LASER SYSTEMS FOR DETECTING BIOLOGICAL ENTITIES IN PREMISES WITH PHOTOVOLTAIC SYSTEMS AS THE FUNCTION OF GREEN BUILDING

by

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Rodents cutting the installation system with their teeth were a frequent issue with electric installation in the era of classical architecture. However, contemporary architectural systems with photovoltaic sources of energy, accompanied by premises' smart systems of information and energy transfer, have microorganisms destroying the optical and other types of installation. This work represents building systems of residential premises with photovoltaic sources of energy which point out the segments of urban areas jeopardized by the possible appearance of microorganisms. Afterward, a review of laser techniques for the detection, identification, and destruction of such microorganisms was given. It was concluded where to direct the further laser system development to protect smart buildings from biological contamination.

Key words: photovoltaic, energy, laser, microorganism, laser system, biological contamination

INTRODUCTION

An intelligent building is an optimal combination of structure, equipment, services, and facility management based on user needs, which provides an efficient, comfortable, convenient, and humane environment. Intelligent buildings are energy efficient, have efficient system elements, do not pollute the environment, they are flexible, adaptable, and easy to use. They are also easy to manage and control, providing an advanced level of comfort and convenience. Intelligent buildings are complex systems, so establishing safety, security and optimal operational performance is not without risk. Intelligent buildings have in common smart technology and connection to a smart electrical grid. In this way, it is possible to improve energy stability and quality of life [1, 2]. By increasing the stability of the green economy, technological progress will be more noticeable and the overall energy supply more acceptable for the protection of the human environment. However, some microorganisms attack the power supply system (optical cables) of the building itself. The presence of microorganisms threatens the efficient elements of the building system and can lead to the collapse of the quality of comfort as well as safety. Destruction of these microorganisms can be achieved by using modern laser technologies.

Each laser device has its way of optimizing the laser beam absorption process in the corresponding structure. The interaction of the laser beam with the material is considered today in several time domains of operation: continuous and pulsed: millisecond, microsecond, nanosecond, picosecond, and femtosecond. Depending on the dynamic mode of operation of the laser, various problems of a technical (engineering) and theoretical nature appear. Certain laser designs are equally represented in industry, electrical engineering, microelectronics, science, and medicine.

This paper presents the effect of pumping laser technology in the fight against microorganisms in intelligent buildings.

SOLAR AND PHOTOVOLTAIC SYSTEMS IN THE EUROPEAN UNION

Application of solar systems

Atmospheric changes and changed energetic conditions on planet Earth are consequences of technological development. It should be emphasized that the largest source of energy on Earth originates directly from the Sun [3, 4]. Although seemingly with no priority, renewable sources of energy have been used more and more for ecological and economic reasons. The price difference between solar energy and other

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conventional technologies can be reduced only with further development of semiconducting diode stabilities and their resistance to the impacts of primary and secondary cosmic radiation [3].

It can be concluded that one of the primary European Union (EU) aims is, by 2030, to raise the energy and energetic activity savings by up to 30 %, thus following up the already achieved results [4]. Through many case studies, the EU points to the necessity of expanded exploitation of solar energy systems in urban areas, whose application creates economic and ecological benefits and thoroughly affects better living comfort [5]. PV UP-SCALA consortium, as well as the ICA PVPS program, are only some of the further practice examples of solar systems application in the EU, which should be taken as guidelines for the implementation of these projects in our country also [6, 7].

Application of photovoltaic systems in EU cities

Through conducting the national goals for the implementation of solar technology, numerous initiatives were organized within the EU for projecting and implementing as large a fund of photovoltaics, including all the possible risks before and after the solar system is implemented. Photovoltaic systems in urban politics are a strategic project financed by the European fund whose members used the experiences gained in the Netherlands, Germany, France, Spain, and Great Britain. This project complements the activity conducted by the International Agency for Energy. The general public is familiar with the solar energy potential. The price of solar technology, as a limiting factor, has been reduced [8] bearing in mind that the price of solar energy has been in a significant drop. Therefore, this technology is becoming very competitive in the market in comparison with other types of energy.

