Experimental study and modeling of hydrodynamics and light distribution in a photobioreactor for the culture of encapsulated microalgae (ValoAlgue project)

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Introduction

Cultivation of encapsulated microalgae to product high added value metabolites.

Luciferase is partially excreted from this *Chlamydomonas reinhardtii* strain.

Benefits

Easy harvesting

Continuous process

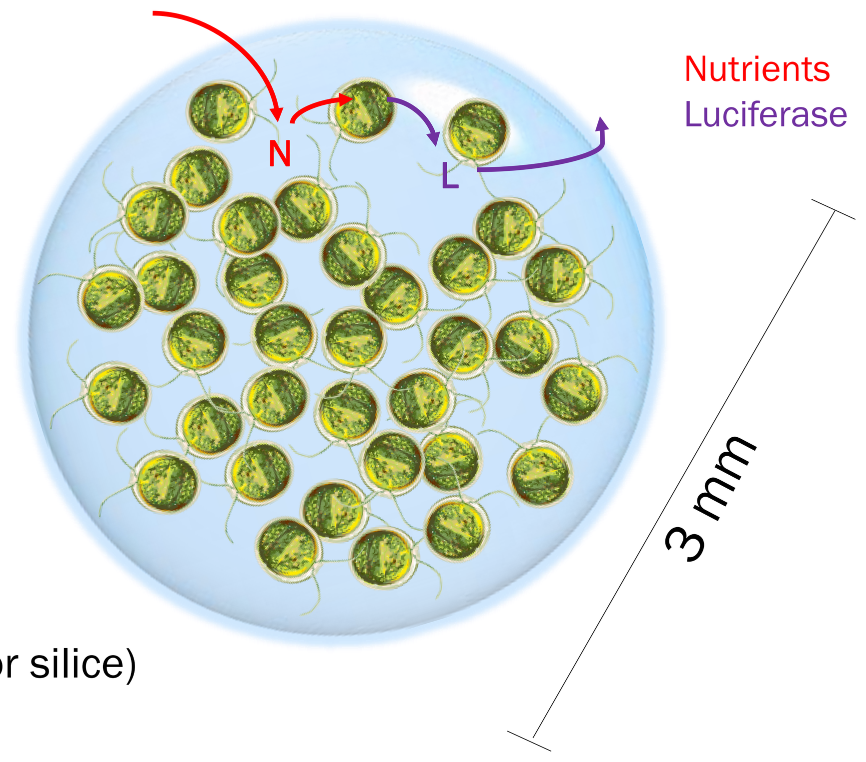
Convenient manipulation

Challenges

Growth control

Constraints on immobilisation matrix (alginate and/or silice)

Lack of large scale experiments



Algae Factory Consortium

ValoAlgue project – Encapsulated microalgae

UsinAlgue project – Strain selection, Mass culture

- Chemical and Biochemical Processes Engineering – UMONS, Université de Mons
- Inorganic Materials Chemistry – Université de Namur
- Chemical Engineering – Photobioreactor design – Liège université
- Life Sciences, Bioenergetics

Photobioreactor

Rectangular fluidized bed reactor: improve light distribution and CO_2 transfer

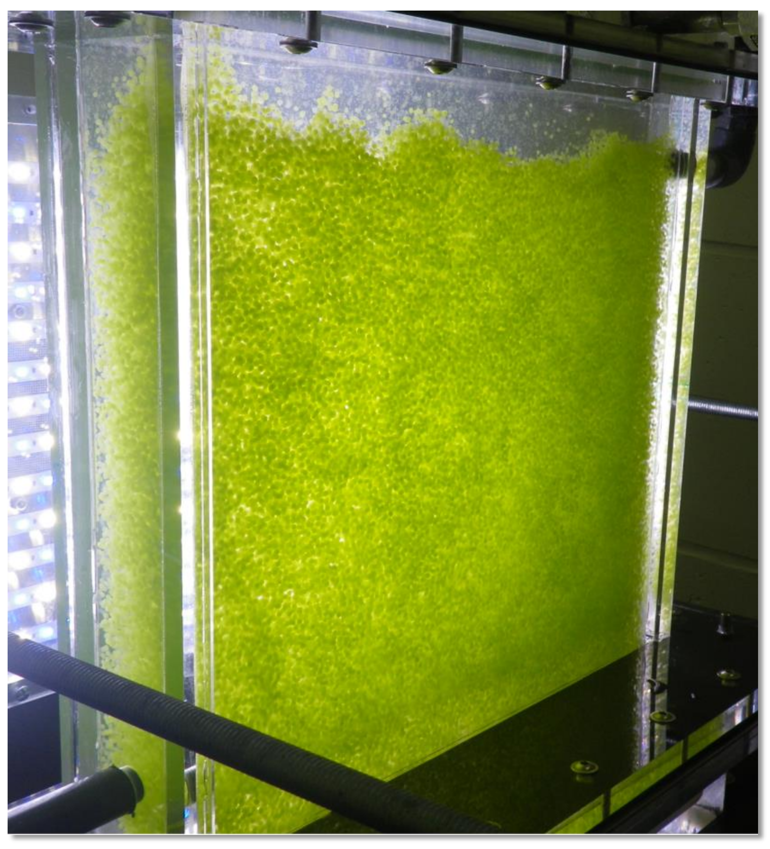
Volume of ~ 5 liters

34 cm width

38 cm height

4 cm depth

Contains around 1 liter of beads (apparent volume)



