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Environmentally Clean Mitigation of Undesirable Plant Life Using Lasers

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Figure 1: Plant mitigation of an opium poppy field, using our laser diode system mounted on an aerial platform.

I. Abstract

This concept comprises a method for environmentally clean destruction of undesirable plant life using visible or infrared radiation. We believe that during the blossom stage, plant life is very sensitive to electromagnetic radiation, with an enhanced sensitivity to specific spectral ranges. Small doses of irradiation can arrest further plant growth, cause flower destruction or promote plant death. Surrounding plants, which are not in the blossoming stage, should not be affected. Our proposed mechanism to initiate this effect is radiation produced by a laser. Tender parts of the blossom possess enhanced absorptivity in some spectral ranges. This absorption can increase the local tissue temperature by several degrees, which is sufficient to induce bio-tissue damage. In some instances, the radiation may actually stimulate plant growth, as an alternative for use in increased crop production. This would be dependent on factors such as plant type, the wavelength of the laser radiation being used and the amount of the radiation dose. Practical, economically viable realization of this concept is possible today with the advent of high efficiency, compact and powerful laser diodes. The laser diodes provide an efficient, environmentally clean source of radiation at a variety of power levels and radiation wavelengths. Figure 1 shows the overall concept, with the laser diodes mounted on a movable platform, traversing and directing the laser radiation over a field of opium poppies.

II. Introduction

The Need for Undesirable Plant Mitigation

The need to remove and destroy undesirable plants is as old as civilization. The problem is currently solved by: 1) physical plant destruction (manual and mechanical removal), 2) the use of various chemicals (herbicides) or 3) the use of biological agents (bio-agent such as the weevil). The first solution requires human participation, which can be expensive, time consuming and often times difficult to implement in remote areas. The second solution is associated with collateral damage (such as contamination of drinking water), long-term environmental consequences and a general public opinion against the use of chemicals from an ecological perspective. The third solution's effectiveness is neither totally controllable nor predictable, corresponding to varying degrees of success. We propose to attack the undesirable plant during the time of blossom growth. The use of radiation, in the spectral range of high absorption of the tender parts of the blossom, can selectively heat these areas to temperatures high enough to initiate tissue damage. Even if the plant itself survives after irradiation, the degradation will be sufficient to stop the plant from reaching full maturity, especially with regards to harvesting of plants used in the manufacture of drugs (opium poppy, cannabis sativa).

III. Background

The idea to use laser radiation during the blossom stage to promote plant destruction has been suggested previously [1,2]. However, in the referenced publications, the authors suggest the use of laser radiation that is tightly focused on specific areas of the plant. There are several drawbacks to this scheme which include the following: the high price of lasers, the low electrical to optical efficiency of the laser corresponding to a large power management system requirement, a sophisticated laser-target aiming system, the need to use a computer vision system for target selection and the very small amount of plant throughput due to the small laser spot size (millimeters in size). In addition, these lasers used radiation wavelengths that were not optimized for efficient plant absorption, and the intensity of the lasers used was simply that which was available and certainly not optimized for plant specifics.

We suggest the use of powerful diode lasers as the irradiation source. This compact and powerful radiation light source has a 50% electrical to light conversion efficiency, is extremely compact, and capable of extended continuous operation (Figure 2: a commercially available 100 kilowatt diode array, about the size of a small loaf of bread and weighing about twice that of a standard bowling ball). The high power of the diode array makes it possible to illuminate a wide area (several square meters) of plant growth simultaneously without aiming specifically at the plant's blossoms. To destroy the plant, the blossom need only be heated to where the tissue is elevated in temperature and protein denaturation starts.

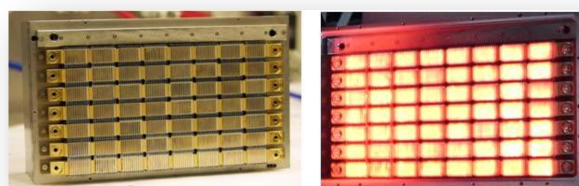

Figure 2: 100 kW, 560 bar diode array manufactured by SiMMtec.

As a numerical example, consider the following: the meristem, or blossom portion of the plant, has a thickness of about 1 mm. Assuming that the medium is mainly water, an absorbed radiation flux of ~10 joules/cm^2 will increase the temperature of this part of the plant to over 20 degrees Celsius, which is sufficient for arresting plant growth or causing plant destruction. For a single 100-kilowatt laser source, previously described and with a laser spot size of 1 meter by 10 meters (rectangular area), the required amount of irradiation will be attained by moving at a very moderate speed of 1 meter per second (~ 2.2 miles per hour). Multiple laser sources would be used to irradiate large surface areas. Figure 3 is representative of a laser diode mounted on a movable platform, and the radiation footprint that it would be able to provide. The altitude of the movable platform is several times the long dimension of the rectangular area and can vary as required by the application specifics (terrain, foliage, etc).

