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

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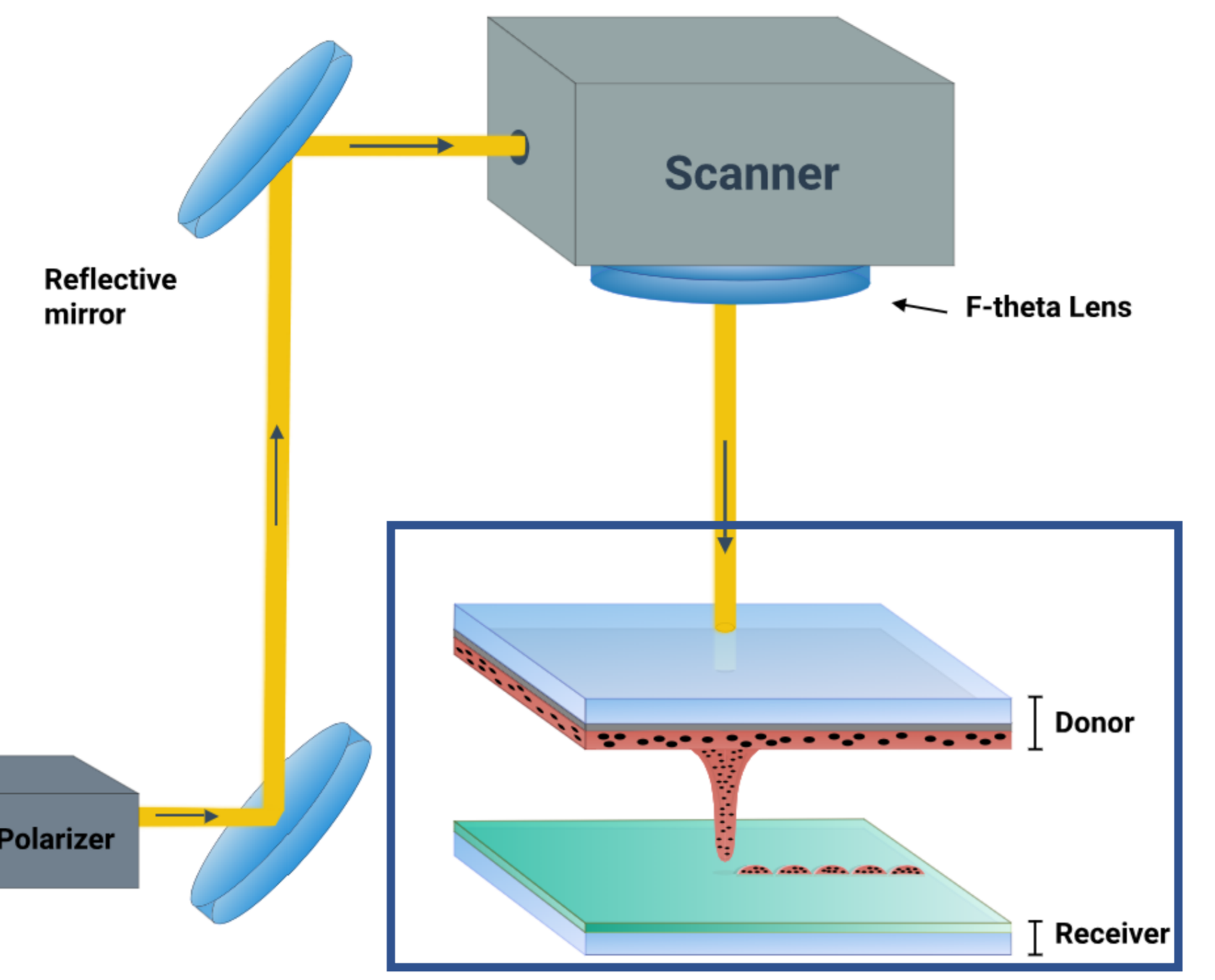
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Motivation

