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Guiding the Honeybee Navigation System Using the Second-Harmonic Line Width of 456 nm Nd:GdVO₄ Laser to Prevent CCD Phenomenon

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Abstract

Today, one of the biological problems is electromagnetic pollution in the environment. The intensity of electromagnetic radiation is so pervasive that it is now known as a form of latent and silent pollution. The study of the biological effects of these waves on the growth and development of living insects - such as bees - are considered by many scientific communities around the world. However, the response of honey/wild bees to traps designed to selectively stimulate bee light receptors by fluorescent light indicated that selective arousal of the blue light receptor type was highly attractive. In this paper, to selectively stimulate the blue light receiver in bee species in order to guide the bee navigation system to return to its hive and prevent the colony collapse disorder (CCD) phenomenon, high-efficiency continuous laser emission by second-harmonic line width of 456 nm Nd:GdVO₄ laser is proposed.

Keywords: Electromagnetic Waves, Colony Collapse Disorder (CCD) Phenomenon, Bee Navigation System, Nd:GdVO₄ Laser, Fluorescent Blue Light.

1. INTRODUCTION

Increasing use of radio, television, radar and telecommunication towers and high pressure stations has increased the amount of electromagnetic radiation in the environment [1-4].

Large amounts of magnetic radiation in the environment are generated by mobile telecommunication towers. Insects and small creatures are the first living organisms to be affected by this radiation. Some bee species are, however, becoming extinct due to not returning to their hive, which is called colony collapse disorder (CCD). Studies show that radio frequencies and electromagnetic waves have deceptive biological effects and in turn, disrupt the functioning of biological systems of living organisms and lead to their destruction [5].

If the number of masts and cell phones increases, honey bees may become extinct in the coming decades. Studies have shown that radiation at 900 MHz is very bioactive and changes the physiological function of living organisms [6]. Bees, in general, are arthropods that are key species in the ecosystem that pollinate more than 90 commercial products around the world [7]. The increase in deaths in bee colonies around the world has led to a phenomenon in which the number of bees in the hive decreases rapidly without leaving any signs of disease [8].

According to literatures, it is reported that radio frequency and electromagnetic radiation have misleading biological effects that disrupt the functioning of biological systems of living organisms [9].

However, to selectively stimulate the blue light receiver in honey bee in order to guide the bee navigation system to return to its hive and prevent the colony collapse disorder (CCD) phenomenon, high-efficiency continuous laser emission by second-harmonic line width of 456 nm Nd:GdVO₄ laser is proposed. The beam is conducted By SHG process with a nonlinear crystal BiB₃O₆ (*BiBO*) under laser diode 880 nm pumping with emission level of ${}^4F_{3/2}$.

2. The Effect of Electromagnetic Waves on Honey Bees

EMF electromagnetic fields, also known as electric fog pollution, are known as a form of latent and silent pollution. Electromagnetic waves are widely used in modern technology and communication [10]. Due to various mobile phone sources, however, radio and microwave frequency pollution is considered an important factor in reducing the population of insects such as honey bees [11, 12]. The CCD phenomenon occurs when worker bees leave the hive to collect food and never return to the hive; this occurs when the hive population

suddenly disappears [13]. Some scientists believe that the new CCD phenomenon occurs due to electromagnetic radiation. Recent studies show that the mortality of many animals and insects, such as bees, birds and bivalves, is due to exposure to the EMR field [14-16]. In his study on the effect of pollution caused by electromagnetic waves of mobile phone antennas on honeybee, Balmori (2009) found that microwave and radio frequency contamination creates a weird potential to reduce the population of animals and plants near mobile towers [17].

3. Magnetic Navigation System in Honey Bees

Honey bees sometimes fly more than 12 km from the hive to collect food [18]. Using the sense of sight and smell, they mark the environment around the hive and use them to find and track the way back to the hive [19]. In addition to being signaled by sight and smell, the bees are able to detect the earth's electromagnetic fields and waves and use them as navigation means [20, 21]. However, there are two types of magnetic navigation systems in honey bees:

A) *Magnetic navigation system based on magnetic structure* [22]: due to the presence of a type of bacterium with magnetic properties called Fe_3O_4 that is the bee's abdomen and reacts to the magnetic field [22, 23]. This property gives the bees the ability to sense even minor changes in the field lines. If these delicate structures are exposed to the least amount of magnetic pollution, they will disrupt the bee's navigation system [24].

B) *Chemical magnetic navigation system* [25]: also known as light-dependent magnetic sense, it conducted by cryptochrome (a receiver of blue ultraviolet rays in plants and animals [26]).

Honey/wild bees benefit from a composite imaging system consisting of ultraviolet, blue, and green light receptors. Color space models show details of how the visual signal received by these light receptors is processed at the neural surface by the bee's brains [27]. Ostroverkhova et al. studied the response of bees to traps with different spectral characteristics under certain outdoor conditions. Extraordinary absorption of a wide range of honey bee species is reported in a highly unrefined blue fluorescent trap in the 480-420 nm spectral range of UV rays. Analyzing the spectral characteristics of fluorescent and non-fluorescent traps and their relationship with the number of honey bees absorbed in each trap, they found that fluorescent blue light in the range of 480-430 nm is particularly attractive to bees. Figure 1 below shows the average number of bees adsorbed to each trap per day within the range of light receptor sensitivity. The properties of the traps used by Ostroverkhova et al., are summarizes in Table 1.

