Optical and Acoustical Methods in Science and Technology

# The Role of a Laser Photography Device Illuminator in Acquisition of Spatial Information

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The paper is concerned with practical studies of illuminator role in the process of acquisition of spatial information with use of laser photography device. The laser photography device working according to the time-spatial framing method needs both acquisition and illumination process to happen in a very short-time. Fulfillment of both conditions is necessary for proper operation of this device. Using a specialized laser illuminator determines the growth of information potential of the laser photography device and allows reducing parasitic impact of daylight. The presented solution not only improves typical vision systems parameters but it introduces new quality for imaging devices.

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## 1. Introduction

Recent information systems acquire data from various sources. Sensor elements and systems are a specific group of data suppliers. Imaging systems deserve special attention. Data acquired by imaging devices is called imaging information. There are many imaging systems available. One of the most common groups of these devices is vision systems. There are a few parameters that describe the informative potential of particular solutions such as spectral range, resolution, sensitivity etc. Continuous growth of information potential and the search for new solutions for emerging application areas lead to development of imaging techniques.

Vision systems can be classified according to many criteria. Division into active and passive systems is just one example.

Every solution has its pros and cons but only applications decide the importance and usability of a particular property of a vision system. It means that for some group of applications active work mode is inadmissible while for another one can be the only solution.

An example of an active imaging solution in which the illuminator plays one of the most important roles is in a time-spatial framing method [1]. The laser photography device (LPD) working according to this method needs both acquisition and illumination process to happen in a very short-time. Fulfillment of both conditions is necessary for proper operation of this device.

In the literature a notion of selective space imaging is not very popular however it can be found as the range gated imaging method [2]. A time-spatial framing method is a wider notion and also takes time aspects into account [3].

Using a specialized illuminator determines the growth of information potential of the laser photography device [4]. This solution not only improves typical vision systems parameters but it introduces new property characteristics only for this particular imaging method.

## 2. Imaging scene illumination

The active imaging methods are not a new issue. These kinds of solution can be found in medical applications (diagnostics) for example. Active imaging is also very popular in surveillance applications especially in night vision systems. These solutions use illuminators with continuous illumination time which means that illuminated objects can become more visible to an imaging sensor. In many applications, using additional illumination gives proper results. What if an active solution is insufficient?

Let us imagine a different situation — a need of registration fast of changing phenomena. There are many factors deciding if we are able to realize such a task. According to the current state of technology the most natural solution would be to use a high speed camera.

What if we do not have a high speed camera? Is this task impossible? We can use additional illumination and strobe lighting. A short illumination time (with long shutter time) enables registration of dynamically changing phenomena.

Are there any other parameters except energy and time that influence the process of image registration? These are for example wavelength and connected to it objects reflective properties, luminescence (Fig. 1a), light polarization (Fig. 1b), interference — digital holography (Fig. 1c).

Considering the factors above it can be admitted that during previous analysis all basic properties of light and its impact to image registration process were included. Is that right? There is one key parameter, constant in

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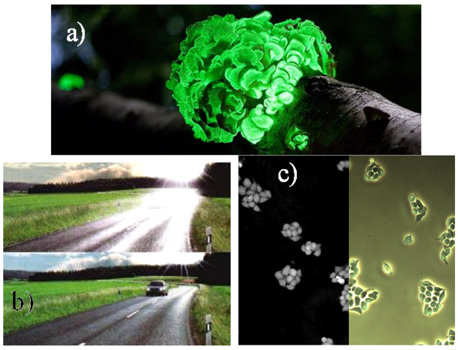


Fig. 1. Influence of illumination parameters to imaging: (a) luminescence, (b) polarization, (c) interference — digital holography.

a specific medium in which electromagnetic waves propagate — the speed of electromagnetic waves. There was no application of light speed in vision systems until now. Thanks to developments in nanotechnology an application already exists.

