ULB, TIPs department

Master Thesis and Internships

Applied physics, soft/wet microrobotics, photonics, precision mechanics, wetting, nose-to-brain drug delivery, and biomedical topics

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25/04/2022

Contents

Cleaning optical lenses from biological fluids in endoscopy (+internship in LysMedical (Waterloo (BE))

Promotors: Pierre Lambert

Supervisors: Loïc Blanc (Lys Medical), Joël De Coninck (wetting)

Context:

There is a variety of applications requiring to remove water droplets from transparent surfaces: cleaning solar cells, removing rain droplets from cameras or biological liquids from endoscope's lenses. Lenses are mostly made of glass, which is an hydrophilic materials. Water-based droplets and liquids therefore tend to wet these surfaces because of minimal surface energy considerations. These wetting properties are the result from properties of surfaces (surface energy) and liquids (surface tension).Therefore, literature mentions methods to (re)move droplets from a surface by changing this surface energy: hydrophobic coatings combined with some shear stress (air on a windshield), electrowetting (using electric field to deform and displace droplets – [Lee2017, Chung2019]), wettability gradients and vibrations to displace droplets towards lower surface energy area [Sun2020]. It is also possible to tune surface tension with chemicals (surfactants) or temperature gradients (thermocapillary effect) [Piñan2021].

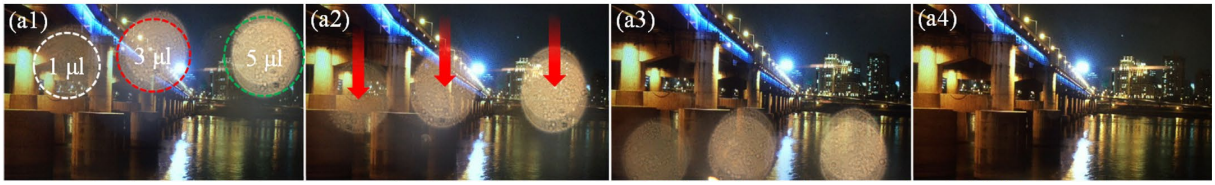


Figure: Removal rain droplets from a camera for automobile [Lee2017]

Goals:

The goal of this internship and this master thesis is to develop a solution to passively clean an optical lens with a few millimeters diameter. The student will propose and tests the most promising solutions combining the requirements expressed by the Belgian company Lys Medical, the solutions mentioned in literature and the tools available at ULB (coatings, surface texturation of glass, thermocapillary effects triggered with an infrared laser).

Tasks:

Literature survey, requirements analysis (biocomptability, size, usages…), experimental tests (producing hydrophobic surfaces with coatings, infusion and textures of hydrophilic surfaces with plasma, flame, coatings). The tests will be done in the company, the coatings and glass structuration will be done in ULB/TIPs.

[Chung2019] SK Chung, KY Lee, DY Lee, Cleaning apparatus and method, patent EP 3 460 460 A2 (2019)

[Lee2017] KY Lee, J Hong, SK Chung, Smart self-cleaning lens cover for miniature cameras of automobiles, Sensors and Actuators B, Vol 239, Pages 754-758 (2017)

[Piñan2021] F. Piñan Basualdo, A. Bolopion, M. Gauthier, P. Lambert, A microrobotic platform actuated by thermocapillary flows for manipulation at the air-water interface, to be published in Science Robotics, 31st March 2021

[Sun2020] D. Sun, K. Boehringer, An active self-cleaning surface system for photovoltaic modules using anisotropic ratchet conveyors and mechanical vibrations, Microsystems and Nanoengineering, 6(1), 87 (2020)

Design of an respiration simulator and in vitro study of nose-to-brain drug delivery using nasal replicas

Promotors: Benoit Haut & Pierre Lambert

Supervisor: Clément Rigaut – clement.rigaut@ulb.be

Description: Nose-to-brain drug delivery is a very promising way to deliver drugs. For this purpose, the airflow generated by a spray device must convey the drug particles through the nose and deposit them in the so-called olfactory area. Since each patient nose anatomy is different, this process must be optimized to become patient specific. To this end, nasal replicas based on patients' CT Scan can be 3D printed. However, have the right geomotry of the nasal cavity is just the first step and more instrumentation is needed to reproduced more realistic drug deposition in the nose.

