Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2026, т. 24, № 1, сс. 301–316
https://doi.org/10.15407/nnn.24.01.0301

PACS numbers: 42.25.Dd, 42.30.Ms, 81.07.Bc, 83.80.Lz, 87.85.gf, 87.85.Pq, 87.85.Rs

Laser Speckle Analysis of Blood Coagulation: Overview and Prospects for Use in Military Medicine

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The article discusses a promising technology for assessing the blood-coagulation system, namely, laser speckle analysis (LSA), with an emphasis on the use of optical nanostructured components to improve the quality of diagnostics. A review of the physical foundations of the method, modern scientific research and comparison with traditional viscoelastic haemostatic assays TEG, ROTEM, ClotPro is carried out. Particular attention is paid to the role of nanotechnological solutions (anti-reflective nanocoatings of the 'moth-eye' type, plasmon Ag, Si nanoparticles and silver nanofilms with a thickness of 40–80 nm) in the formation of a stable, high-contrast speckle pattern. The mechanisms of reducing parasitic reflections, increasing light transmission and amplification of the local light signal due to the effects of the local and surface plasmon resonances are described. As shown, the introduction of such nanostructures into the configuration of the LSA sensor can improve significantly the signal-to-noise ratio, increase the spatial resolution and accuracy of the assessment of the microdynamics of formed blood elements. The potential of portable implementation of LSA with nanoreinforced optical elements for the field and military medicine Role 2, Role 3 is highlighted, where the applicability of conventional coagulation devices is limited. The proposed approach combines optical diagnostics and nanotechnology methods, which open up new opportunities for the creation of a new generation of mobile biomedical sensors. This work emphasizes not only the technological novelty of LSA, but also its direct clinical value for increasing the effectiveness of treatment in conditions of emergency and military medicine.

У статті йдеться про перспективну технологію оцінки системи згортання крові, — лазерну спекл-аналізу (LSA), — з акцентом на застосування оптичних наноструктурованих компонентів для підвищення якости діягностики. Проведено огляд фізичних основ методу, сучасних наукових досліджень і порівняння з традиційними високоеластичними гемо-

статичними системами TEG, ROTEM, ClotPro. Особливу увагу приділено ролі нанотехнологічних рішень (антивідблискувальних нанопокриттів типу ‘moth-eye’, плазмонних наночастинок Ag, Si і срібних наноплівок товщиною у 40–80 нм) у формуванні стабільного, висококонтрастного спекл-патерну. Описано механізми пониження вторинних відбивань, підвищення світлопропускання та посилення локального світлового сиґналу за рахунок ефектів локального та поверхневого плазмонних резонансів. Показано, що впровадження таких наноструктур у конфіґурацію LSA-сенсора може значно поліпшити співвідношення сиґнал/шум, підвищити просторову роздільчу здатність і точність оцінки мікродинаміки формених елементів крові. Підкреслено потенціял портативної реалізації LSA з нанопосиленими оптичними елементами для польової та військової медицини Role 2, Role 3, де можливості використання класичних коаґуляційних пристроїв є обмеженими. Запропонований підхід поєднує оптичну діягностику та методи нанотехнологій, що відкриває нові можливості для створення нового покоління мобільних біомедичних сенсорів. Ця робота підкреслює не лише технологічну новизну LSA, але й її безпосередню клінічну цінність для підвищення ефективности лікування в умовах екстреної та військової медицини.

Key words: laser speckle analysis, fibre-optic light guides, blood coagulation, nanocoatings, optical diagnostics, military medicine.

Ключові слова: лазерна спекл-аналіза, волоконно-оптичні світловоди, згортання крові, нанопокриття, оптична діягностика, військова медицина.

(Received 10 August, 2025; in revised form, 15 September, 2025)

1. INTRODUCTION

High-quality monitoring of blood clotting is critically important in various clinical and emergency situations, in particular, during surgical interventions, injuries, in ICU, and in combat conditions [1–5]. Rapid detection of coagulopathy or hypercoagulation allows the timely use of blood products, haemostatic drugs or anticoagulants, which directly affects the quality of medical care [6–9].