One area of specific interest is the control and mitigation of plants used to make illegal drugs, such as the opium poppy and cannabis sativa. Vast areas of these specific plant fields can be treated by the use of laser diodes in a short amount of time as described above. Treating these plants at the appropriate time in their life cycle (blossom stage) can have a dramatic affect on the plant growth and the harvest yield.

The choice of laser wavelength is a key performance parameter. As a general rule of thumb, radiation in the short absorption wavelength regime produces a nondestructive burn of the plant surface in addition to requiring a lot of energy. A more suitable wavelength that will work for many plants is the strong water absorption band in the infrared, below 1.3 microns. Another option is to tailor the laser diode system to be used at a specific wavelength suitable for the absorption of a particular plant, corresponding to its color absorption center. The format of the radiation, continuous wave (cw) or pulsed, produced by the laser diodes is also a parameter that can be used to enhance the overall effectiveness of the system.

In the case of processing for aquatic plants and weeds, the laser diodes would operate in blue-green wavelengths, corresponding to the transparency window for water. Control and mitigation of a floating aquatic weed such as the water hyacinth and harmful algal blooms are just two examples of aquatic growth that need to be controlled. Heavy infestations can have a variety of negative consequences including: altering of ecosystems, human health placed at risk, marine mammals that are either injured or killed, fishing, agriculture or recreational industries suffering significant economic losses, and blockage of rivers - correspondingly affecting hydroelectric plants. Using laser diodes provides an environmentally clean and efficient method for control of these types of aquatic plants and weeds.

In some instances, the radiation may actually enhance plant growth (for increasing crop production as an example), again depending on the plant type, laser energy, duration of the radiation on the plant, laser wavelength, etc. Needless to say, optimization of the laser diode wavelength via experimental studies and analysis must be done for each specific application to ensure the desired results.

IV. CONCEPT OVERVIEW

The proposed system is straightforward in concept (see Figure 3). The basic concept consists of a laser radiation source (laser diodes) mounted to a movable platform. The platform can be land, water or air compatible, and capable of covering relatively large areas of plants/weeds in a reasonable amount of time. This allows the radiation, being emitted by the laser diode source, to impinge on plants (blossoms) to either arrest further plant growth, cause plant death or in some situations, enhance plant growth. The distance of the laser diode to the plant can vary from a few meters to tens of meters away. Large areas can be treated in short periods of time since only several seconds of radiation need be administered to each plant. As mentioned previously, the final disposition of the plant is a function of many parameters (laser radiation energy, laser wavelength, elapsed time of the laser radiation on the plant, etc.).

We believe our design provides the following new ideas:

1. New method to arrest plant growth or cause plant death of undesirable plants and weeds. The method is environmentally clean.
2. New method to enhance plant growth. The method is environmentally clean.
3. The source of radiation is laser diodes, compact in size and weight, and efficient in converting electricity to light radiation.

4. The laser diode radiation source can be tuned to be application specific. This includes laser: energy, wavelength, time on target, laser format (pulsed or continuous wave operation).

5. The radiation source can be placed on a variety of platforms, including helicopters or UAV's (unmanned aerial vehicles) for aerial field processing, moving ground vehicles compatible with agriculture processing equipment, and boats or barges for applications in the marine environment.

Figure 3 identifies the simple design of our proposed system. The laser diodes are in a self-contained package, with performance parameters suitable for the specific application. The laser diode technology has already been demonstrated and is available commercially. The 100-kilowatt laser diode shown in Figure 2 is manufactured by SiMMtec, Allison Park, PA. Since 2003, the power management and thermal management systems required for the laser diode have been thoroughly tested and validated using the Solid State Heat Capacity Laser (SSHCL) testbed facility at Lawrence Livermore National Laboratory.

The aerial platform shown in Figures 1 and 3 is called HYSTAR, manufactured by The Alliance Enterprise Corporation, Mill Valley, CA. This platform can be made in a variety of sizes, from a few meters in diameter to tens of meters in diameter, again showing the maturity of the technology. As previously mentioned, many different platforms can be used, depending on the specifics of the application; we show this aerial platform only as an example.

The specifics of the application, namely the type of plant/weed of interest, the environment that it is in, etc., all need to be taken into account when developing the laser diode system. Specific experimental testing will be conducted to ensure that the laser radiation parameters are optimized for the specific plant of interest. Field tests will be conducted to further benchmark the technology and provide for a real world demonstration of the proposed invention.