The light propagating in a space travels a distance of about 300 000 km in one second. Such large distances are used mainly in astronomy. If we consider nanosecond time, distance is just about 30 cm for every nanosecond, and this is a dimension that is simpler applicable. The time-spatial framing method and its implementation in the LPD is an example of such an application [5–7].

What is the most characteristic property of this method that distinguishes the LPD from other vision devices? The basic property of the LPD is that the device allows registration of a strictly defined fragment of space in a specified time period. A block diagram of this device is shown in Fig. 2.

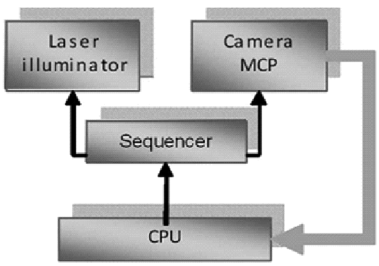


Fig. 2. Block diagram of the LPD.

## 3. Illuminator parameters impact to imaging information

### *3.1. Time aspects of imaging information*

#### *3.1.1. The beginning of image acquisition*

Measurements of fast changing phenomena are not a simple matter. The key problem is the ability to define an image registration point in time. We can define this as a synchronization of a camera and observed process. In laser photography a point in time is strictly connected with spatial localization of an object (Fig. 3).

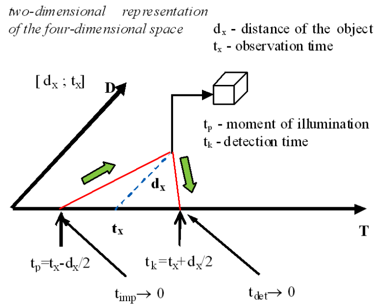


Fig. 3. The beginning of image acquisition.

The beginning of generating laser radiation is the key for proper definition of the beginning of event registration. With the growth of distance between an object and the LPD the time of laser pulse generation also grows.

#### *3.1.2. Time period of image acquisition*

During registration of dynamic phenomena it may be necessary to define the time period of image acquisition. Similar to definition of point in time, spatial object location is needed when defining a time period of image acquisition (Fig. 4).

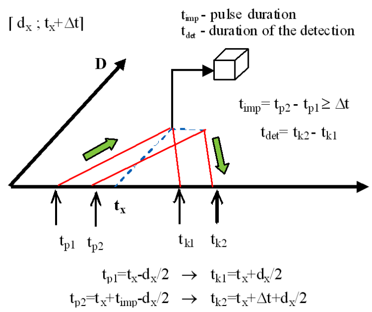


Fig. 4. Time period of image acquisition.

With the growth of illumination pulse width the time period of image acquisition also grows. The time period is directly proportional to time.

### *3.2. Spatial aspects of imaging information*

A unique property of the LPD is the ability to define the observation space as a distance to an observed scene and its depth.

#### *3.2.1. The distance to observed scene*

The difference time between the beginning of laser radiation and its detection is useful in the process of definition of distance of the observed scene. The distance to the object is bigger than the time relation between illumination and detection (Fig. 5).

#### *3.2.2. The depth of observed scene*

The illuminator plays a very important role in the process of definition of observation depth. With the growth of illumination pulse width the depth of observation grows (Fig. 6).

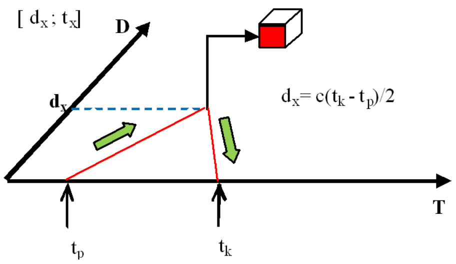


Fig. 5. Definition of distance to observed scene.

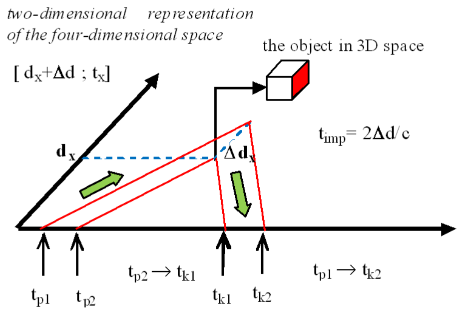


Fig. 6. Definition of depth of observed scene.

