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Experimental tests and simulations of the microPBR4D algae culture system

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***Abstract*—To reverse the climate change trend, ArrCO2 is proposing a pathway within an industrial ecosystem to answers economical demand for oils, complex sugars, proteins and carbonate while returning CO_2 to a fossil form as a by product. This industrial ecosystem is a reproduction of one of the world biggest carbon sink on earth, which is the blooming of coccolithophores linked with the liberation of calcium by (bio)weathering. To grow coccolithophore at an industrial scale world wide, a new device to grow algae was designed called microPBR4D. This facility should have the highest annual biomass production by unit of ground compared to current photobioreactors. In theory microPBR4D should improve the maximal photosynthetic efficiency (energy in biomass per unit of absorbed light) of 9 % of the full solar irradiance. The objective of this PhD is to measure several predicted features of this new class of photobioreactor. The characteristics expected are cell densities higher than in liquid culture, light distribution in time and space synchronized with electrochemical transfer velocity of photosynthesis, increase of PAR from UV conversion, electricity generation using infrared energy and energy storage.**

***Keywords*—**
- **IE: Industrial ecosystem.**
- **microPBR4D: micro photobioreactor.**
- **LTI: light transmitting item.**
- **LPU: light processing unit.**

I. Introduction

ArrCO2 propose a pathway within an industrial ecosystem (IE) that starts with atmospheric CO_2 and ends up with carbonate containing products that can store CO_2 during geological time spans. It links economical growth to carbon sequestration. This IE associates a biogas reactor, a photobioreactor and ashes from incinerator plant. It diverts CO_2 coming from biogas combustion to provide a carbon source to an intensive culture of carbonate producing algae. The nitrate and phosphate sources would by diverted from digestate, thus avoiding nitrous gas emissions commonly associated with handling it. The oxygen produced by the algae can be used to make a wet oxidation pretreatment of the biomass. It leads to delignification of lignocellulose by converting lignin into to acids, on which methanogenic bacteria consortia can feed, thus largely increasing biogas production yield and reducing the digestate volume to handle.

In the case of carbonate producing algae, calcium which is normally part of the micro elements of a classic plant fertilizer, is becoming a marco element as predicted by a stoichiometric equation of coccolithophore culture mass balance. To mimic the liberation of calcium through the (bio)weathering process, ArrCO2 looked for industrial amounts nearby digestor. It found large amounts of calcium in ashes produced by household waste incineration plants.

At the heart of this IE, there is a culture of carbonate producing algae. To meet the demand for a convenient and efficient algae culture reactor, ArrCO2 developed a new class of algae culture system called microPBR4D, which is the subject of this PhD proposal.

II. State of the Art

The classical types of large scale algae culture are outdoor pounds, enclose outdoor photobioreactors or indoor culture in greenhouse using plastic tubing, plastic bags or similar container. These systems makes it energy inefficient to maintain optimal growth temperatures. They also have a large energy lost due to solar reflexion and reflection.

This problem is becoming even greater with light reflecting cultures of coccolithophore.

To solve the light distribution problem, research were made to increase available light inside photobioreactors by using optic fibers.

ArrCO2 tried to improve it by adding a foam layer that could increase the cell density around the light source. However due to the high cost and fragile nature of optic fiber, ArrCO2 has done research to find different light transmitting item (LTI) that could mitigate the disadvantages of optic fibers while keeping its advantage of even light distribution.

III. Research Objectives and Approach

All the obstacles between the sunray and the photosynthetic systems were reviewed. Technical solutions were proposed to optimize the energy transfer. The objective of this PhD is to answer the question how do they perform experimentally.

A. Research Objectives

- *Outdoor tests of the heliostat system for microPBR4D*

An heliostat was specifically designed to track the sun all day long and to reflect light into the optical entrance of the photobioreactor with a minimal lost due to reflexion and refraction.

- *Outdoor measurements of the LPU performances*

  The light which enters the LPU is treated to remove excessive heat from infrared and to produce electricity necessary to power the system. To avoid the mutagen effect of the UV, the LPU converts UV to photosynthetically active radiation (PAR) and the visible light is optimized to improve photons photosynthetic yield. To avoid a big light gradient within the LTI and achieve an homogeneous light distribution, the LPU has a system to distribute light dynamically at 360° to the LTI. The frequency of the light distribution can be tuned to try to synchronize the light arrival with the electrochemical transfer velocity of photosynthesis. ArrCO2 put forward the digital photosynthesis hypothesis which states that there is an optimal operating frequency that can avoid photo inhibition while allowing an optimal amount of photons to be processed by the photosystems.

