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High repetition rate laser-induced printing of biopolymers: time-resolved study of multiple jet dynamics

Lucas Duvert, Adrien Casanova, Jérôme Robin-Ducellier, Frédérique Magdinier, Anne Patricia Alloncle

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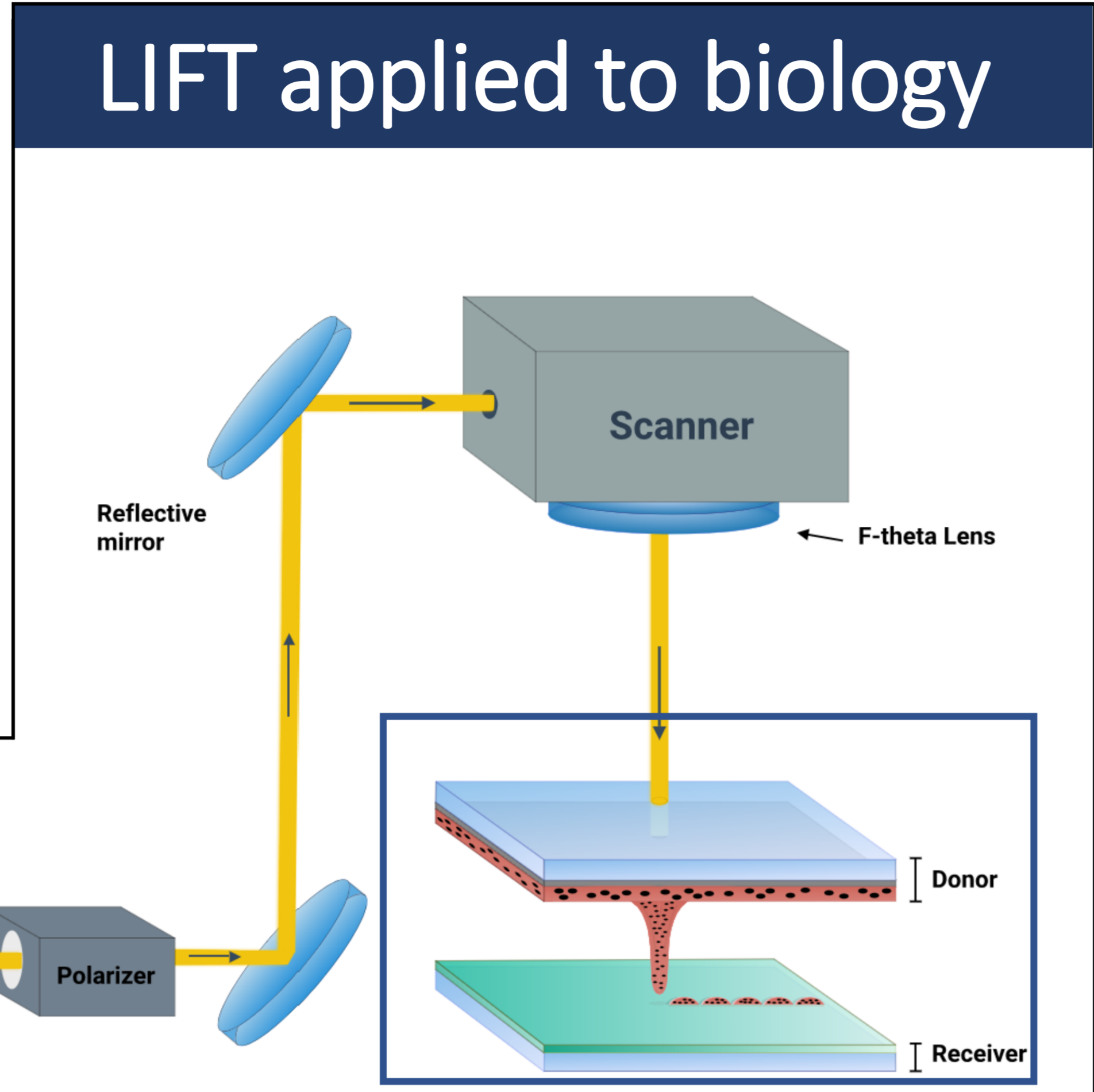
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L. Duvert¹, A. Casanova¹, J. D. Robin², F. Magdinier², P. Delaporte¹, A. P. Alloncle¹
¹Aix-Marseille University, CNRS, LP3 UMR 7341, Campus de Luminy, Case 917, 13288, Marseille cedex 9, France
²Aix-Marseille University, INSERM, MMG, Marseille Medical Genetics, 13385 Marseille, France

Motivation

- Development of pluripotent induced stem cells
- Creation of *in vitro* biological models
- Creation of complex cell arrangements with bioprinting
- Use of Laser Induced Forward Transfer (LIFT) for precise cell deposition

Regenerative medicine
 Pharmaceutical testing
 Pathology studies



Advantages of LIFT

- Nozzleless system
- Large range of fluid viscosity
- High printing resolution
- High spatial resolution

Objective of the study :
 From High velocity → High mechanical stress
 To Slow velocity → Reduced mechanical stress
Increased cell viability and recovery

Single jet dynamic

Jet height as a function of gel thickness

(Time normalized to maximum reached) Alginate 3% + Glycerol 10% 277mJ/cm²

Layer thickness → Maximum jet height

Evolution of the jet height as a function of time after the laser impact

Alginate 2% + Glyc rol 10%

Pulse energy → Maximum jet height

Influence of viscosity

Viscosity → Reproducibility Stability

From high-speed impact to a soft deposition While keeping a very high spatial resolution

Characterisation of the ejection dynamic

Why is real time visualisation important ?

Characteristics of jets depending on:

- Viscosity of the bioink
- Energy of the laser pulses
- Thickness of the gel layer deposited on the donor

Jet height depending on time

Maximum height reach by the jet

Set up for capturing the dynamics

- Camera coupled with nanosecond flash
- Pictures with high temporal resolution
- Artificial reconstruction of one dynamic with series of individual delayed jet pictures

Original image → Jet isolation → Extremum finding

No jet / Explosion → Stable jet → Out of range / fragmenting

Multi-jets dynamics

Spacing dependence

Distance between each laser shot

Time dependence

- Viscosity → Modify dynamic duration
- Laser energy → Modify dynamic duration

Enough delay for single jet mechanism

Compromise: Fast printing → Larger spacing → More printing possibilities

Conclusion

Deposition of hydrogel lines containing cells

- Process optimization
- Next: characterization survival with optimal velocity