- 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

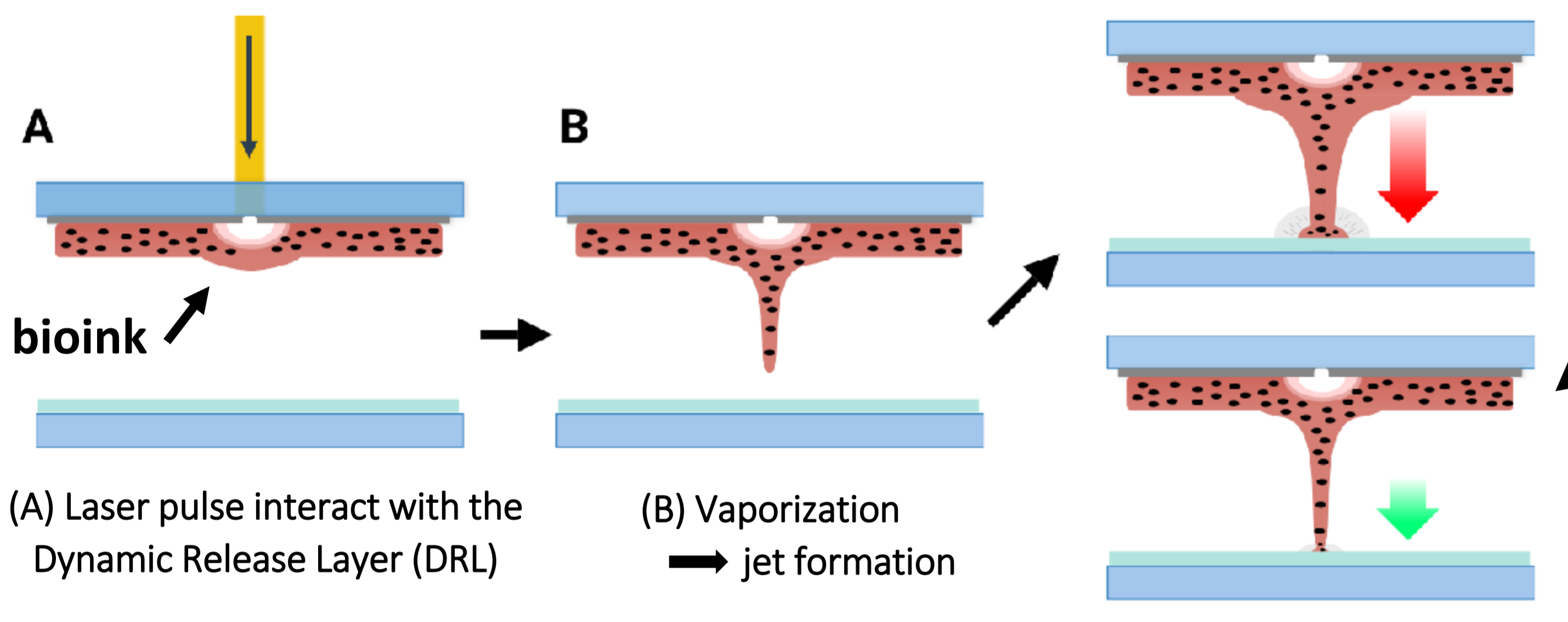
Regenerative medicine  
 Pharmaceutical testing  
 Pathology studies