*3.2.3. 3D scene parameters*

Knowing the distance to an object and the depth of observation it is possible to define 3D spatial representation of image [6, 7]. Information of field of view of receiver module is useful for definition of a section of observed scene (Fig. 7).

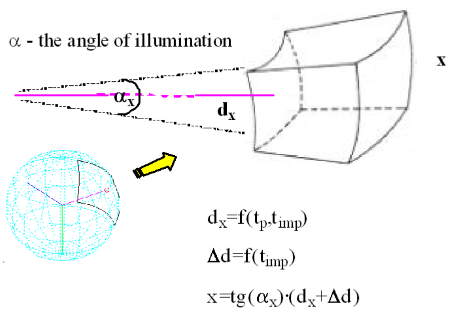


Fig. 7. Observed space with defined image acquisition parameters.

The role of the illuminator during the process of 3D space definition is to provide proper pulse time parameters — the beginning of the pulse, its duration and angular illumination of observed scene [8–10].

### *3.3. Radiometric and spectral aspects of imaging information*

The key role during image synthesis process plays the radiation registered by receiver module of the LPD. This radiation is a function of the laser source, propagation path of the illumination beam, observed object and receiver path.

*3.3.1. Image quality*

The most important role of the illuminator is to provide a proper amount of energy from a source. The level of energy has to be high enough to travel between the LPD and an object, and to provide a good quality image (Fig. 8).

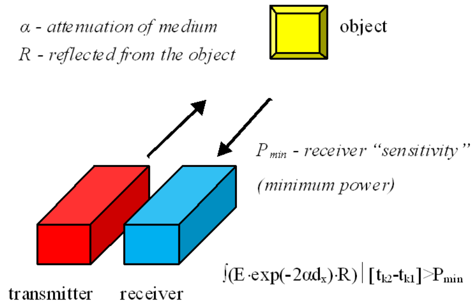


Fig. 8. Energy requirements for good image quality.

Energy is not just a function of source energetic parameters but also a few other components:

— transmission optics, which should provide scene illumination with an angular field of view not less than field of view of receiver module (to avoid vignetting). In case of laser over-energy for example it is possible to modify transmitting optics parameters and use them to control energetic parameters of illuminating beam (Fig. 9).

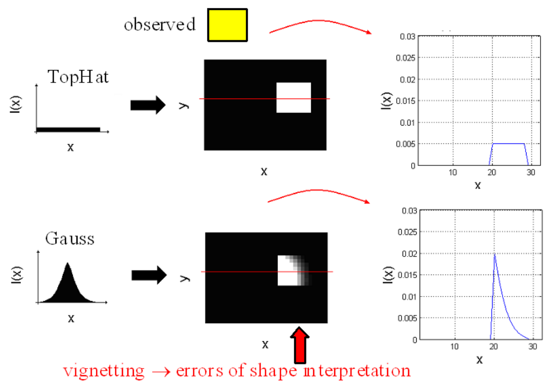


Fig. 9. Impact of transmitting optics.

— transverse profile of laser beam, which should have a "flat" characteristic. Obtaining a proper transverse profile is possible by using a laser with TopHat generation type. When using a laser with Gaussian beam flat characteristics can be achieved by using a diffuser (Fig. 10).