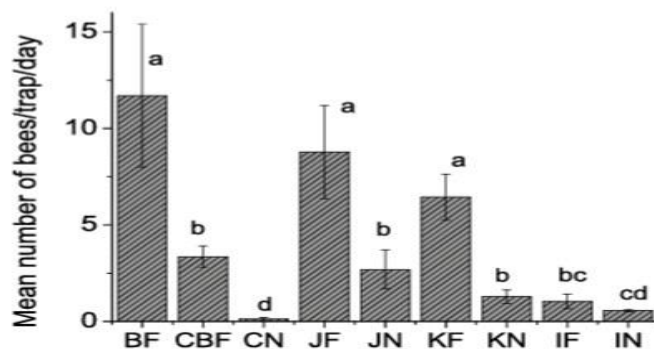


Fig. 1. Average number of honey bees absorbed per trap per day (bars) in the range of light receptor sensitivity [28]

Table 1. Properties of the traps [28]

Trap	Wrap/paint	Color under ambient light	Fluorescence wavelength at max
BF (Blue fluorescent)	None	Blue	430 nm
CN (Clear non-fluorescent)	None	Clear	None
CBF (Clear blue fluorescent)	CN+paint 1 ^a	Clear	435 nm
GF (Green fluorescent)	CN+paint 2 ^a	Green	512 nm
GN (Green non-fluorescent)	CN+R389S ^b	Green (“Chroma Key Green”) ^c	None
JF (Blue fluorescent)	CN+R68S ^b +paint 1 ^a	Blue (“parry Sky Blue”) ^c	435 nm
JN (Blue non-fluorescent)	CN+R68S ^b	Blue (“parry Sky Blue”) ^c	None
KF (Blue fluorescent)	CN+R382S ^b +paint 1 ^a	Blue (“Congo Blue”) ^c	435 nm
KN (Blue non-fluorescent)	CN+R382S ^b	Blue (“Congo Blue”) ^c	None
IF (Purple fluorescent)	CN+R349S ^b +paint 1 ^a	Purple (“Fuchsia”) ^c	435 nm
IN (Purple non-fluorescent)	CN+R349S ^b	Purple (“fuchsia”) ^c	None

3. Guiding Honeybee Navigation System Using the Second-Harmonic Line Width of 456 nm Nd:GdVO4 Laser

High efficiency continuous wave emission in the second harmonic line width of 456 nm Nd:GdVO4 laser is generated by direct pumping of a diode with a wavelength of 808 nm to the level of $^4F_{5/2}$ and 880 nm to the level of $^4F_{3/2}$. By modifying the water performance under pumping 880 nm, it was observed that approximately 3.8 watt is generated at a wavelength of 456 nm from Nd:GdVO4 laser with $M^2 = 1.4$ and $\eta_{0\alpha} = 0.274$ at laser medium with %0.4 thickness and a BiBO crystal with dimensions of $3 \times 3 \times 12 \text{ mm}^3$ is produced as a frequency doubler in a Z-type cavistrap; which is totally unique source of excitation of the blue light receiver type.

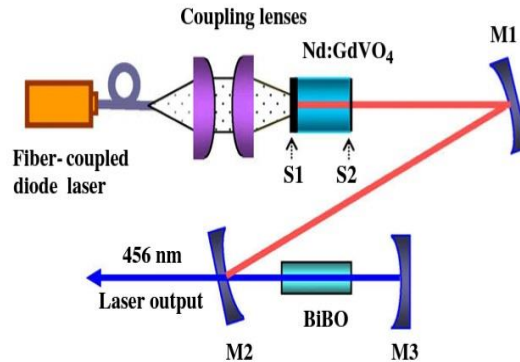


Fig. 2. Schematic diagram of experimental settings for the doubled frequency of the 456 nm blue laser; the distance from S1 to M1, from M1 to M2 and from M2 to M3 mirrors are 110, 400 and 56 mm, respectively [29].

Citing studies on the inherent superiority of color in honey bees - which showed that targets with higher spectral purity and visual stimuli at 480-430 nm are stronger absorbers than other wavelengths [28] - the Second-Harmonic line width of 456 nm Nd:GdVO4 laser is proposed to use the blue laser light to guide the bees track back to the hive and prevent the CCD phenomenon since the beam is a more efficient source than fluorescent traps.

In order to collect, analyze and study a subject, there are different methods such as finite element method [30-34], finite volume method (numerical methods for approximate solution of differential equations), field research, statistical methods, case study, review paper. Review paper, however, is used in the current paper.

4. CONCLUSIONS

The suggestion for controlling the honey bee colony population is to use laser light at the bee colony site. These findings could be a powerful tool for beekeepers and farmers. For example, if farmers need to pollinate their crops, they can use laser blue light to attract the bees for pollination. The technique is also used by beekeepers to guide bees to track the path back to the hive and prevent CCD.

Honey bees have shown a stronger response to fluorescent traps in the range of 430 to 480 nm. The paper aimed to stimulate blue light receptors in honey bees by high efficiency continuous wave emission in the second harmonic line width of 456 nm Nd:GdVO₄ laser which is generated by direct pumping of a diode with a wavelength of 808 nm to the level of ${}^4F_{5/2}$ and 880 nm to the level of ${}^4F_{3/2}$.

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Ethical approval: This article does not contain any studies with human participants or animals performed by the authors.

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