Implementation of photovoltaic energy is much faster than it was expected, especially in urban environments of developed countries. This effect can be explained in two ways: flexibility of application, and economy.

The value of investment in photovoltaic technology is exposed to various risks, whether they be operational or constructional. Those risks need to be transparent and thus very predictable to anyone willing to invest [9]. Photovoltaic systems in urban politics are a project of developing huge energy nets. The involvement of many countries in the development of this project resulted in the determination of the most successful implementation methods. By intensive application of photovoltaic nets, whole residential blocks were built whose energy supply was based on photovoltaic energy conversion. Figure 1 shows residential premises with solar energy technology in North Reina – Westfalia (NRW) [10].

ELECTRO ENERGETICS AND UTILIZATION OF RENEWABLE SOURCES IN THE REPUBLIC OF SERBIA

The production of electric power for different appliances should be following nature. Solar cells utilize only one energy source, solar energy. Besides this, they are suitable for handling and due to that, they are getting a distinguished position regarding the wide range of applications. The lower price of photo connectors made them very competitive in the market. These cells could undertake a part of the role of building materials. Based on the rich analyzed experience with the production and application of solar energy in the EU, a question is raised of what the circumstances are in the Republic of Serbia.

Intensive utilization of solar energy and other renewable types of energy in Serbia will depend on con-

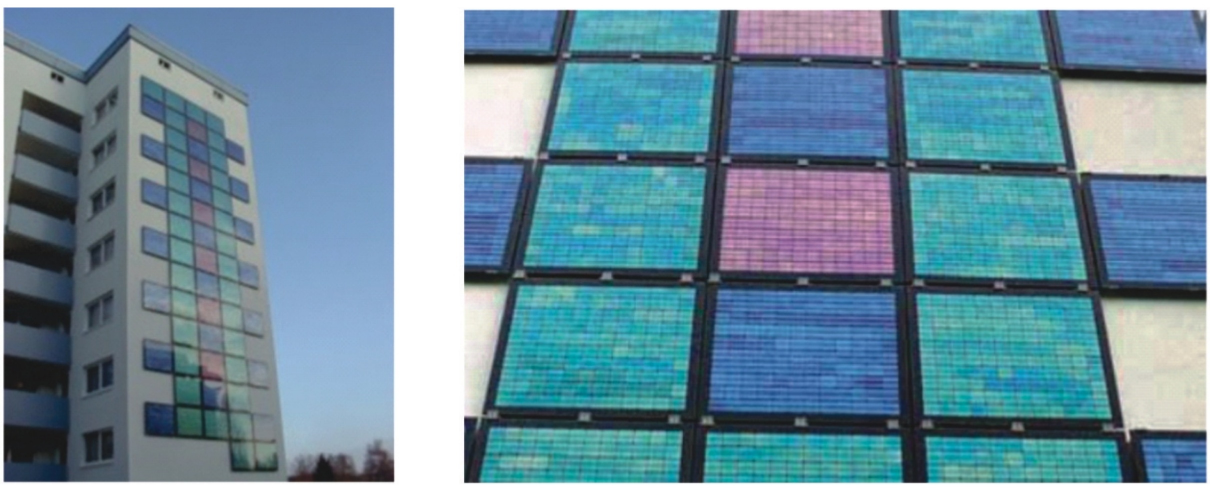

Figure 1. Residential premises with solar energy technology in North Reina – Westfalia (NRW), the color of a photovoltaic installation on a building (ASG) [10]

ducting the "National Action Plan for the Use of Renewable Energy Sources (NAPOIE)" [11]. The number of sunny hours in Serbia goes up to over 2000, which is more than many other European countries. Even though Serbia possesses a significant amount of renewable energy, the activity in this field so far has been quite insignificant. The reasons for that are insufficient developmental support and financial investments in renewable energy.

RELIABILITY OF PHOTOVOLTAIC SYSTEMS IN URBAN CENTERS

Photovoltaic cells were earlier mostly made of monosilicon and were more or less harmless. To get as great as possible energy thickness, solar cells started being produced of polymer or organic materials advanced in time [12, 13]. Organic cells are light and applied over plastic foliage, but they are treated as a dangerous building material due to being flammable. For that reason, various laser detectors are necessary within the systems of solar cells which could ignite and cause fire inside the construction object.