Reactor characterization

Hydrodynamics
- Experimental: Particle Image Velocimetry (PIV)
- Model: Computational Fluid Dynamics (CFD)

Light
- Experimental: Photosynthetically Active Radiation (PAR) probe
- Model: Light distribution (attenuation law)

Microalgae properties

Biological activity
- CO_2 consumption and O_2 production
- Biomass growth
- Photosynthetic activity
- Metabolites productivity

Hydrodynamics → Bead circulation → Passage frequency in illuminated and dark zones ← Light

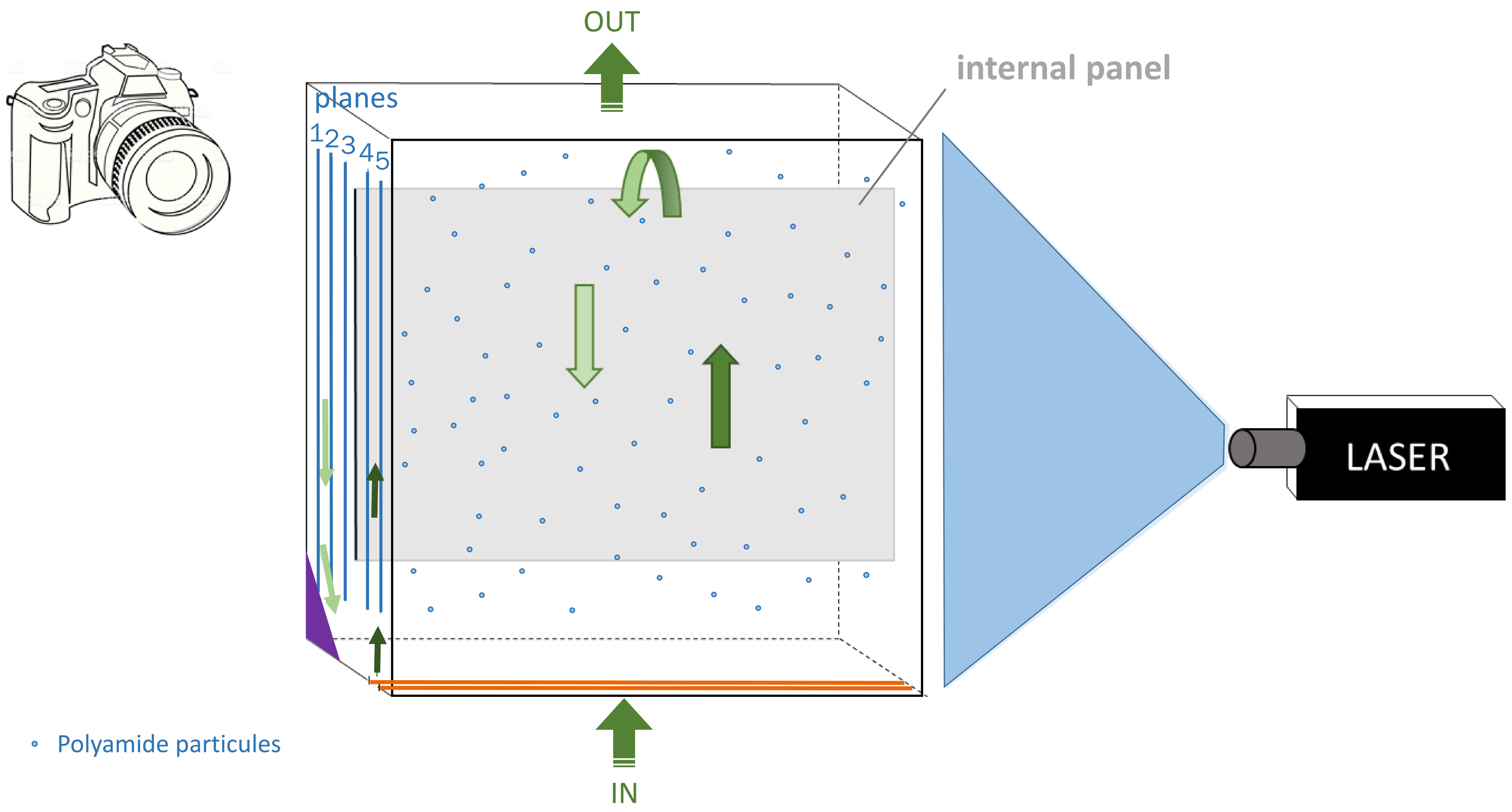
Passage frequency in illuminated and dark zones ↔ Biological activity

Methods

PIV and CFD monophasic characterization

- 2 different pump flow rates: 400 l/h and 500 l/h (optimal fluidization)
- Laminar, Transient flow: 300<Re<400 at the inlet
- Velocity at the inlet between 0.3 m/s and 0.4 m/s
- Average of 500 images on 100 seconds period
- CFD: 1 million meshes, 0.02 seconds time step
- 5 vertical planes