Goal of the master thesis: The pumps commercially avalable cannot reproduce the real inspiration pattern made by humans. Moreover, innovative drug administration devices requiring the patient to blow into them have been developed. So, these devices also need a system to reproduce the expiration of a patient to be tested properly in the labs. Thus, this thesis aims to create a new system to simulate the respiration of the patient and study the influence of different respiration conditions (quiet breathing, sniff, etc.) on the dose delivered to the olfactory zone of nasal replicas.

Tasks of the master thesis:

- Literature review / state of the art
- Conception of an apparatus reproducing human respiration
- Comparison of the powder trajectories in the nose between the new apparatus and classical pumps

[1] Xi et al. 'Nasal and Olfactory Deposition with Normal and Bidirectional Intranasal Delivery Techniques: In Vitro Tests and Numerical Simulations', J Aerosol Med, 2017

[2] Häußermann et al. 'A System to Reproduce Human Breathing Patterns: Its Development and Validation', J. Aerosol Med., 2000

[3] Schroeter et al. 'Experimental Measurements and Computational Predictions of Regional Particle Deposition in a Sectional Nasal Model', J. Aerosol Med., 2014

Instrumented nasal replica and CFD simulations for nose-to-brain drug delivery (+internship in the Barcelona Supercomputing Center, Spain)

Promotors: Benoit Haut & Pierre Lambert
Supervisor: Clément Rigaut - clement.rigaut@ulb.be

Internship contact: Hadrien Calmet – hadrien.calmet@bsc.es
https://www.bsc.es/research-development/research-areas/biomechanics/respiratory-system

Description: Nose-to-brain drug delivery is a very promising way to deliver drugs. For this purpose, the airflow generated by a spray device must convey the drug particles through the nose and deposit them in the so-called olfactory area. Two main techniques exist to reproduce the drug administration in the nose: experiments using nasal replicas and Computational Fluid Dynamics simulations.
The internship and the master's thesis are designed to be complementary but can also be done independently.

Goals of the internship: Two goals can be defined (according the main interest of the student):

- Assess the sensibility of the drug deposition pattern to changes in the procedure of administration (modification of the particle injection, particle size, inspiratory flow, etc.)
- Based on experimental studies already done in ULB, improve the similary between experiments and simultions. This point is crucial to enable predictive uses of the simulations.

Goals of the master thesis: As for the internship, to goals can be defined, according the main interest of the student:

- Measure the sensitivity of the deposition pattern in the nose experimentally. The goal is to pinpoint the critical parameters which should be controlled to ensure efficient nose-to-brain delivery.
- Design new nasal replicas incorporating pressure and/or velocity sensors and use them to measure air flows in the cavities. Thanks to these sensors, it would be possible to validate CFD simulations intending to improve nose-to-brain delivery.

For both goals, better strategies to target the olfactory region of the nose can be suggested and tried experimentally.

Tasks:

- Literature review / state of the art
- Modelisation of a spray in the nasal cavity using a CFD code
- Experimental measure of the flow or particle deposition inside the nose
- Propositions to improve the nose-to-brain delivery.

[1] Xi et al. 'Nasal and Olfactory Deposition with Normal and Bidirectional Intranasal Delivery Techniques: In Vitro Tests and Numerical Simulations', J Aerosol Med, 2017

[2] Warnken et al. 'Personalized Medicine in Nasal Delivery: The Use of Patient-Specific Administration Parameters To Improve Nasal Drug Targeting Using 3D-Printed Nasal Replica Casts', Mol. Pharm., 2018

[3] Calmet et al. 'Nasal sprayed particle deposition in a human nasal cavity under different inhalation conditions', PLOS ONE, 2019

Nasal casts for nose-to-brain delivery : Classification of nasal cavities based on drug deposition tests

Promotors: Benoit Haut & Pierre Lambert

Supervisor: Clément Rigaut – clement.rigaut@ulb.be

Description: Nose-to-brain drug delivery is a very promising way to deliver drugs. For this purpose, the airflow generated by a spray device must convey the drug particles through the nose and deposit them in the so-called olfactory area. Since each patient nose anatomy is different, this process must be optimized to become patient specific. To this end, nasal replicas based on patients' CT Scan can be 3D printed. However, the anatomy of each patient is different and can influence the deposition.

