tissue structures through a layer-by-layer biomaterial deposition [1]. Our laboratory has pioneered a laser-assisted bioprinting technique known as LIST. LIST employs low-energy nanosecond (ns) laser pulses (532 nm) pulses to transfer cell-laden inks from a glass microcapillary to a receiving substrate with high precision [1-2]. Here, I will present modeling results and experimental data on a new fiber-based implementation of LIST that eliminates the use of bulky beam delivery optics, thus enabling miniaturization of the printing head and integration with hand-held systems. We sought to understand how key process conditions affect printability. Model inks (1-10 cP) were printed using the fiber-based system (Fig. 1a) employing a glass capillary with a 200 μm laser-machined opening acting as a nozzle. Jet dynamics were acquired using fast imaging (Fig. 1b). A model for the simulating the printing process was built in COMSOL, accounting for thermocavitation and fluid dynamics (Fig. 1c). We have validated our model using experimentally measured jetting parameters such as pinch-off time (140-310 μs), jet velocity (2-16 m/s), and deposited volume (0.5-12 nl). We further explore how the model can be used to predict the printability of non-validated formulations as well as to optimize the printing architecture, including the capillary and opening size. Our findings suggest that fiber-based LIST has uncompromised printing performance compared to the bulky free-space system [1-2], while allowing easy integration with robotic and/or hand-held systems. The system is of particular interest for in-situ bioprinting applications, such as wound repair.

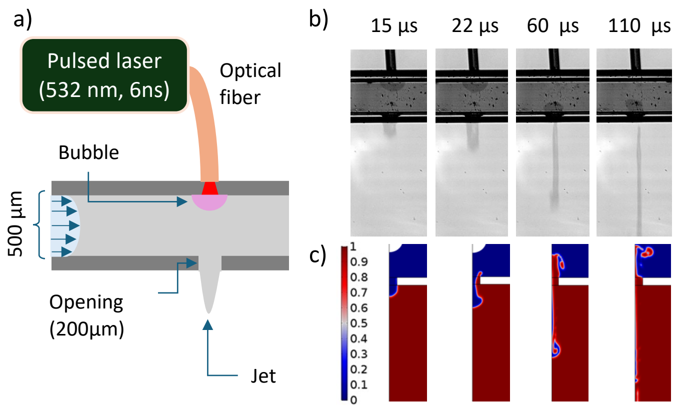

Figure 1: a) Schematic overview of the fiber-based printing setup. b) High-speed imaging of ink jetting and c) corresponding ink jetting simulation for a model ink (laser energy per pulse: 100 μJ)

References: [1] H. Ebrahimi Orimi, S. S. Hosseini Kolkooh, E. Hooker, S. Narayanswamy, B. Larrivee, C. Boutopoulos H. Ebrahimi Orimi et al., Sci Rep 10 (2020) 9730; [2] K. Roversi, H. Ebrahimi Orimi, M. Erfanian, S. Talbot, C. Boutopoulos, Bio Protoc 12 (2022) 1–12