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The Latest Development of Laser Application Research in Plant Factory

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Abstract

Essential resource elements in crop production are light, water, carbon dioxide and fertilizer. Optimum design for air-conditioning and lightings in plant factory system is required to realize the economical operation of plant factory because most energy consuming elements of plant factory system are air-conditioning and lightings. In this sense application of solid state lighting sources such as LED in plant factory system have been promoted to expect some reduction of running cost in lighting. Research work of solid state laser application in plant factory has just started recently at Osaka Prefecture University Plant Factory Research Center. The latest development of laser application research in plant factory will be reported in this article.

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Keywords: laser; LED; plant factory, plant growth control; PWM

1. Introduction

The recent development of LED application for s in between and even the durability of lamps, appropriation of its narrow spectrum, requirement of DC power source and the huge initial cost. After much trial and error, researchers succeeded in improving the lamps and developing their cultivation method by analyzing how plants react to lights. The entire process from seeding to harvesting can be done mechanically, which reduces man power, bringing the project closer to achieving profitability.

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Many of plant factory researchers initially got the idea that LED could reduce running cost significantly when they become aware of the NASA project which used LED lights to grow plants in space (Fig. 1). The LED application in plant factory brought better prospects of future plant factory business expansion. Then plant factory related projects aim not only to provide consumers with safe and secure food but also to support future expansion of the new industry.

Fig. 1. Lettuce and chard are among crops tested at NASA's Kennedy Space Center in Florida for future space gardens.(NASA Kennedy Space Center)

Since affordable LASER diodes were developed, our LED technologies developed for plant factory systems have become more useful in terms of developing advanced lighting systems for plant growth control. By looking more closely into the thylakoid reaction, it has been found that LASER application on plant factory may give tremendous solutions to problems associated with for lighting for the plant growth control.

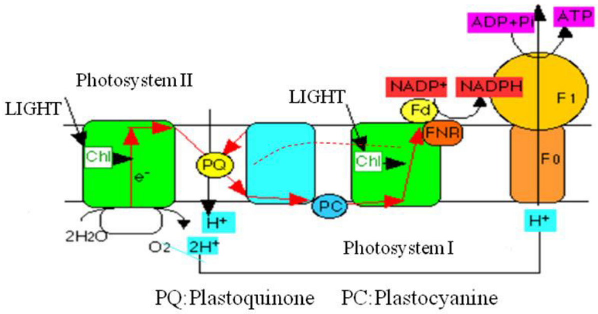

Fig. 2. Thylakoid reaction

2. Application of Scan LASER

Fig.3 illustrates one of scan LASER applications among various energy saving strategies for growing vegetables in plant factories. The coherent nature of laser light allows a narrow beam to be produced, which allows the use of optical scanning to draw patterns or images on 3D surfaces without refocusing for the differences in distance, as is common with video projection. The conventional illumination method to grow vegetables is that photons, which drive the photosynthesis, are fallen all over the space where plants are growing and spaces in between plants. One example of illumination methods by scan LASER is that photons are shot into each head of vegetable avoiding spaces in between.

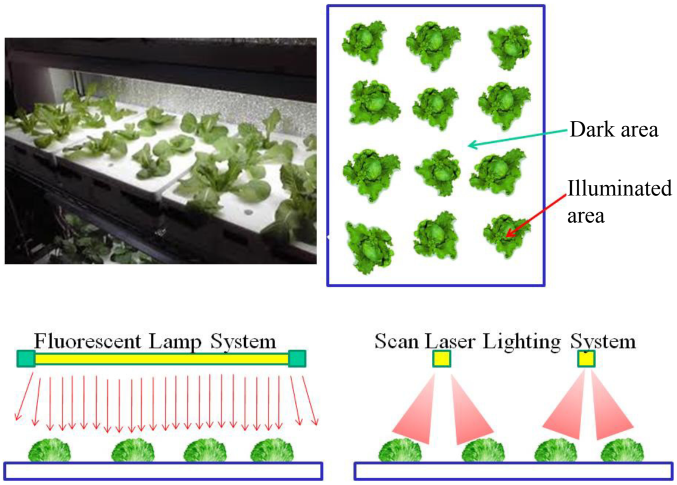

Fig. 3. Scan LASER illuminates where it is needed

3. LASER Projector to Grow Vegetables

As shown in Fig. 4, a commercial LASER projector equipped with 50 ~ 100 mW LDs and MEMS mirror was used to culture radish sprouts for green salad. The 3 LASER beams consisting of 450nm, 570nm and 640nm respectively become a single beam by a semitransparent mirror. Fig, 5 shows that radish sprouts were grown under a scan LASER lighting as good as a regular florescent lamp lighting. The scan rate was about 25MHz which means that a beam spot was stayed over a group of photoreceptor cells of which function is to catch photons for a few 10 ns.

