Computational analysis of hydrodynamics and light distribution in photo-bioreactors for algae biomass production

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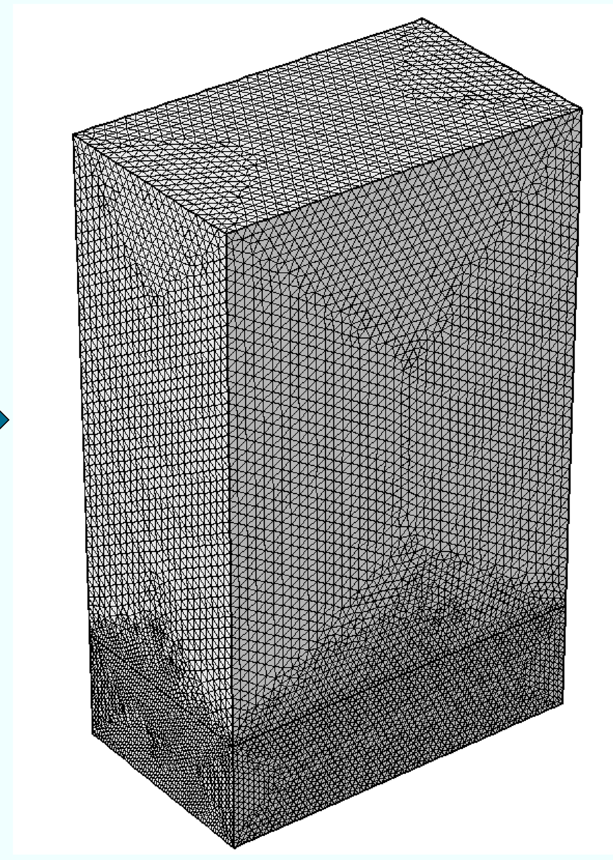
Introduction

Microalgae are proven to have great potential in a variety of fields including commercial industry, water treatment, agriculture and source of biodiesel [1] [2]. To realize the full potential of microalgae, optimal operating conditions for their cultivation in photo-bioreactors (PBR) need to be identified in order to maximize productivity, lipid content, and efficiency of photosynthesis. The most important parameters affecting PBR performance are reactor shape, light intensity distribution, algae growth and other metabolic properties. The presented study aims at optimizing these parameters using Computational Fluid Dynamics (CFD) simulations with the COMSOL Multiphysics software.

1. Hydrodynamics

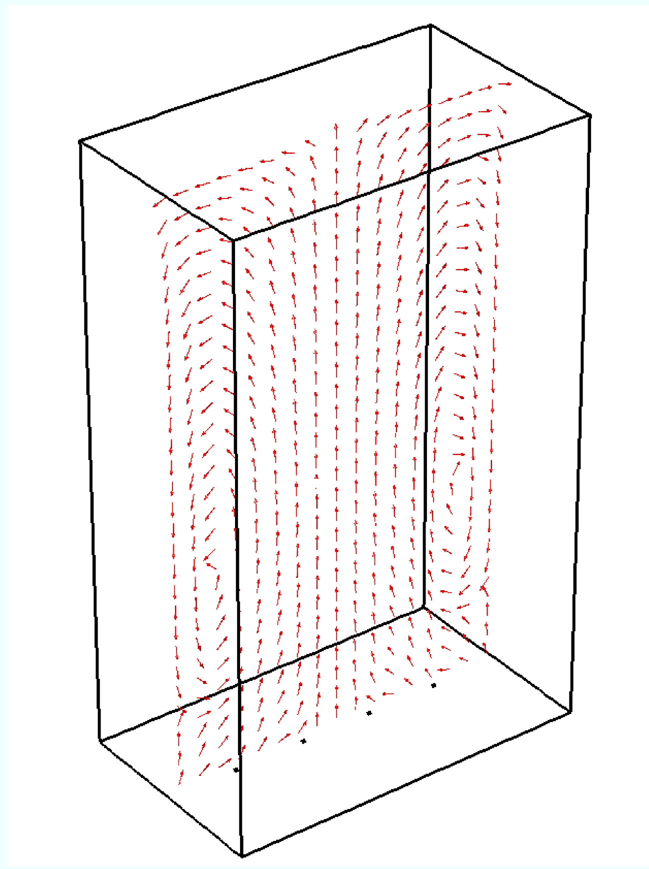
- Hydrodynamic studies using the turbulent bubbly flow model of COMSOL Multiphysics are being performed.
- Only liquid and gas phases are considered during these simulations (no microalgae cells considered).
- This model solves the Navier-Stokes equations using Eulerian approach for both phases
- The bioreactor is a lab scale flat panel reactor (10.34x6.1x20.83cm) with a liquid holding capacity of 1L