To minimize this harmful effect, pumping of the used-up photovoltaic systems must be enabled [13]. In [14], there is a thorough physical and mathematical explanation of how the method of photovoltaic systems' pumping can secure the minimization of the damage and breakdowns caused by the appearance of biological matters inside the photovoltaic systems of urban premises.

ELIMINATION AND THE BEST POSSIBLE CLEANING OF PHOTOVOLTAIC SYSTEMS FROM BIOLOGICAL CONTENT IN URBAN CENTERS BY PUMPING OPTIMIZATION OF LASER SYSTEMS

The complexity and versatility of biological systems and objects, as well as big differences in the character of their interactions with electromagnetic radiation, especially in the optical area, determine a wide range of methods for diagnostics of these phenomena. Real-life practice showed that long-expiry and high-intensity lasers should be used for that purpose [15]. They cover wavelength areas of 100-300 μm and power of a few Hz to dozens of GHz. Figure 2 shows the levels of power and energy of some of the most popular and frequently used lasers. The latest experiments show that the results of the elimination and destruction of biological waste mostly depend on the laser system pumping [16].

Classic photobiology, using common sources of radiation, has successfully developed in time. The problem of elimination of living entities and destruction of their biological remnants in urban areas is a minor aspect of application and can be conducted only with laser sources having changeable parameters.

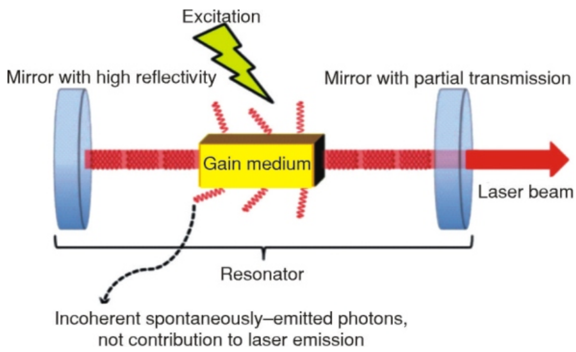

Figure 2. Schematic presentation of a laser device [16]

To obtain variable radiation, the phenomenon of Raman combinatory scattering (RSC) is most frequently used. One representative of the RSC lasers is semiconducting InSb, based on the Raman scattering with a spin variation [17]. The wavelength area of this laser, while pumping with CO laser radiation, is 5-6,5 μm, and while pumping with CO_2 laser, it is 9-14 μm. Generation power is achieved in wide specter areas, with a speed of 2 cm kHz^{-1}. While utilizing superconducting magnets, the adjusting area is approximately 80 cm^{-1}.

RAMAN LASERS, ON RSC IN GASES AND CONDENSED ENVIRONMENTS

Using a laser with colors [18] as a source of pumping enables the Raman lasers with hydrogen gases to obtain equal preregulation in the 185 nm – 7 μm area. For a condensed active environment, such as a single-mode quartz fiber light conductor, there is no conditioning inside the variable pumping source. Using the radiation of a few watts of strong granite lasers in a few hundred meters long fiber light conductor, radiation is obtained in the area of 1,08-1,13 μm for the first and 1,15-1,175 μm for the second Stock's theorem. RSC lasers refer to a wide variety of laser systems using different methods of nonlinear optics. Generators of the second harmonic, generators of frequency difference, and parameter generators belong there as well. This type of laser exhibits an optimal intensity of coherent radiation.

For generating the second harmonic, crystals $L_iN_bO_3$ (with a pumping wavelength of $\lambda = 1.06$ μm) are most frequently used. The transformation efficacy of the second harmonic is usually not bigger than 10-50 %. In that way, both laser radiation with a fixed and with a variable frequency can be transformed. It is essential to provide synchronized angled temperature settings of a nonlinear crystal for achieving a stage wave synchronization that interreacts. While using the color laser with frequency distancing, an area of 217 μm to 450 μm is covered [19]. For generating the radiation of nominal frequencies and higher harmonics, it is possible to use blends of inert gases and metal steam together with crystals. This widens the areas of setting and coherent radiation up to the vacuum UV field (four harmonics of a granite laser with λ = 2,66 μm in a blend of Xe-Ar leads to a radiation emission on λ = 88,7 μm).