Classic laboratory tests such as prothrombin time (PT), activated partial thromboplastin time (aPTT), and fibrinogen levels provide limited insight into the dynamic process of clot formation. Instead, viscoelastic haemostatic (VHA) methods, including thromboelastography (TEG), rotational thromboelastometry (ROTEM), and ClotPro, provide real-time assessment of coagulation kinetics, clot strength, and lysis process [10]. These systems have become the gold standard in cardiac surgery, traumatology, and liver transplantation [11–13]. However, their widespread use is limited by technical complexity, high cost, the need for trained personnel and sensitivity to mechanical stability, which limit applicability in field

or combat conditions [14].

In recent years, optical methods, in particular, laser speckle analysis (LSA), have attracted attention as a promising alternative for non-contact and operative assessment of blood clotting [15]. By capturing dynamic changes in the speckle structure that occur when coherent laser radiation interacts with a blood sample, LSA allows indirectly assessing the process of clot formation without physical contact or moving parts [7]. Such properties make the method especially interesting for creating compact, reliable, using fibre-optic LEDs, and potentially suitable for use in the field [16].

In the context of the full-scale war of the Russian Federation against Ukraine, the need for rapid and portable medical diagnostics has increased significantly. Stabilization points, UGS, and frontline medical units operate in resource-constrained environments where traditional thromboelastography systems often cannot be installed [10]. Compact an optical diagnostic method capable of assessing blood clotting without stringent installation requirements could significantly improve the effectiveness of care in such conditions.

The purpose of the review is to summarize the current state of research in the field of laser speckle analysis for monitoring blood coagulation, analyse its correlation with standard thromboelastography, highlight the advantages and limitations of the method, review the use of nanoreinforced optical elements, as well as the prospects for its implementation in military and field medicine.

2. OVERVIEW OF THROMBOELASTOGRAPHY

Thromboelastography is a method of visualizing and quantifying blood clotting processes in real time. It allows you to trace all stages of clot formation from initiation to fibrinolysis based on changes in the mechanical properties of a blood sample.

The classical thromboelastograph (TEG) and its modern analogues (ROTEM and ClotPro) use a viscoelastic analysis model. The principle of operation is to measure the force that is transmitted between a rotating or oscillating element (bowl or stem) and a clot that forms in a test tube with a blood sample [17].

The main parameters that the thromboelastograph fixes:

— R (Reaction Time)—the time before the onset of coagulation (thrombin activation);

— K (Kinetics)—the time until certain clot strength is reached;

— α angle (Alpha angle)—the rate of formation of the fibrin framework;

— MA (Maximum Amplitude)—the maximum strength of the clot, which characterizes platelet and fibrin function;

— LY30 or ML (Lysis)—the degree of fibrinolysis 30 min after reaching MA.

ROTEM and ClotPro use similar parameters, but with their own terminology, for example, CT (Clotting Time), CFT (Clot Formation Time), MCF (Maximum Clot Firmness), LI30/ML.

Due to its high information content, thromboelastography is widely used in cardiac surgery, traumatology, obstetrics and resuscitation. The method allows you to reduce the use of blood components, optimize anticoagulant therapy and prevent thrombotic complications [18, 19].

At the same time, the use of the above systems in the field is complicated due to their need for stable horizontal placement, the absence of vibrations, temperature sensitivity, as well as the high cost and need for personnel training. This opens up the prospect for the development of alternative methods, in particular optical ones, such as laser speckle analysis [10].

3. THEORETICAL FOUNDATIONS OF SPECKLE ANALYSIS

Laser speckle analysis (LSA) is based on an optical phenomenon that occurs, when a heterogeneous medium is illuminated by coherent laser radiation [20, 21].

Because of the interaction of the beam with microscopic structures (for example, blood cells or plasma components), a characteristic interference pattern is formed on the surface of the sample, namely, a speckle structure. It has a random appearance, but changes in time in response to micromovements, diffusion of particles or changes in the rheological properties of the medium [16].

In dynamic analysis, which is used to study blood coagulation, a change in the intensity or contrast of the speckle structure over time is recorded [21]. In the initial stages of coagulation, when the cells are still moving in the plasma, there is a high variability in intensity. As the fibrin clot forms and the particles lose mobility, the variability decreases, and the speckle pattern stabilizes.