Actual bioreactor picture

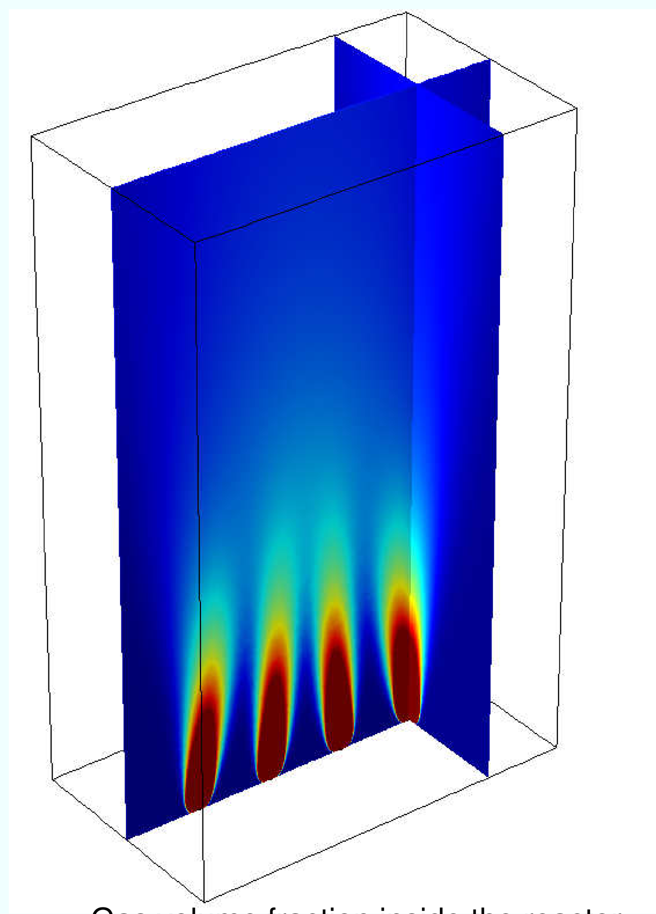


Discretized mesh

Solving Navier-Stokes equation



Velocity vector in the central plane in the reactor



Gas volume fraction inside the reactor