LIFT applied to biology



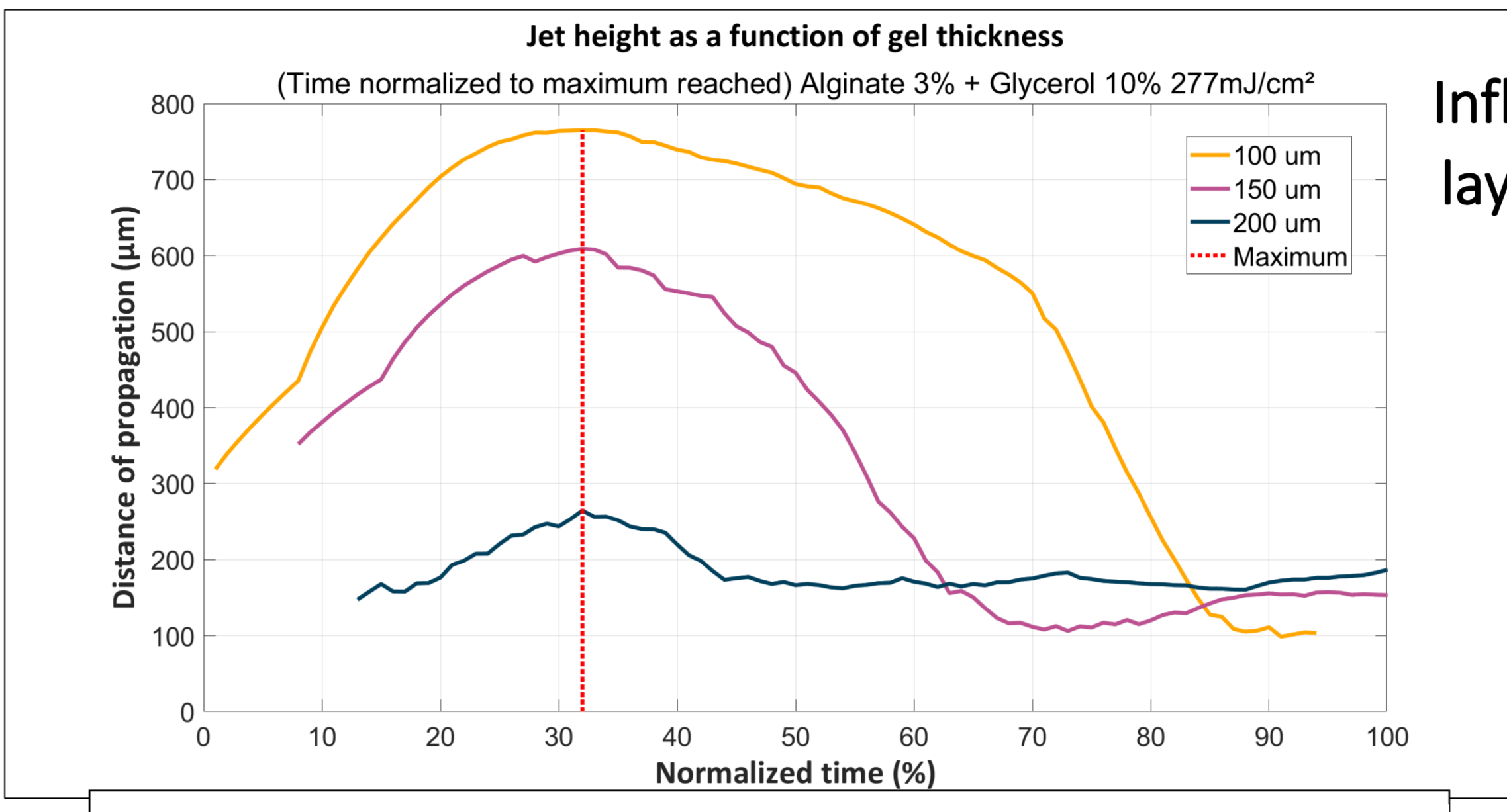
Advantages of LIFT

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

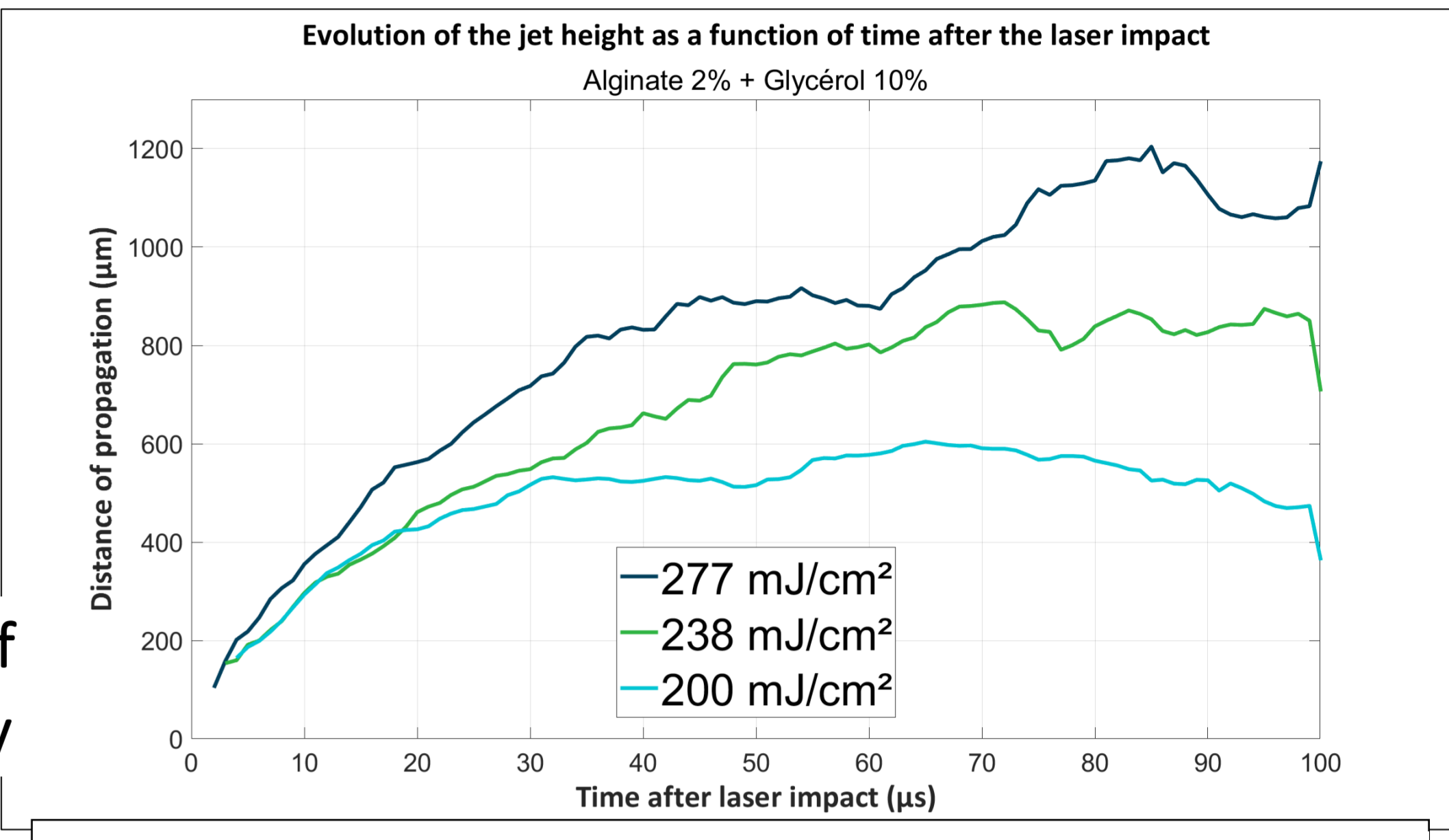


Objective of the study :  
 From High velocity → High mechanical stress  
 To Slow velocity → Reduced mechanical stress  
 Increased cell viability and recovery