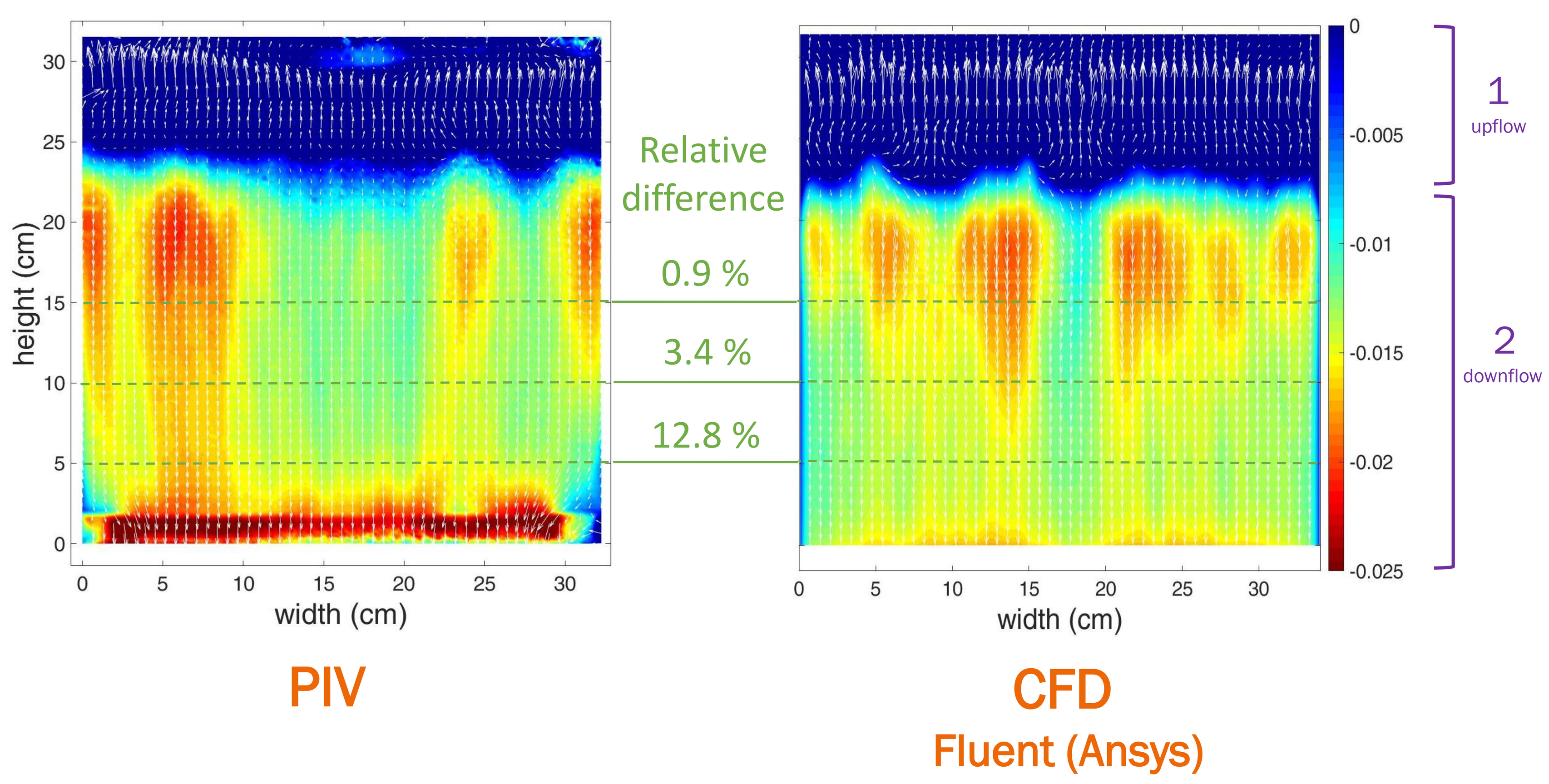
PIV setup



Bead recirculation improved by the internal panel, the off-center injection (1 mm) and the bottom prism

Monophasic Results

Plane 3: mean axial velocity (m/s) – descending flow



- Chaotic motion: statistical time averaging needed
- Experimental error in PIV between 10% and 16% (depending on the height)
- Observation of two zones (upflow (1) and downflow (2)) above and alongside the internal panel due to the recirculation
- Measured values are systematically lower than simulated ones (between 1% and 13%)

Conclusion

The agreement is satisfying between measurements and simulation because discrepancies between measured (PIV) and simulated (CFD) mean axial velocities fields are lower than experimental error.

Discrepancies can be explained by the very high influence of the measurement plane position on axial velocities (plan 1 is near the wall, plans 4 and 5 are close to the injection) and the difficulty of making PIV measurements in exactly similar planes as CFD simulations.

Perspectives

- Diphasic PIV and CFD: including beads (solids) to evaluate solid influence on the flow
- Light distribution measurements to quantify bead absorption and scattering and define illuminated and dark zones. Their influence on metabolites productivity will be integrated in the model.

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