The laser radiation passes through the blood sample, after which a speckle pattern is formed, which is recorded by the camera through the optical system and in a short period of time (Fig. 2) [22].

One of the key parameters is speckle contrast, which can be calculated from the standard deviation of pixel intensity in a specific time or space window. A decrease in contrast indicates an increase in the mobility of particles, while its increase indicates the stabilization of the structure, *i.e.*, the formation of a clot [14].

Other analysis techniques include constructing temporal autocorrelation functions, estimating average phase shift, detecting optical vortices, or statistical changes in image texture. All these ap-

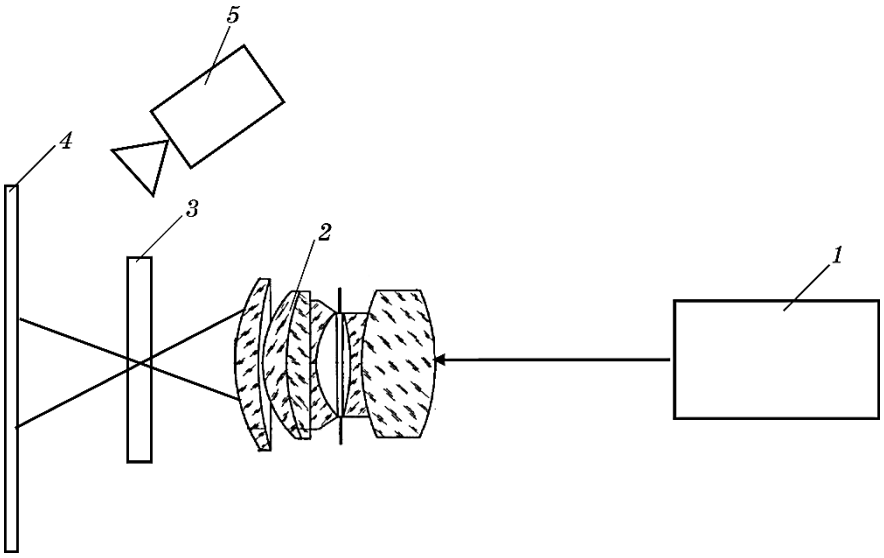

Fig. 1. Structural diagram of a laboratory setup for recording speckle images [22]: *1*—He–Ne laser; *2*—lens; *3*—blood sample; *4*—recording screen; *5*—camera.

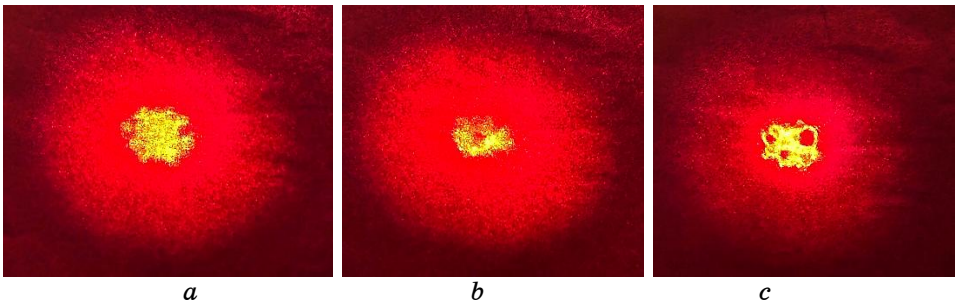

Fig. 2. Control speckle image.

proaches are aimed at obtaining information about the micromovements of blood cells, which change in the process of coagulation.

Thus, the LSA provides an indirect but informative assessment of the stages of blood clotting without physical contact with the specimen. The technique is characterized by high sensitivity, does not require markers or reagents and can be implemented on compact fibre-optic LEDs [23, 24].

The following sections discuss examples of studies, in which LSA has been used to assess blood coagulation, in particular, compared to thromboelastography systems.

4. REVIEW OF STUDIES ON THE USE OF LSA TO ASSESS BLOOD CLOTTING

Over the past decade, a number of studies have been conducted that have demonstrated the effectiveness of laser speckle analysis (LSA) in assessing blood-clotting parameters. One of the first large-scale studies in which a system based on LSA was developed to measure the viscoelastic properties of blood during coagulation. The authors showed that the indicators obtained using this method show a high correlation with the data of traditional mechanical rheometry [21].