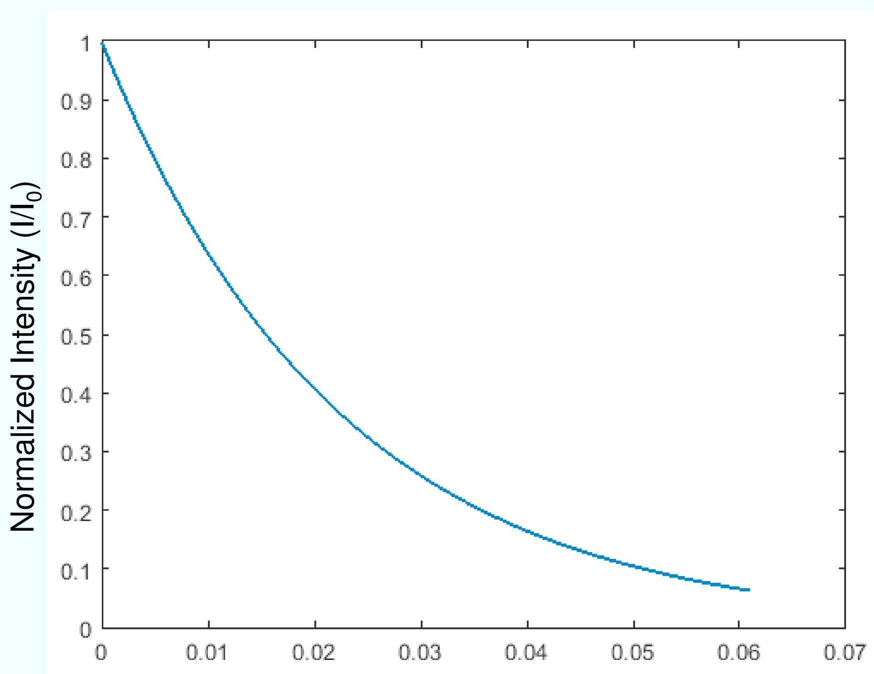
2. Light Intensity Distribution

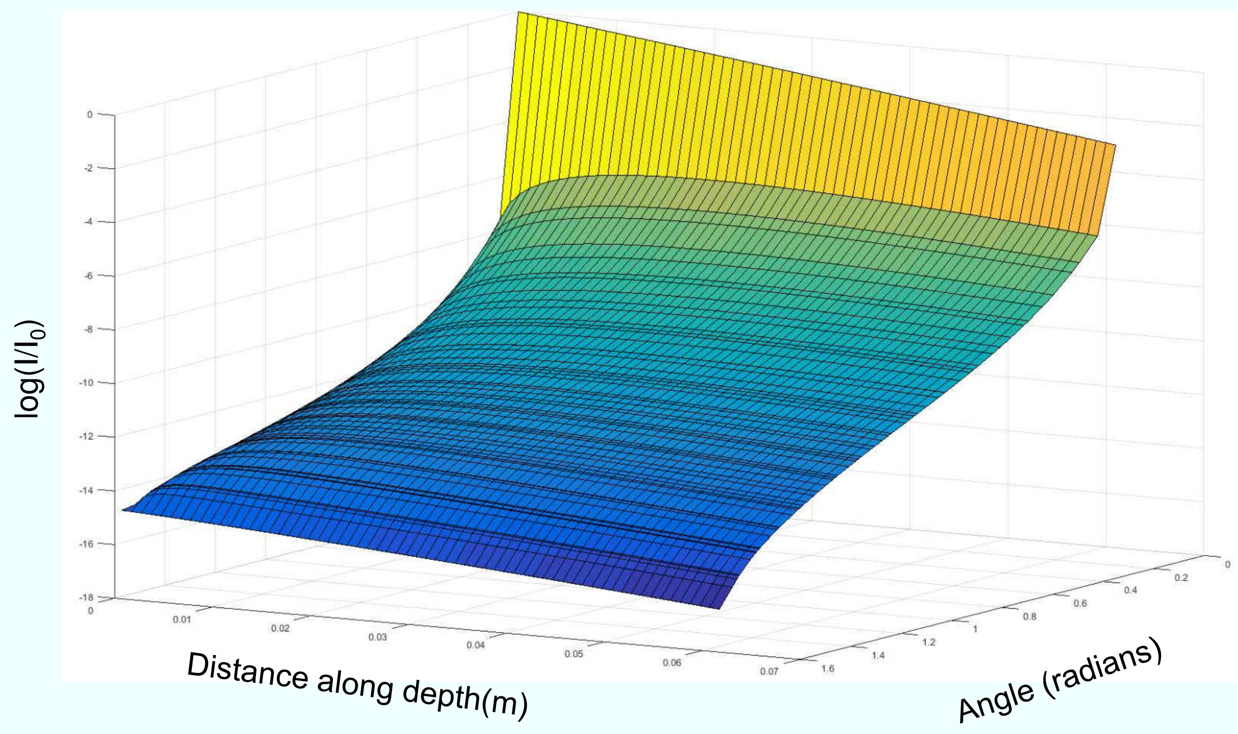
- Light intensity distribution is achieved by solving radiative transfer equation (RTE)