Single jet dynamic



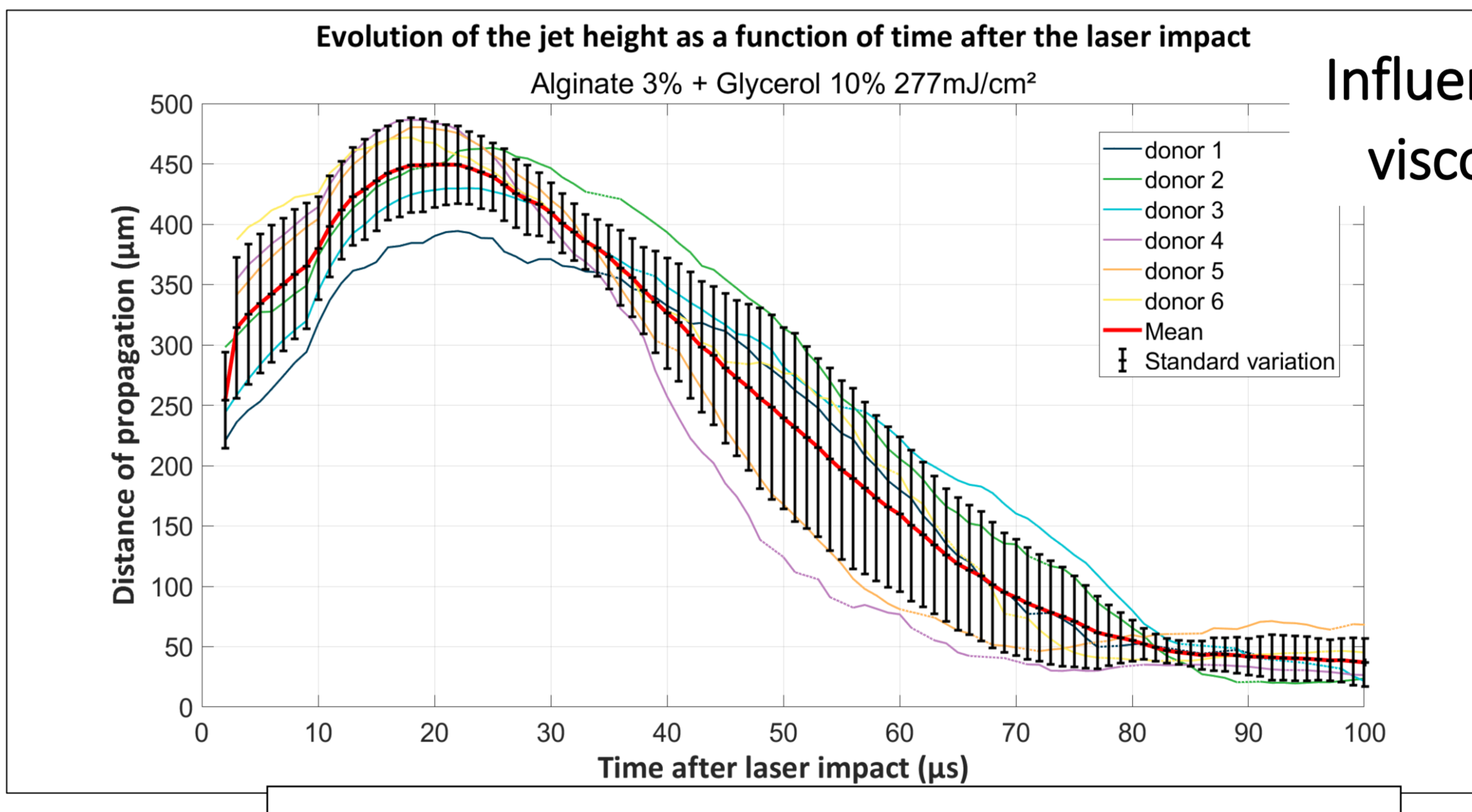
Influence of gel layer thickness



Influence of laser energy