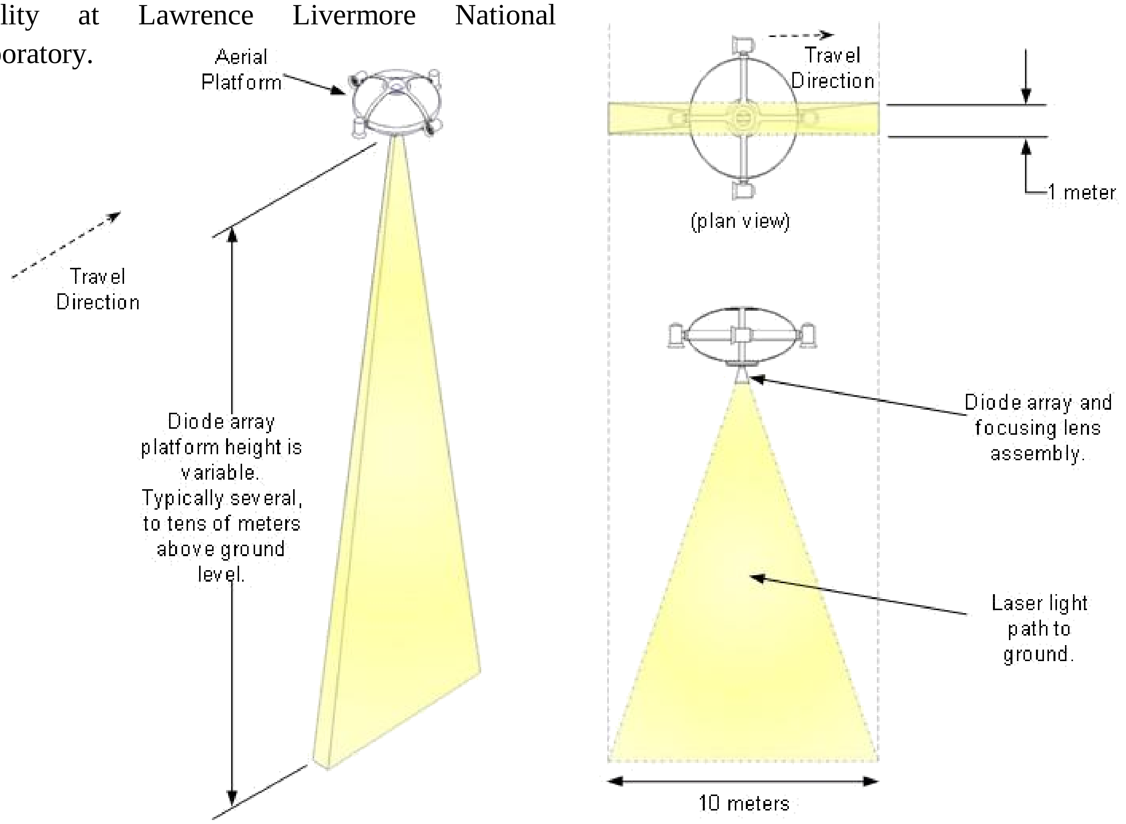

Figure 3: Basic components and dimensions of our laser diode plant mitigation system.

V. ECONOMICS

- *Cost*

The cost to deploy the first system is estimated at approximately $1 million.

A significant percentage of this cost, approximately 35%, is attributed to the high-powered diode array and its associated hardware.

This cost includes the high-powered diode array (the laser), the platform of choice, and the ancillary equipment required.

Subsequent systems would cost significantly less as a result of design simplification and lower production costs.

Since a first article has yet to be designed and built, it is difficult to estimate with strong confidence the actual cost of the total initial system as described. However, the attributes of the system, as explained in previous sections, strongly support significant cost reductions for future deployments.

- *Schedule*

The time required to deploy the described system is dependent upon three main areas: fabrication time for the diode array, fabrication/integration time of the laser system to the transport system, and the time required to conduct tests on the plant(s) of interest to ensure optimization of the laser parameters. Based upon the current rate of progress, we believe the initial plant mitigation system could be available approximately one year from this whitepaper's publication. Initial plant testing in a laboratory environment could begin within a month's time, as several high-powered diode arrays are available for immediate use in the SSHCL laboratory.

VI. CONCLUSION

We have described a very simple, efficient and environmentally friendly system to destroy undesirable plant life using radiation induced by a laser.

The key technological advancement that supports this concept is the development of high-powered diode arrays, our laser source. The compactness, simple architecture and robustness of today's diode array is the key technology that allows our cost effective and efficient system to be proposed.

A rough order of magnitude cost of $1 million for the first plant mitigation system is estimated, being able to be deployed in a timeframe of one year. Initial testing on plants in a laboratory environment could commence within a month's time frame.

Although many engineering details need to be resolved to make this system a reality, we believe that all of the major subsystems and components are mature enough to warrant serious support of this concept. Our philosophy is to take a reasonable first step, make a simple system initially, learn from our experience, and build on our successes over time to gain increased performance and capability in subsequent systems.

VII. REFERENCES

[1] Scott. Ralph A. (March, 1972) "Laser Plant Control". United States Patent 3,652,844.

[2] Mathiassen S, Bak T, Christensen S, and Kudsk P. "The Effect of Laser Treatment as a Weed Control Method". Http://www.sciencedirect.com. August, 2006.