Further research [25] proposed alternative ways to analyse speckle patterns, including the detection of optical vortices, which allowed for improved temporal resolution and accuracy in determining the moment of clot formation. In this work, a comparison was also made with the parameters of the thromboelastograph, which confirmed the clinical relevance of the technique.

Other studies have adapted the LSA to the conditions for assessing coagulation in gel-like media, demonstrating the wide versatility of the approach and the possibility of modifying the method to meet the needs of medical diagnostics.

All of the above-mentioned papers highlight the potential of LSA as a non-contact, fast, and cost-effective alternative to traditional coagulology methods. Although clinical use is still in the prototype phase and *in vitro* studies, the availability of comparative data with thromboelastography suggests significant prospects for use in resource-limited settings, including Role 2, Role 3 medical care for the wounded [1].

5. COMPARATIVE ANALYSIS OF LSA AND TEG/ROTEM/ClotPro

Comparison between laser speckle analysis (LSA) and traditional highly-elastic methods for assessing blood coagulation (TEG, ROTEM, ClotPro) allows us to determine the advantages and limitations of each of the approaches, as well as the potential of LSA in clinical applications, as shown in Table 1 below [1, 6, 7, 25].

Main parameters for comparison are as follow.

Despite the fact that thromboelastography is a recognized clinical standard, its use in difficult conditions (combat, field, mobile hospitals, *etc.*) is significantly complicated due to sensitivity to tilt, vibration and the need for consumables. LSA can be implemented as an alternative in the form of a compact, non-contact device that allows you to obtain quickly information about the state of haemostasis even under minimal laboratory conditions.

In Table 2 [21, 26–28] below, there is a comparing the quantitative indicators obtained by traditional thromboelastography tech-

TABLE 1. Comparative analysis of LSA and TEG/ROTEM/ClotPro.

Setting	Thromboelastography (TEG/ROTEM/ClotPro)	Laser speckle analysis (LSA)
Onset of clotting	R/CT	Speckle variability reduction time
Rate of clot formation	K, α/CFT, α	Contrast change gradient
Maximum clot strength	MA/MCF	Speckle field stability and intensity
Fibrinolysis	LY30/ML	Secondary increase in variability (experimental)
Contact of the sample with the instrument	Need	Not required
The need for reagents	Yes (*e.g.*, activators)	No
Research time	30–60 min	5–20 min (depending on implementation)
Field use	Limited	Possible (with proper implementation)

TABLE 2. Comparison of quantitative indicators of TEG, ClotPro and LSA.

Setting	TEG/ClotPro (average)	LSA (similar indicator)
R, min	5–8	5–7 (Contrast stabilization start)
MA, mm	55–70	Variation index = 0.75–0.90
Clot formation time	≅ 10 min	≅ 8 min
Viscosity (indirectly)	—	Speckle rheology (LSR scale 0–1)

niques (TEG, ClotPro) and the corresponding parameters, which are evaluated by laser speckle analysis (LSA), according to literature sources.

At the same time, the LSA does not yet have full clinical validation and requires further research, in particular using various coagulation profiles, *in vivo* testing, as well as the development of data interpretation standards. Despite this, the already available experimental comparisons demonstrate a high degree of correlation between optical performance and results obtained with TEG/ROTEM.

To visualize the main differences between classical thromboelastography methods and laser speckle analysis of comparison in the context of use in clinical and military practice, the following is a comparative in Table 3 [1–4, 6, 15, 19, 21].

TABLE 3. Comparison of application possibilities in the clinical and military practices of TEG, ROTEM, ClotPro and LSA.

Setting	Thromboelastography (TEG/ROTEM/ClotPro)	Laser Speckle Analysis (LSA)
Method type	Mechanical–optical	Optical (based on coherent scattering)
Contact	Pin	Contactless
The need for reagents	Reagents are needed	No reagents
Time to get the result	10–60 min	2–10 min
Mobility	Stationary device	Portable, POC option possible
Vibration sensitivity	High (requires a stable surface)	Low (can be adapted)
Possibility of field use	Low	High

In this way, LSA not only complements classical methods, but also has the potential to replace them in specific situations where classical equipment is unavailable, less practical or too difficult to use.