- *Laboratory tests of lamellar 4D photobioreactor*

  The latest model of lamellar LTI is designed to channel light to the cell culture. Furthermore based on experimental observations of the sedimentation of coccolithophore culture in laboratory, ArrCO2 hypothesized that the lamellar LTI could allow a cell density higher than liquid culture density.

B. Approach

This research will be a combination of computer simulations and field and laboratory experiments.

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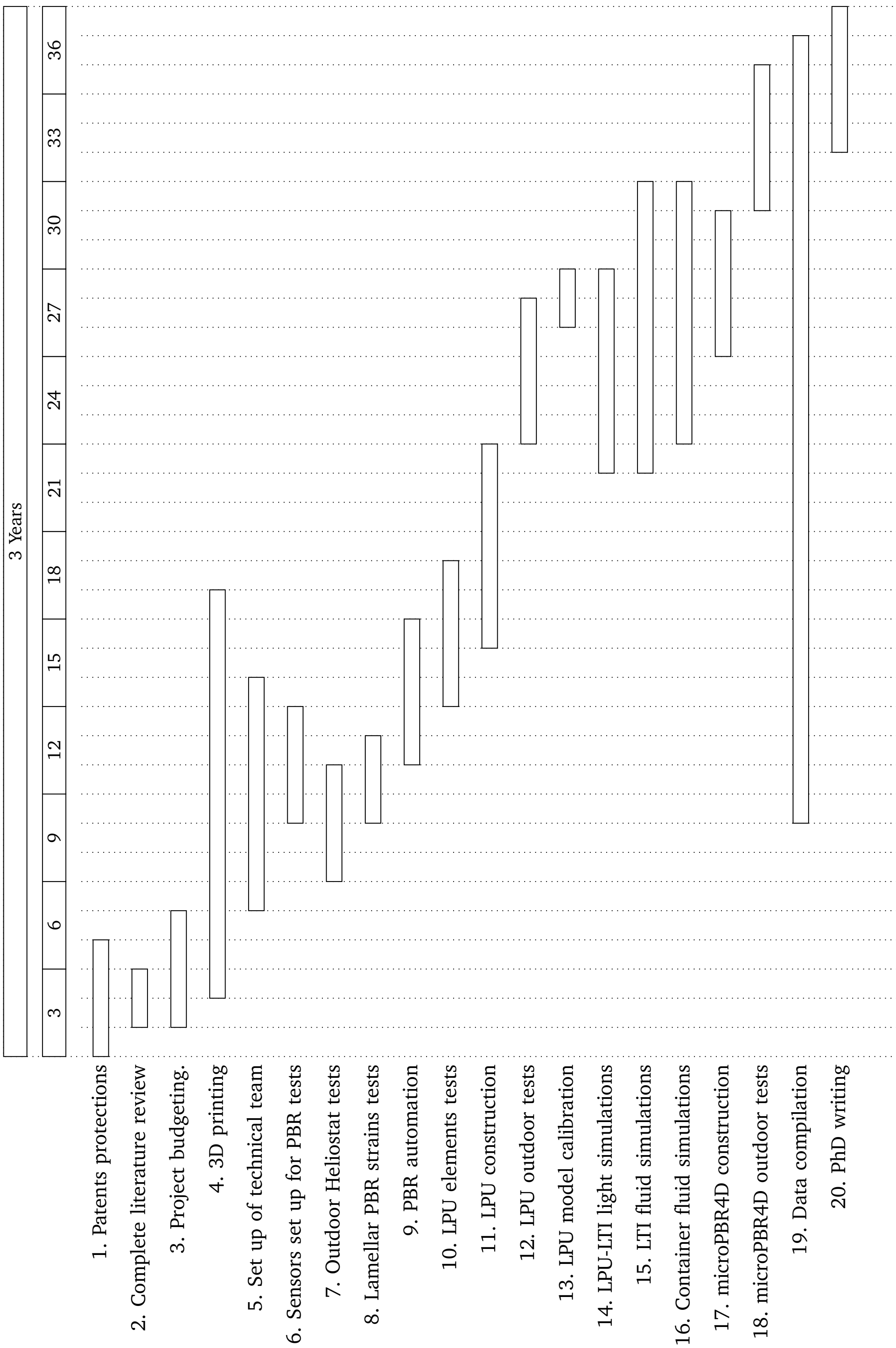
I. TIMELINE



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