Nonlinear radiation mixing of two lasers with visible area, one of which is adjustable, enables the generating of different frequencies in the IC specter area and that is the basis for building spectrometers of various ranges. With an A_r^+ ion laser and a color laser, whose radiations are mixing in the crystal $L_iN_bO_3$, it is possible to obtain variable coherent radiation in the area of 2,2-4,2 m [19]. As for the nonlinear optical devices, an important place belongs to the parameter generator of light (PGL) which represents a nonlinear crystal within the optical resonator. It is pumped by a laser with a fixed frequency. PGL is set either by rotating the crystal or by changing its temperature. While pumping the crystal $L_iN_bO_3$ with the second harmonic granite laser radiation, a parameter generation is obtained in the area of 0,55-4 μm. Crystal rotation of 40° changes its wavelength from 1,4 to 4 μm [20].

One of the most important features of lasers is the ability to receive very short light impulses. Only the basic principles of receiving short and super short impulses are given, together with some data explaining the possibilities of the lasers already described. The term super short impulse length has changed by several orders of magnitude since the 1980th [21]. For getting gigantic impulses, the regime of factor modulation is applied in the resonator. It is obtained by swift switching on and off of the losses in the resonator. This regime is characterized by shorter and much stronger impulses compared to the regime of free generation. Electro-optical, magnetic-optical, acoustic-optical, or mechanical modulators are used as optical lids. Those are passive lids on colors and alkaline halogenic crystals with color centers or gases with suitable zones of absorption, which is a nonlinear absorption inside the resonator. The modulation factor regime is achieved with all laser types. Most frequently, it is used for obtaining short and strong impulses in lasers attached to a hard entity or CO_2 lasers. Typical values of the gigantic impulse length are 10-100 ns.

Significantly shorter lengths can be obtained in the regime of synchronization of multiple horizontal, narrow, longitudinal (TEM_{00q}) modes. If a certain phase correlation among the modes is set, some modes exhibit radiation in synchronicity. That regime is called induced mode synchronization. To achieve induced synchronization, modulation of losses or optical length of the resonator is used, through electro-optical and acoustic-optical modulators whose frequencies are close to the intermodular frequency interval C/2nL, fig. 3 [22].

In the synchronization regime, modes intervene internally and express short light impulses. Their length is determined by the specter width and the width of the generating line, $\tau_i = 1/$, where τ_i is pulse length, and γ – width of the source line (10^9-10^{10} Hz). The impulses are determined by the time interval t, which is defined by the intermodal frequency interval, t = 2nL/c, where nL is optical length of the resonator, c- speed of light, and n – refractive index of the active medium. The length for gas lasers is sub-nanosecond. For lasers attached to a hard entity, the lengths are $10^{12} – 10^{13}$ Hz and τ_i < ps. For lasers on colors, $\gamma = 10^{14}$ Hz, and actually, femtoseconds of length can be achieved [22].

The method of synchronized optical pumping is considered to be a very efficient method for obtaining super short impulses 10^{-11}-10^{-13} s, with adjusting of the wavelength. This method consists of enforced active mid-laser modulation with frequencies, which can be either equal or represent a multiple of reciprocal resonator time interval rounds. Such a laser generates bunches of impulses, synchronously following the impulses of pumping. If the source of pumping is a laser with synchronized modes, the optical length of the laser pump and the variable laser must be highly precisely aligned [22].

More or less for all the variable lasers taken into consideration in this work, synchronous pumping was achieved. Those are lasers on color centers, semiconducting and Raman lasers, parametric generators, and lasers on organic colors which started expanding their application and have been industrially produced for quite a long time now. Some of the features they have are a wide area of settings, significant efficacy, and the ability to generate impulses much less in length than the impulses of pumping. Those are impulses of high spectral quality. Due to that feature, they are of special interest for precise kinetic spectroscopy and fiber-optical systems, serving the purpose of impulse compression in time.