6. PROSPECT FOR USE IN THE FIELD

Assessing blood clotting in resource-limited settings, especially in field or combat situations, requires technologies that are as autonomous, fast, and easy to use as possible. In such conditions, traditional thromboelastography systems are often unusable due to limitations in mobility, the need for calibration, reagents, constant power supply, and stable horizontal installation.

Laser speckle analysis (LSA) has a number of features, which determine its peculiarity for use in the field:

— contactless (it reduces the risks of contamination, simplifies maintenance and allows integration into sealed modules);

— no need for reagents (it allows you to reduce costs and minimize logistics dependencies);

— compactness and energy efficiency (the technology can be implemented on the base of portable lasers and CMOS cameras);

— rapid analysis provides results within 5–20 minutes, which is critical with a mass admission of patients);

— possibility of installation in mobile laboratories or medical platforms (ambulances, stabilization points, field surgical hospitals, *etc.*).

In the context of the war in Ukraine, such decisions are especially relevant. Domestic stabilization points often operate with

minimal equipment, in the field or in rooms without a stable power supply. LSA devices can be implemented as portable diagnostic modules for the initial assessment of the coagulation status of victims, which will allow timely decisions on transfusion, the use of anticoagulants or referral to the hospital.

The minimum requirements for laboratory diagnostics vary significantly depending on the level of the medical unit. Coagulation tests PT, aPTT, INR are included in the mandatory list only for Role 3 units, while for Role 2 such tests are not provided as mandatory [1]. This creates a potential clinical risk, since urgent surgical interventions are often performed at the Role 2 level in conditions of limited laboratory infrastructure, which makes it impossible to detect coagulopathy in time. Lack of access to coagulogram results can delay critical decisions about blood transfusion, fibrinogen administration, or anti-shock measures [6, 29].

In this context, portable technologies, such as laser speckle analysis (LSA) or thromboelastography (TEG/ROTEM), can significantly enhance the diagnostic capabilities of Role 2 [30]. Due to autonomy, high speed of obtaining results 5–15 minutes and the absence of the need for reagents, such methods are able to provide a prompt assessment of haemostasis even in unstable conditions [31]. This makes them particularly suitable for Damage Control Resuscitation (DCR) scenarios, which, according to modern military doctrine, are actively implemented at the Role 2 level. LSA can act not only as an alternative to classical laboratory coagulation, but also provide continuous monitoring of the state of coagulation before, during and after surgery, which significantly increases the chances of survival in patients with polystructural injury.

Most patients admitted to the Role 2 level have combined and combined combat injuries accompanied by massive bleeding. According to clinical studies, acute traumatic coagulopathy (ATC) can occur already at the prehospital stage (for in 25–35% of seriously injured patients [32]). In such situations, delay in identifying blood-clotting disorders significantly worsens the prognosis and can lead to unjustified blood loss, hypothermia and fatal complications. As stated in the updated European guidelines for the treatment of bleeding, the use of POC methods for monitoring haemostasis can significantly reduce the time to clinical decision-making compared to traditional laboratory tests [33]. If such technologies are integrated into the Role 2 structure, it is possible to achieve more effective coagulopathy control, which corresponds to modern principles of management of seriously injured patients in the war zone.

In the context of optical diagnostics, it is also worth noting that physical and chemical environmental factors affect the biosynthetic activity of microalgae specifically for each species. For example,

may either stimulate or inhibit the synthesis of metabolites, including lipids, carotenoids, chlorophylls, proteins and carbohydrates. In addition, the spectrum and intensity of light, as well as the duration and frequency of exposure to ultrasound, UV and α-radiation, are able to alter the metabolic pathways of microalgae, which demonstrates the breadth of possibilities for the influence of physical factors on cellular processes, which is consistent with the mechanisms that underlie laser speckle analysis.

7. NANOCOATING OF OPTICAL COMPONENTS TO IMPROVE SPECKLE IMAGE QUALITY

In a configuration where laser radiation is directed at an angle of 45° directly at the sample, and the reflected signal is recorded through the lens, optical transparency and the purity of the optical path play a key role in the formation of a high-quality image [34, 35]. Under the conditions of laser speckle analysis, even minor parasitic not required on the lens or objective surfaces can cause interference noise, a decrease in contrast and errors in the analysis of particle dynamics [36].