Goal of the master thesis: This thesis aims to compare the drug delivery between different patients' nasal cavity. The goal is to classify them in a limited number of categories, based on their anatomical characteristics. This categories will then be used to optimise the drug deposition in each familly and draw guidelines usefull for health practitioners.

Tasks of the master thesis:

- Literature review / state of the art
- Drug deposition tests in nasal casts
- Classification of the different anatomies

[1] Forbes et al. 'A consensus research agenda for optimising nasal drug delivery', Expert Opin. Drug Deliv., 2020

[2] Keeler et al. 'A Computational Study of Nasal Spray Deposition Pattern in Four Ethnic Groups', J Aerosol Med, 2015

[3] Yarragudi et al. 'Olfactory Targeting of Microparticles Through Inhalation and Bi-directional Airflow: Effect of Particle Size and Nasal Anatomy', J. Aerosol Med., 2019

Surface state enhancement for glass micro-structures manufactured with a femtosecond laser.

Promotors: Pierre Lambert (TIPs), Stephane Godet (4MAT)
Supervisors: Adam Chafai, Mateo Tunon de Lara, Loïc Amez-Droz

Context: High-precision glass micro-structures can be obtained by subtractive manufacturing using a femtosecond laser. After being locally exposed to the laser radiation, the fused silica glass (a-SiO_2) is chemically etched. Due to the excellent elastic and optical properties of a-SiO_2, this technology finds numerous applications in the fields of micromechanics (e.g. force sensors), optics (e.g. optical fibers), microfluidics (e.g. complex microchannels) [Bellouard2012]. However, the performance of these systems is limited, inter alia, by the surface state. When a polishing step is impossible, strategies must be found to enhance the surface state.

Goals: With the conjoined expertise of the TIPs and 4MAT laboratories, the goal of this master thesis is to develop manufacturing strategies to enhance the surface state and other critical aspects of the manufacturing through characterizations and optimization of the Femtoprint machine. The characterization will be achieved with metrology tools (profilometry, scanning electron microscopy). The optimization of the identified critical aspects will be based on the understanding of the manufacturing technology and on the Design of Experiment method [Montgomery2019]. Attending the MECA-H501 soft-microrobotics course is therefore strongly advised.

Tasks: Literature review; design of the test samples and end-to-end manufacturing on the FemtoPrint; surface state analysis; optimization of the key parameters of the process; development of a manufacturing strategy enhancing the surface state without sacrificing too much manufacturing speed (rough and finish passes method for milling machines)..

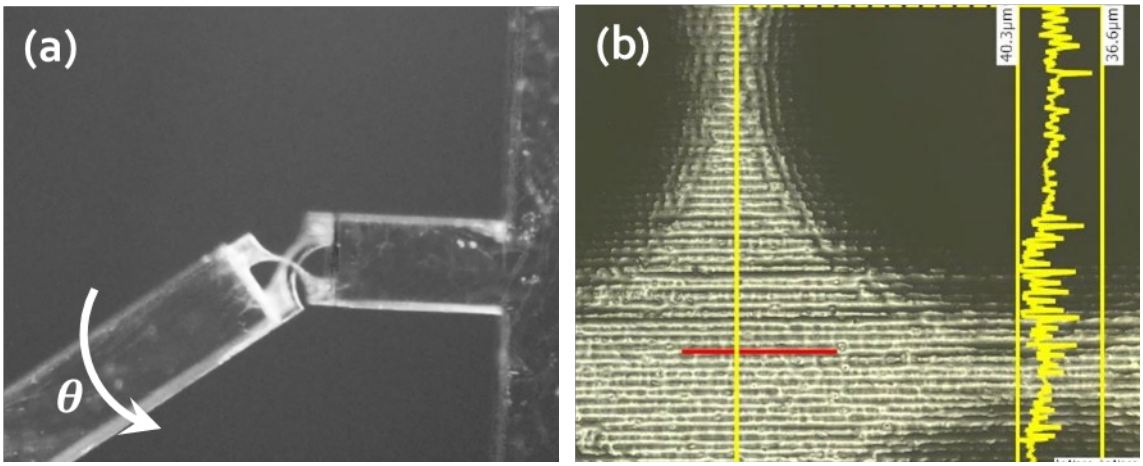


Fig.: (a) Glass micro-joint in deflection, yielding a pure rotation of the blade (credits: L. Amez-Droz, TIPs); (b) 3D confocal microscopy of the surface state of a glass structure.