Using the method of synchronized pumping, impulses with lengths in the range between a few picoseconds to a few hundred femtoseconds are usually obtained. For lasers on colors with synchro pumping, typical impulses are 2,5-10 ps of medium power 80-100 mW, with recurrence frequency of individual impulses of 100 mW and with the energy of individual impulse 1-20 nJ and maximum power of 0,5-2 kW.

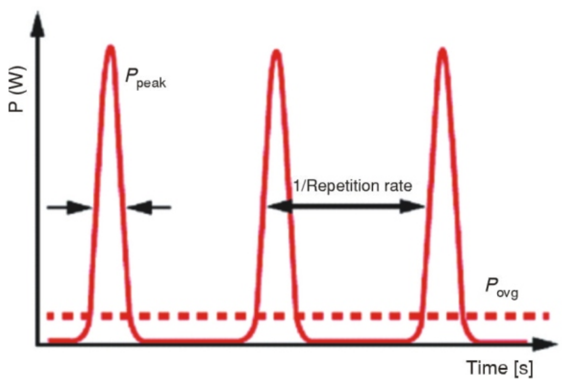

Figure 3. The specter of longitudinal laser modes [22]

It used to be considered that the shortest impulses were obtained in lasers on colors around 40 fs in length. Their amplification of 250 kW power in the peak and maximal compression in one fiber 0,7 cm long light conductor enable them to obtain 8 ps long impulses, which represents almost four periods of optical oscillation and is close to the theoretical limit.

Lasers with synchronized mode have a high frequency of several kHz and several GHz. One of their basic features is a large mid energy of the impulse.

CONCLUSIONS

The paper thoroughly explored the combination of a photovoltaic energy source and a detector, *i. e.* the eliminator of biological contaminators. The emphasis was on laser systems that can be built-in inside premises with photovoltaic power supply systems, to remove biological colonies that could bring about a complete functional collapse of the power supply system. For that purpose, laser systems usually used in medical, diagnostic, and aggressive procedures were chosen. Significant attention was paid to choosing a laser system for diagnostics and elimination of unwanted biological systems consisting of wide specter of wavelengths, impulse duration, and power. Laser systems with pumping were chosen since they support operating which provides the laser impulse power - starting with the one necessary for location and identification of the biological system, up to its physical elimination. Based on the provided findings, it is possible to make suggestions for the further development of one such system, which could have an even wider specter of impact and better efficacy.

Protection of communication cables, done by laser protection can be recommended in future designs of intelligent buildings.

AUTHOR'S CONTRIBUTIONS

Writing-original draft preparation, visualization – V. Z. Trifunović- Dragišić; review, editing, and supervision – I. M. Despotović. Both authors have read and agreed to the published version of the manuscript.

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ЛАСЕРСКИ СИСТЕМИ ЗА ДЕТЕКЦИЈУ БИОЛОШКИХ ЈЕДИНКИ У ОБЈЕКТИМА СА ФОТОНАПОНСКИМ СИСТЕМИМА КАО ФУНКЦИЈА ЗЕЛЕНЕ ГРАДЊЕ

У класичној архитектури чест проблем са електричним инсталацијама правили су глодари који су зубима секли инсталациони систем. Код савремених архитектонских система са фотонапонским изворима енергије уз елементе, интелигенције објекта система за пренос информација и енергије, микроорганизми уништавају оптичке и друге типове инсталација. У овом раду, приказани су системи изградње стамбених објеката са фотонапонским изворима енергије на основу којих се јасно види који су делови урбаних целина угрожени могућношћу појаве микроорганизама. Након тога је дат преглед ласерских техника за детекцију, идентификацију и уништење оваквих микроорганизама. Закључено је у ком правцу треба даље развијати ласерски систем за заштиту интелигентних зграда од биолошке контаминације.

Кључне речи: фотонапон, енергија, ласер, микроорганизам, ласерски систем, биолошка контаминација