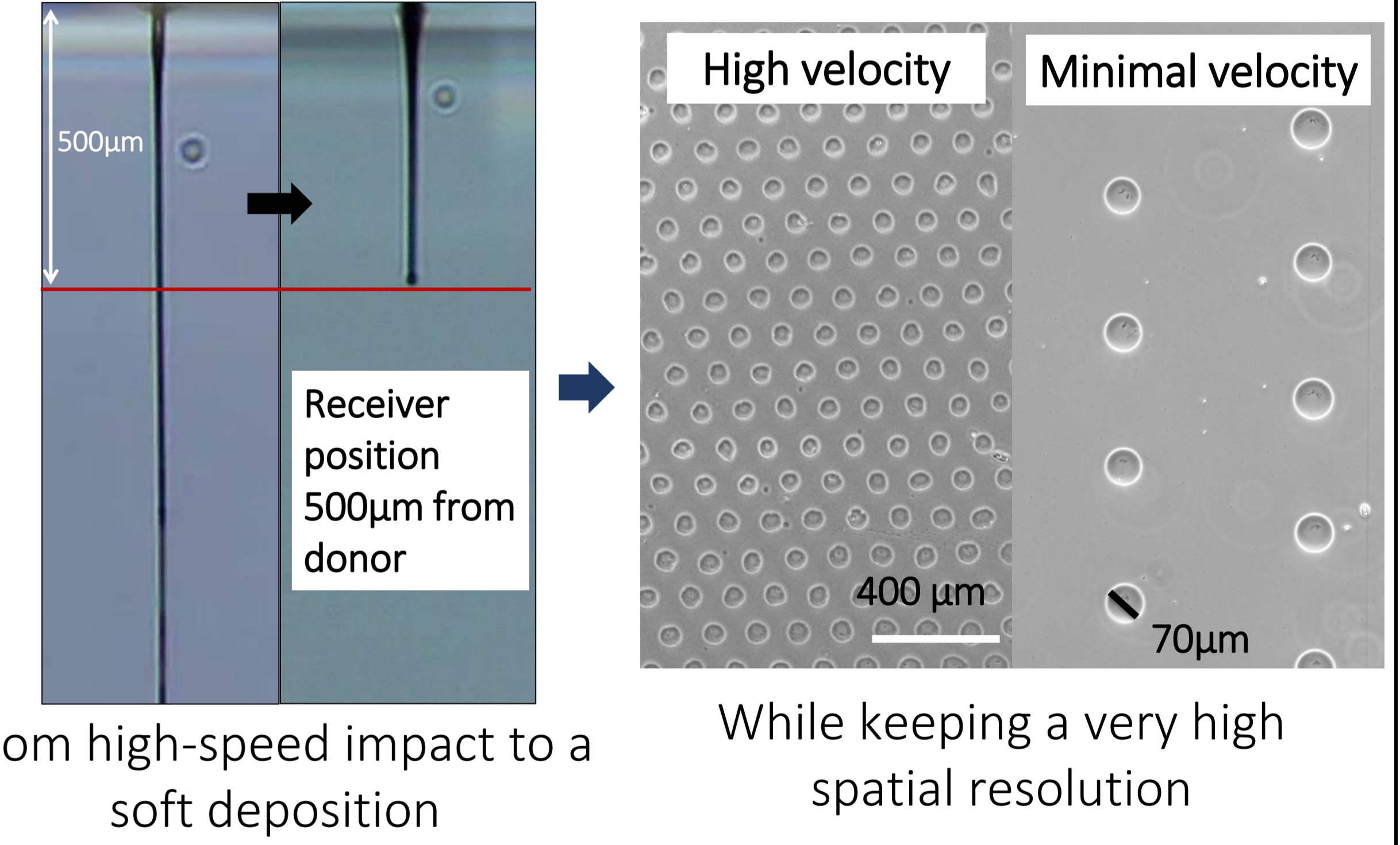
Layer thickness → Maximum jet height

Pulse energy → Maximum jet height



Influence of viscosity