$$\frac{dI}{ds} = -\kappa I - \sigma_s I + \frac{\sigma_s}{4\pi}\int I(\bar{s}_i)\Phi(\bar{s}_i,\bar{s})d\Omega_i$$

- HG approximation used for estimating scattering phase function Φ

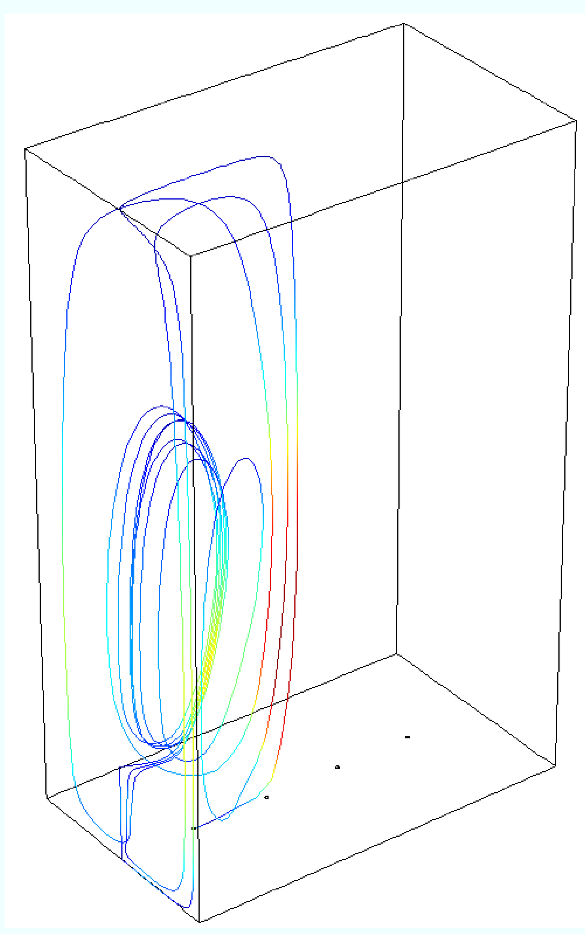
$$\Phi = \frac{1-g^2}{(1+g^2-2g\cos\theta)^{1.5}}$$