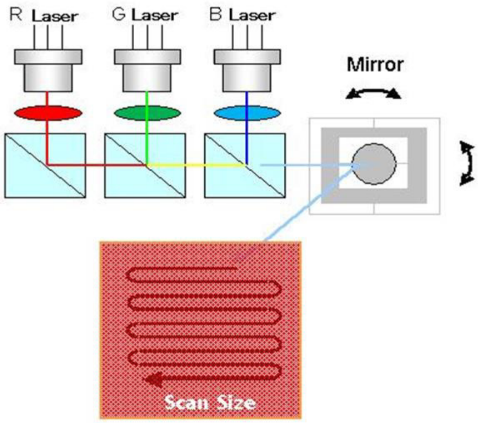

Fig. 4. Schematics of scan LASER projector

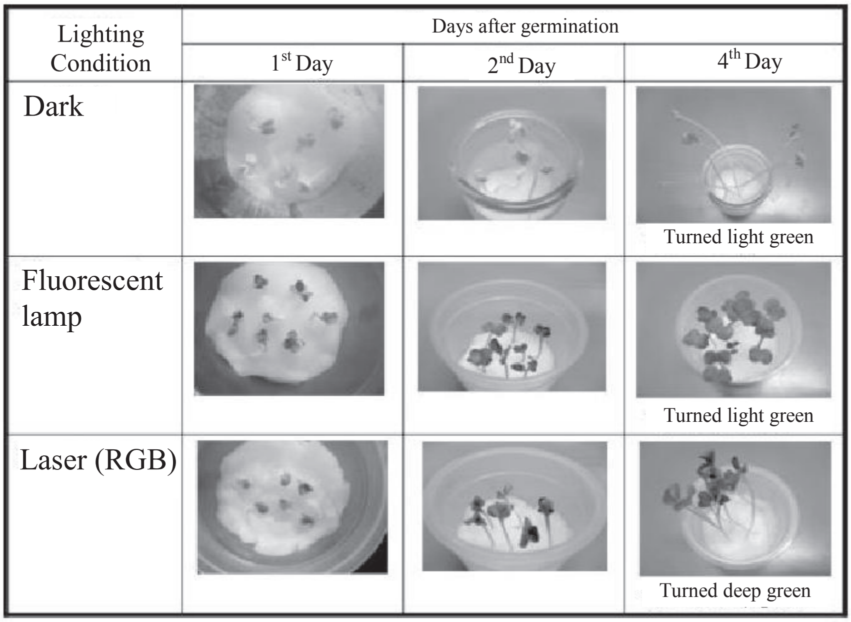

Fig. 5. An experimental result revealed that a less than 1 W scan laser was able to culture radish sprouts

4. PWM to Synchronize the Thylakoid Reaction

In the thylakoid reaction energy charge by photoreceptor cells takes place within a split second. The most effective way to charge those photoreceptor cells is to synchronize the moment of exciting those cells with the illumination when they need photons. Fig. 6 illustrates an idea of PWM to synchronize the photon supply with photoreceptor cell activity. An experiment was conducted to demonstrate the PWM with lettuce cultivation.

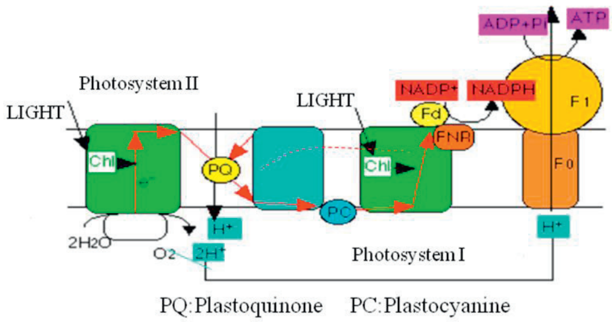

Fig. 6. PWM to synchronize the Photosystem I and II with the photon flush timing

A cw diode laser was used of which specification was the following:

- Power 60mW (234µmol m-1 s-1)
- Wave Length 660nm

- Beam Diameter 14 mm2.

Table 1 shows the PWM conditions. Table 2 shows the experimental result. Lettuce seedlings were cultivated for 2 weeks and the measure their heights and weights. The controls were grown under dark condition. The controls stopped their growth after they used up their initially stored energy in seeds. The result implies that the photosynthesis may take place under PWM lighting condition that leads us to the innovation in tremendous energy saving crop production.

Table 1. PWM Conditions

	On microsecond	Off millisecond
Pulse Width	67.93	6.72

Table 2. Experimental Result

	Height	Fresh weight
Illuminated	92 mm	85 mg
Dark	8 mm	7 mg

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