Viscosity → Reproducibility Stability



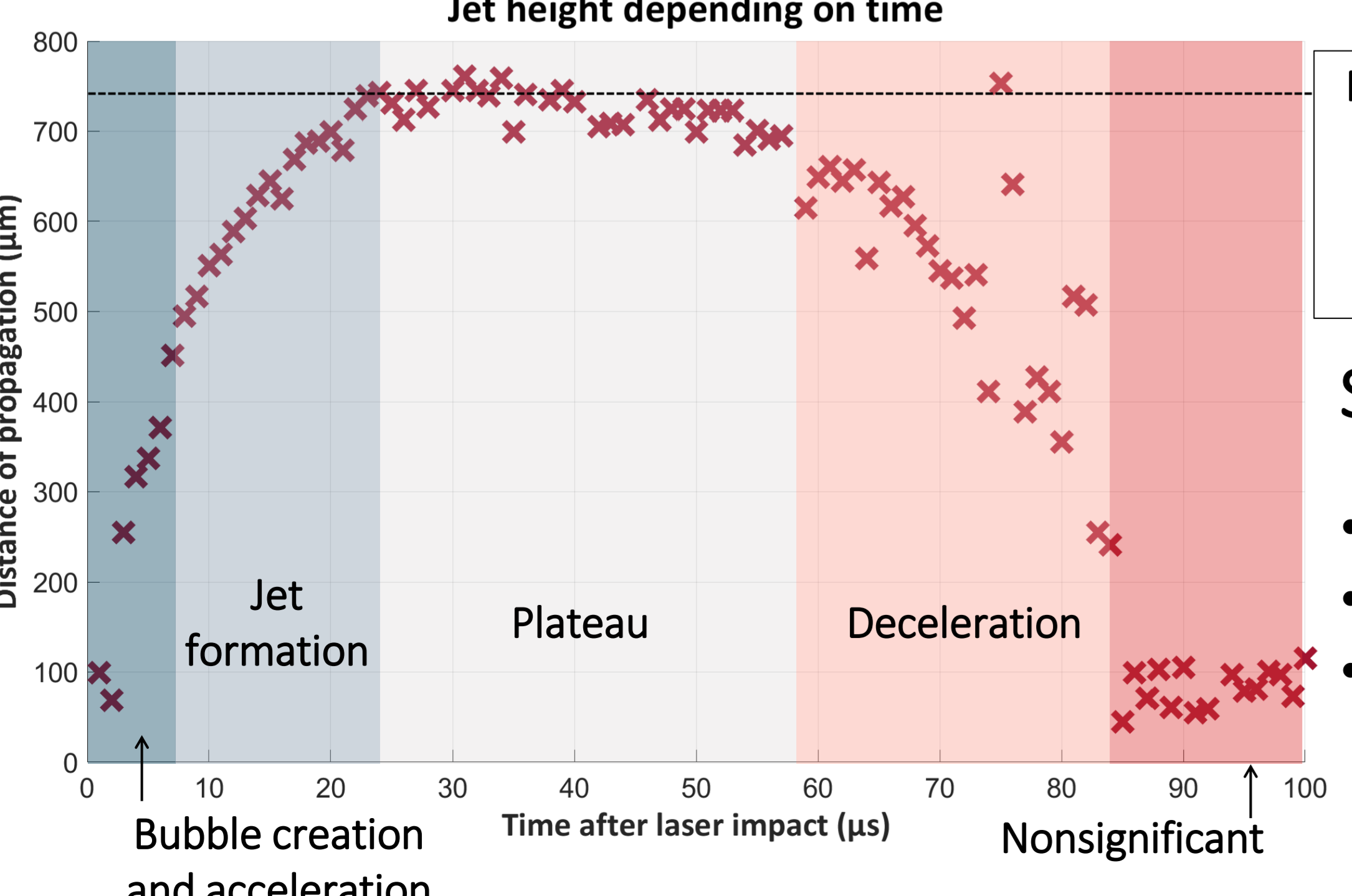
From high-speed impact to a soft deposition