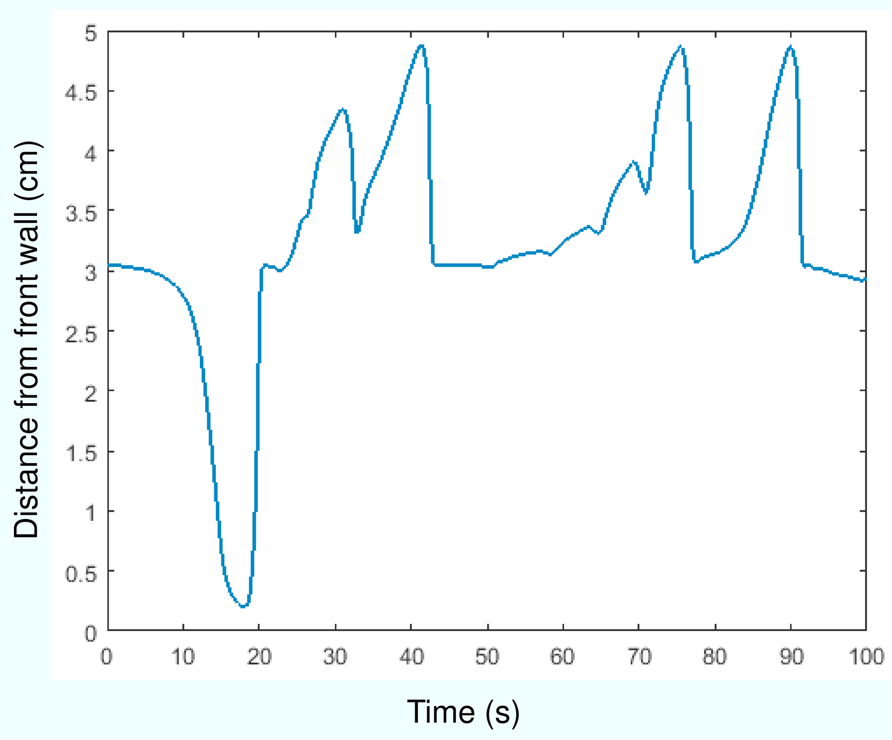




3. Particle Tracing

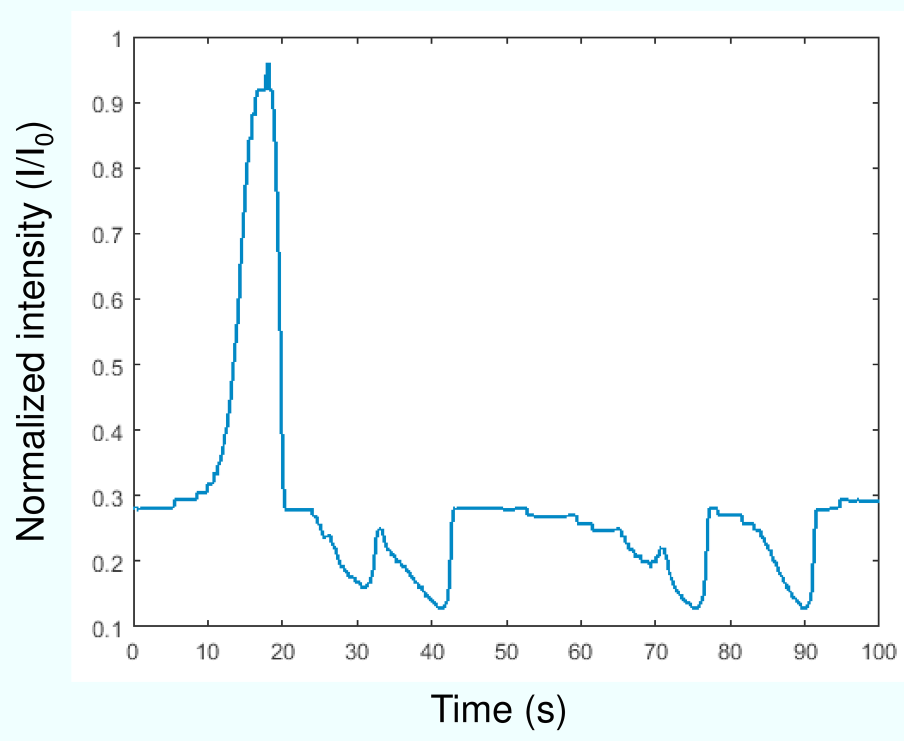
- Path of the microalgae cells are traced with time using the liquid phase velocity profiles from the hydrodynamic study
- Information on the dead zones can also be extracted as the time a particle spends in the critical region





4. Combining Particle Tracing and Light Intensity

- A look-up table showing light intensity experienced by an algae cell with time is made combining data from particle tracing and light intensity distribution



- In future these results will be combined with CO_2 transfer models and then all the parameters will be optimized to achieve the best performance out of the PBR

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
PtJ Projektträger Jülich Forschungszentrum Jülich

5. References

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[2] Bitog et al., (2011) *Comput. Electron. Agr.* **76**: 131-147.

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