*3.3.2. Ability to minimize observation conditions on acquired image quality*

Laser photography is an active method. From a point of view of device work, natural light is a parasitic factor which should be eliminated. Thanks to using a laser

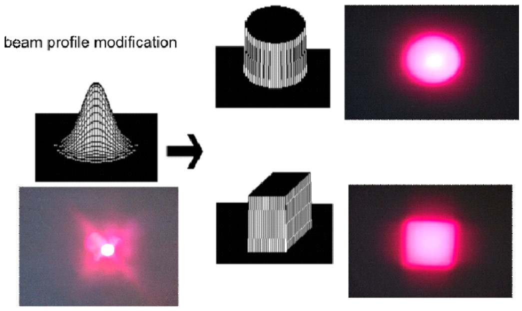


Fig. 10. Impact of transverse beam profile.

source and proper spectral selection on a receiver module minimization of natural light impact can be achieved. This means that image registration is independent of time of day — images acquired with daylight or during night are equal. Thanks to spatial image selection quality, enhancement can be achieved during image acquisition in adverse weather conditions e.g. fog. If the energy reaching the LPD is sufficient enough to synthesize an image, then integrating a fragment of space will cause the contrast enhancement (Fig. 11).

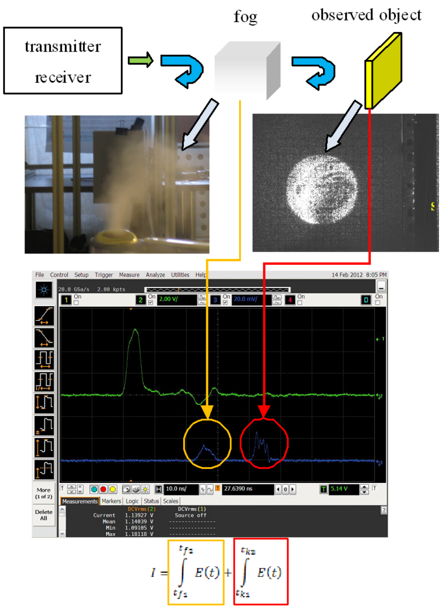


Fig. 11. Mechanism for minimization of adverse weather conditions on image quality.

## 4. Summary

Recent work on the LPD is concentrated on the reconfigurable solution with two types of illuminators (Table).

The research stand made in the Institute of Optoelectronics, MUT allows testing of all the key parameters and properties of illuminators and their impact on the images acquired using the time-spatial framing method. Test results will become a basis to assume application possibilities of the LPD. At a recent stage of development we can say that the method and the device can be a valuable measurement-observation tool which was already confirmed in experiments.

TABLE

Parameters of two types of illuminators.

| | |
|---|---|
| Nd:YAG laser illuminator | |
| wavelength | 532 nm |
| pulse energy | 360 mJ |
| pulse duration | 3–6 ns |
| beam diameter | 8 mm |
| beam divergence | 0.5 mrad |
| maximal repetition | 10 Hz |
| Solid-state laser illuminator | |
| wavelength | 905 nm |
| power | 40–220 W |
| pulse duration | 30–100 ns |
| maximal repetition | 5 kHz |

## Acknowledgments

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## References

[1] M. Piszczek, K. Rutyna, M. Szustakowski, *Europ. Phys. J. Spec. Top.* **154**, 153 (2008).

[2] P. Pardel, *Studia Informatica* **30**, 35 (2009).

[3] E. Nęcka, J. Orzechowski, B. Szymura, *Cognitive Psychology*, PWN, SWPS "Academica", Warszawa 2008 (in Polish).

[4] M. Piszczek, *Acta Phys. Pol. A* **120**, 716 (2011).

[5] M. Piszczek, K. Rutyna, M. Szustakowski, *Pomiary Automatyka Kontrola* **53**, 531 (2007) (in Polish).

[6] T. Pustelny, J. Ignac-Nowicka, Z. Opilski, *Opt. Appl.* **34**, 249 (2004).

[7] A. Medina, *Three Dimensional Camera and Rangefinder*, January 1992, United States Patent 5081530 (1992).

[8] T. Pustelny, I. Zielonka, C. Tyszkiewicz, P. Karasinski, B. Pustelny, *Optoelectronics Rev.* **14**, 161 (2006).

[9] P. Andersson, *Opt. Eng.* **45**, 034301 (2006).

[10] A. Medina, F. Gayá, F. Pozo, *J. Opt. Soc. Am. A* **23**, 800 (2006).