While keeping a very high spatial resolution

Characterisation of the ejection dynamic

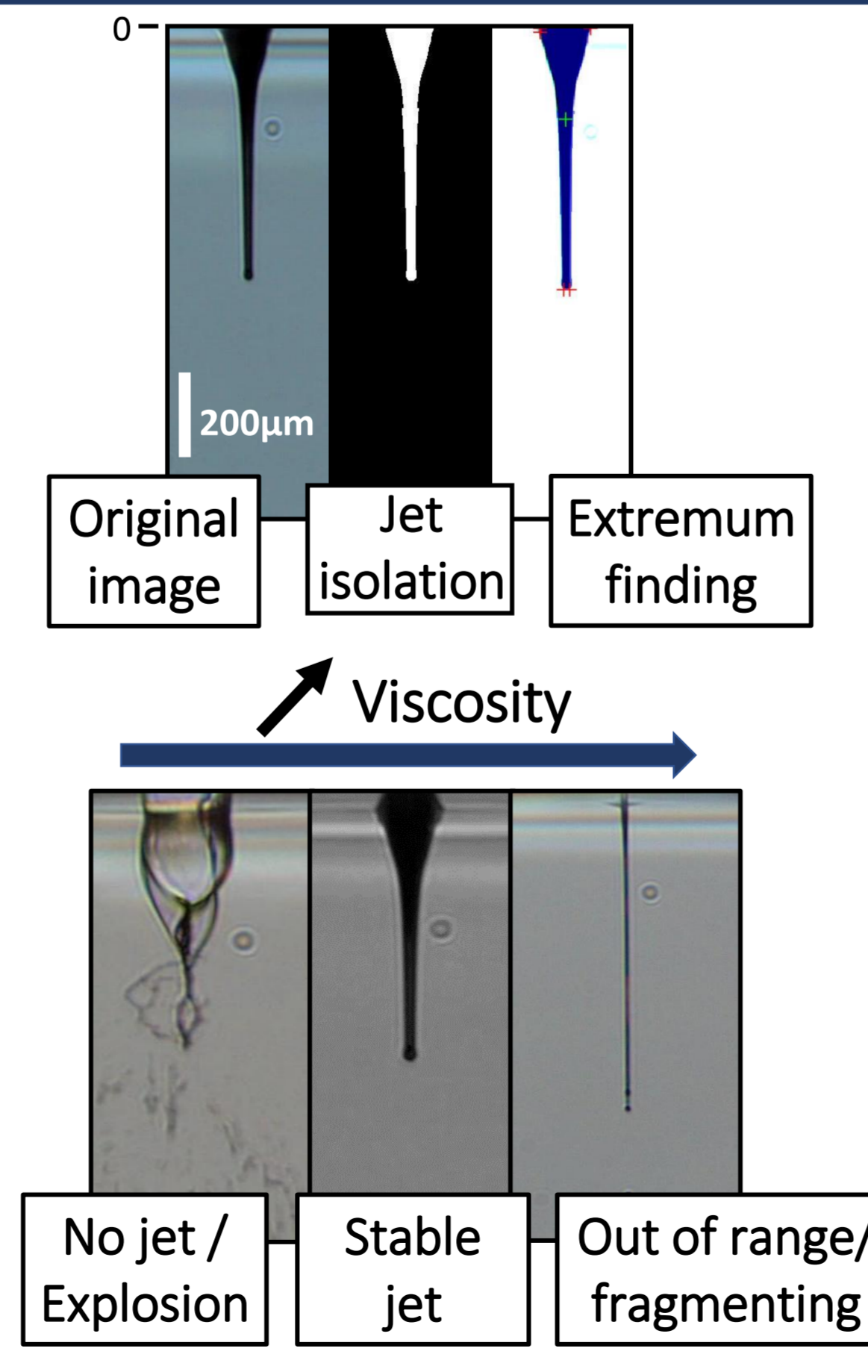
Why is real time visualisation important ?

- Characteristics of jets depending on:
- Viscosity of the bioink
  - Energy of the laser pulses
  - Thickness of the gel layer deposited on the donor



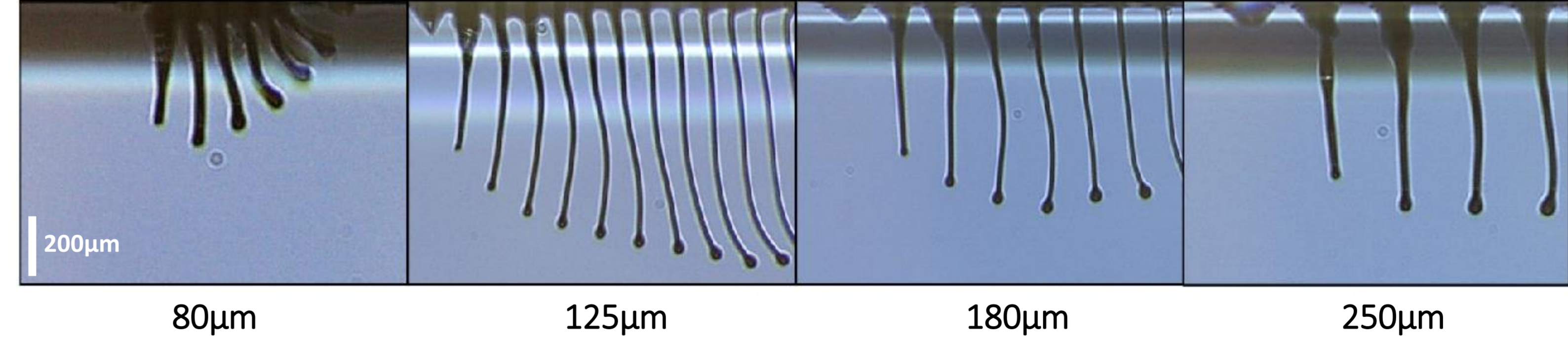
Set up for capturing the dynamics

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



Multi-jets dynamics

Spacing dependence



Time and spatial independence of jets  
 Further stabilisation with receiver

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