Nanoscale particles, especially metallic particles, are essential for increasing the sensitivity of laser speckle analysis due to the phenomenon of local surface plasmon resonance (LSPR) [37, 38]. Under the action of coherent laser light, electrons on the surface of the nanoparticle oscillate synchronously, which greatly enhances the scattering and absorption of light under resonant conditions. This effect produces brighter, more sensitive speckle signals, allowing detection of cell movements or aggregation even with fewer particles or aggregation of cells or protein structures into the bloodstream [28, 39].

One of the most promising solutions is the use of nanostructured anti-reflective (AR) coatings. The *moth-eye coating* mimics the structure of the eyes of nocturnal insects and creates a gradient refractive index at the air–glass interface, which significantly reduces reflection in a wide spectral range even at angular incidence of light [40]. Such nanocoatings reduce reflection from the surface to $< 0.5\%$ and increase light transmission up to 99% in the wavelength range of 400–900 nm [20, 41].

Unlike traditional multilayer AR coatings, which are effective mainly at normal beam incidence, *moth-eye* nanotextures remain effective at oblique angles, which is especially important when observing a sample at an angle of 45° [25].

Another approach is to use coatings with plasmonic nanoparticles (*e.g.*, Ag or Si), which not only reduce reflection but can also amplify the local light signal through the surface plasmon resonance. These

effects allow not only to muffle background noise, but also to increase the amplitude of the speckle signal and image detail [25, 41].

Studies show that such nanocomposites significantly improve the signal-to-noise ratio in optical imaging systems, in particular by reducing scattering and interference artefacts [20].

Nanocoatings also have a positive effect on optical clarity and spatial resolution, as the reduction of spurious reflections allows weak signals to be recorded without additional noise. Combined with high-quality lenses, this provides better focal stability, speckle structure clarity, and a more accurate analysis of microdynamics in the blood sample.

To implement these approaches, methods of nanolithography, ion etching, self-assembly technologies, or nanoparticle sputtering can be used. Most commercial optical manufacturers already offer AR lenses with nanotextures, including Edmund Optics, Thorlabs, Jenoptik, and others.

8. PHYSICAL MECHANISMS OF THE EFFECT OF NANOPARTICLES ON LSA SENSITIVITY

One of the important factors in increasing the sensitivity of LSA is the use of nanoscale structures, whose size is commensurate with the wavelength of coherent laser radiation in the range of 400–900 nm [38]. It is at this scale that the phenomena of localized surface plasmon resonance (LSPR) and surface plasmon resonance (SPR) occur [36]. When coherent light interacts with silver, gold, or silicon nanoparticles, electrons on their surface begin to oscillate synchronously with the electromagnetic field, resulting in a significant increase in the local electric field near the nanoparticles, the formation of ‘hot spots’, and a sharp increase in the intensity of light scattering and absorption [35]. As a result, even minimal changes in the blood microstructure during the initial stages of coagulation become available for registration, which directly increases the sensitivity of the sensor.

Work in the field of biosensors confirms that the nanosize of particles itself allows recording the smallest changes in the refractive index of the medium, which is impossible for classical macroscopic optical elements. The use of nanoparticles in the near-infrared range provides an increase in refractometric sensitivity along with better control of spectral selectivity, which opens up prospects for high-precision biomedical sensors [42]. For LSA, this means that the system is able to record microdynamic changes in the movement of cells and proteins even before the appearance of a macroscopic clot, that is, those that precede the formation of the fibrin scaffold.

Another important mechanism is a sharp increase in the scattering and absorption of light by nanoparticles. For example, it has been shown that scattering from a gold nanoparticle with a diameter of 80 nm can be 10^5 times stronger than fluorescence and 10^{12} orders of magnitude more intense than the Raman signal [42]. For the practical side of LSA, this means that, even when using low-power diode lasers, a sufficiently intense speckle signal is formed, which allows reducing power consumption, simplify the optical circuit and reduce the dimensions of the device. Accordingly, the amplified signal allows you to use compact CMOS cameras without losing the quality of measurements.