[Bellouard2012] Y. Bellouard et al., The Femtoprint Project. Journal of Laser Micro/Nanoengineering. 7, No. 1, 2012. DOI: 10.2961/ jlmn.2012.01.0001.
[Montgomery2019] D. C. Montgomery, *Design and Analysis of Experiments, 10th Edtion, ed. Wiley, ISBN: 978-1-119-49244-3*

Improvement of a mechanical insertion with the Femtoprint machine

Promotors: Pierre Lambert (ULB) , Christophe Caucheteur (UMons)

Supervisors : Mateo Tunon de Lara (mateo.tunon.de.lara.ramos@ulb.be), Loïc Amez-Droz (Loic.Amez-Droz@ulb.be)

Context:

Among the large variety of laser technologies, the femtosecond laser is a very high repetition rate laser (up to 1MHz). It is usually used to create default in all kinds of glass or fiber, or even to micromachine glass parts in 3D at the microscale. The Femtoprint[1] machine relies on these principles, exhibiting many different parameters that can be adjusted very easily for many different applications[2] targeting mechanical or optical domains.[3]

Goals:

The goal of this project is to improve and optimize an actual design with the help of the femtoprint machine. To do so, the student will have to is to design a structure with the Alphacam software the goal of this structure will be to limit the possibility of optical and mechanical loss and simplify the insertion of the input.

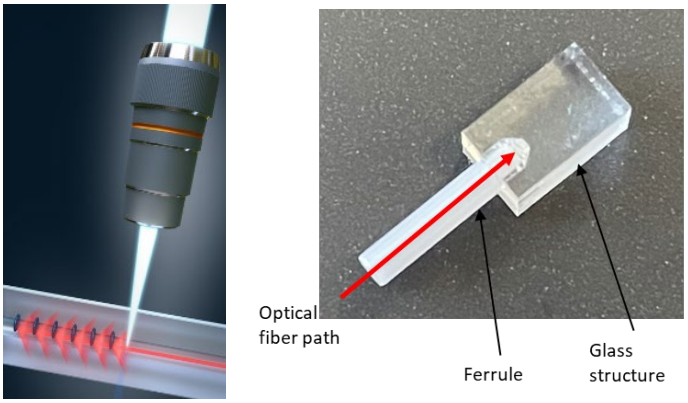


Figure: (A) Design of an inscription with the femtosecond laser, (B) Design on an optical ferules holder

Tasks:

Literature review, optical path measurements, design of a structure, Knowledge in optics.

References

[1]: Bellouard, Y., et al. "The femtoprint project." Journal of Laser Micro/Nanoengineering 7.1 (2012): 1-10.
[2]: Hill, Ryan T. "Plasmonic biosensors." Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology 7.2 (2015): 152-168.
[3]: Bado, Ph, et al. "Dramatic improvements in waveguide manufacturing with femtosecond lasers." NFOEC, Dallas (2002).

Microfabrication complexes optical shapes by using a femtosecond laser

Promotors: Pierre Lambert (ULB) , Christophe Caucheteur (UMons)

Supervisors : Mateo Tunon de Lara (mateo.tunon.de.lara.ramos@ulb.be), Loïc Amez-Droz (Loic.Amez-Droz@ulb.be)

Context:

Among the large variety of laser technologies, the femtosecond laser is a very high repetition rate laser (up to 1MHz). It is usually used to create default in all kinds of glass or fiber, or even to micromachine glass parts in 3D at the microscale. The femtosecond laser relies on these principles, exhibiting many different parameters that can be adjusted very easily for many different applications[2] targeting mechanical or optical domains.[3]

Goals:

In this project the student will have to create different optical structures and thanks to the actual setup in place characterize them and see which is the most representative and which one has the more potential for the different use.

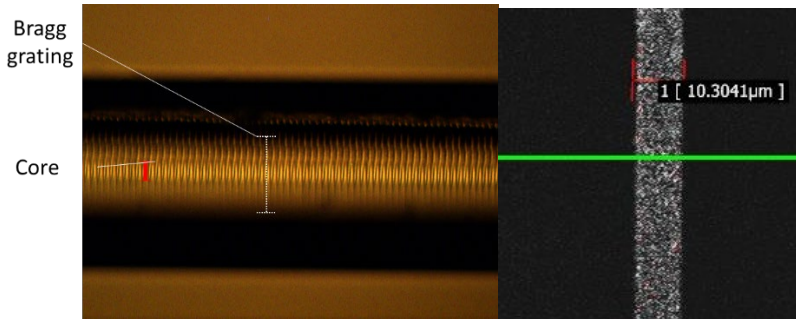


Figure: (A) Picture of a Bragg grating, (B) Microscope picture of an optical structure printed with the femtosecond laser

Tasks:

Literature review, optical path measurements, design of a structure, Knowledge in optics.

References

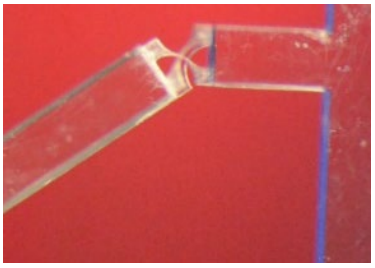
[1]: Bellouard, Y., et al. "The femtoprint project." Journal of Laser Micro/Nanoengineering 7.1 (2012): 1-10.
[2]: Hill, Ryan T. "Plasmonic biosensors." Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology 7.2 (2015): 152-168.
[3]: Bado, Ph, et al. "Dramatic improvements in waveguide manufacturing with femtosecond lasers." NFOEC, Dallas (2002).

Design of a testbench for glass flexure mechanism characterizations

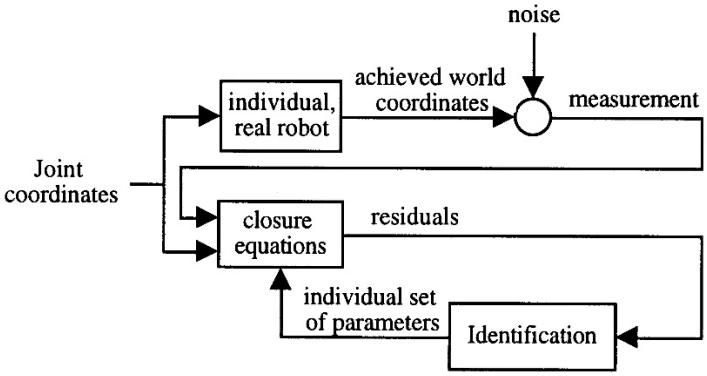
Promotor: Pierre Lambert, **Supervisor:** Loïc Amez-Droz, Matéo Tunon de Lara

Context:

New technology is available at ULB to print 3D micro-devices out of glass (fused silica) with submicron resolution. Considering the outstanding properties of glass, like its low loss factor, its low thermal expansion and its high elastic limit to Young modulus ratio, high-resolution monolithic flexure mechanisms can be obtained.



Amez-Droz 2021, Fused silica flexure pivot



Vischer 2000, Implicit calibration for parallel robots

Goals:

The goal of this project is to design a testbench to characterize flexure mechanisms. The student will discuss with the scientists designing the flexure mechanism to define the testbench specifications. Characterization includes static force analysis and vibration study. He will propose its most promising design and choose the applicable sensing and actuating methods. Then, the testbench will be manufactured and assembled at the laboratory. The student will be able to characterize flexure mechanisms with the help of scientists.

Tasks:

Literature survey, requirement analysis (sensor sensibility, operating range, manufacturability…), kinematics description, analytical model, computer aided design (CAD), experimental characterization.

[Bellouard2009] Bellouard, Y. (2009). Microrobotics: methods and applications: CRC Press.

[Henein2000] Henein, S. (2000). Conception des structures articulées à guidages flexibles de haute précision. Thesis.

[Vischer2000] Vischer, P., & Clavel, R. (2000). Kinematic calibration of the parallel Argos mechanism. *Robotica, 18*(6), 589-599.

[Vischer1998] Vischer, P., & Clavel, R. (1998). Kinematic calibration of the parallel Delta robot. *Robotica, 16*(2), 207-218.