The effect of nanocoatings on the signal-to-noise ratio in the system is no less important. Even minor parasitic reflections from the surfaces of lenses or lenses can lead to interference noise, which reduces the accuracy of speckle analysis. The use of anti-reflective nanocoatings of *the moth-eye type* can reduce the reflection coefficient to $< 0.5\%$ and increase light transmission to almost 99% [43], which ensures the formation of a pure speckle pattern, suitable for further digital processing and creates the prerequisites for a more accurate assessment of cell micromovements. The additional application of plasmonic nanoparticles integrated into the coating allows not only to dampen unwanted reflections, but also to amplify the useful signal thanks to LSPR [23, 44, 45].

An important role in the formation of a qualitative speckle pattern is also played by the coherence of the radiation source. Adjusting the degree of partial coherence can optimize the signal-to-noise ratio in nanoparticle imaging. For LSAs, this approach allows you to reduce the impact of static interference noise and artefacts, while remaining highly sensitive to dynamic changes in the sample. Considering this factor in the design of portable sensors makes them less demanding on ideal operating conditions, which is especially important for military medicine.

The combination of the above-mentioned physical mechanisms makes it possible to create compact and at the same time highly sensitive sensors. Signal amplification at the level of nanostructures reduces the requirements for laser power and camera sensitivity, reduces the number of optical components and simplifies the design of the system, which opens the way for the development of Point-of-Care devices suitable for use in mobile laboratories, stabilization points and field hospitals.

9. NANOCOATING OF CUVETTES: USING SILVER NANOFILM TO RECORD SPECKLE STRUCTURES WITH REFLECTED LIGHT

Laser speckle analysis involves the use of coherent radiation passing

through the sample, but, when using a heated table (so that the blood sample does not dry out), recording the reflected speckle pattern becomes less effective. To obtain a clear and stable image, it is best to have a thin silver nanocoating at the bottom of the cuvette where the blood sample is stored.

The precipitated silver nanofilm with a thickness of 40–80 nm creates an optically active surface that reflects laser radiation with a high coefficient, while allowing the phenomena of local plasmon resonance (LSPR) and surface plasmon resonance (SPR) to be realized at the silver–biological fluid interface. This makes it possible to increase the sensitivity of speckle analysis to micromovements of blood cells or changes in rheological properties during coagulation [46].

Such solutions are widely applied in PPR microscopy, biosensors and laser optical backscatter systems. Silver nanofilms with a thickness of $\cong 50$ nm offer the highest sensitivity to changes in the refractive index of the medium compared to other metals, in particular, gold.

The morphology and thickness of the silver layer has a great influence on the reflective properties and interference effects that form the structure speckle. Samidir Im Nanofilms (≤ 100 nm) gives the best-distributed display for recording speckle pattern [45, 47].

9. CONCLUSIONS

Laser speckle analysis (LSA) has established itself as a promising optical diagnostic tool for assessing blood clotting. Compared to traditional thromboelastography systems TEG, ROTEM, ClotPro, this method has a number of advantages: contactlessness, no need for reagents, the possibility of portable implementation and the speed of obtaining results.

Available studies confirm a high correlation between the indicators obtained with the help of LSA and the parameters of standard coagulological devices. Although the method is still at the stage of laboratory validation, it has significant potential for use in extreme conditions, in particular, in field hospitals, stabilization points, and during emergencies.

Further research should be aimed at standardizing the technique, developing software for signal processing and creating full-fledged prototypes for clinical use. In the future, LSA can become an integral part of mobile diagnosis of haemostasis, especially in conditions of war or disasters, where the speed of decision-making saves lives.

The use of nanocoatings on optical elements, in particular, lenses and lenses, in speckle imaging systems reduces noise levels, im-

proves contrast and image detail, which is critical for the correct analysis of coagulation processes in biological samples.

The integration of silver nanofilm as a reflective element into the optical circuit of the speckle analyser allows:
— to increase optical contrast;
— to enhance the dynamics of the speckle signal;
— to react sensitively to structural and viscous changes in the blood sample during coagulation.

This solution is a full-fledged element of the nanotechnological design of the system, taking into account the scale, application methods (*e*-beam evaporation, sputtering) and nanostructural surface properties.

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