SINGLE-LENS SPECKLE INTERFEROMETER OF TANGENTIAL MICRO-DISPLACEMENTS OF THE SCATTERING SURFACE WITH A SINGLE ILLUMINATING LASER BEAM

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Schematic solutions for lateral displacement speckle interferometers with a single laser beam illuminating a controlled scattering surface and interference of two wave fields scattered in different directions which can be superimposed in several ways have been developed. The simplest way, but with limited sensitivity to displacement, is a scheme with a single lens that reduces scattered wave fields in the image plane of the surface. A mathematical model of the interferometer is being developed based on diffraction transformations of wave fields in the optical system of the interferometer. It is necessary for numerical modeling of interferometer signals and studying the information properties of the signal. The purpose of the research was to develop the theory of the method and develop a mathematical model of the interferometer, to study its physical and metrological properties, in particular, to study the dynamics of the speckle structure and the interference structure of the speckle modulated interferometer signal with a tangential displacement of the scattering surface of the object. Experimental studies show that a single-lens speckle interferometer with correlation processing of a speckle-modulated interference image of a surface area with a tangential displacement uniform in direction and magnitude can serve as an effective high-precision measuring tool for monitoring and measuring such displacements with variable velocity in magnitude and direction. Recording a sequence of image frames allows to determine the law of displacement in time at a speed limited by the frame recording frequency.

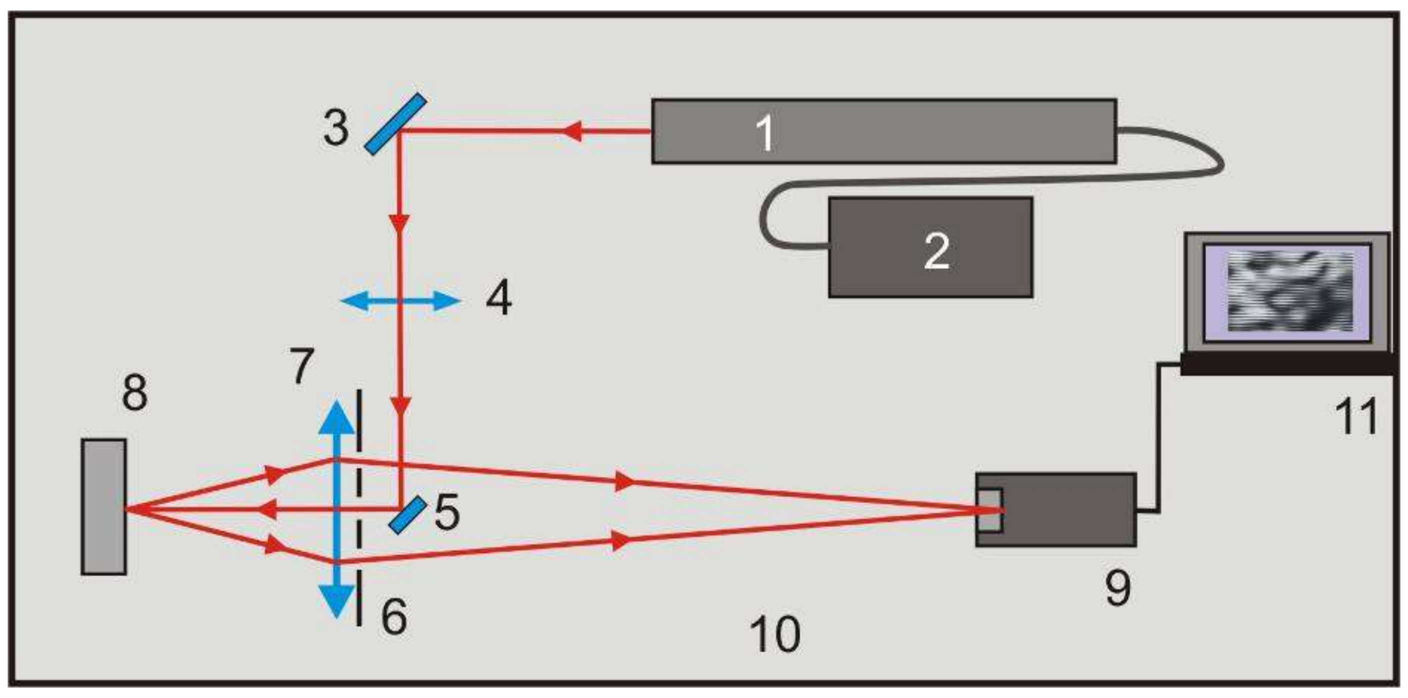
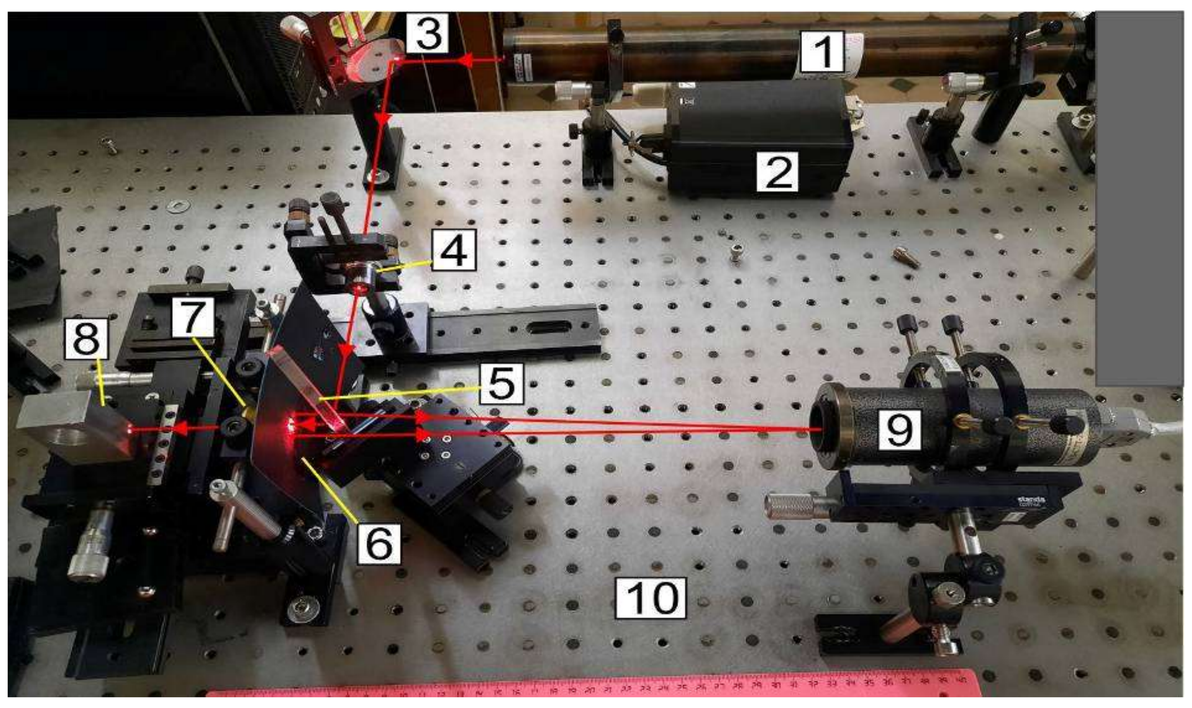
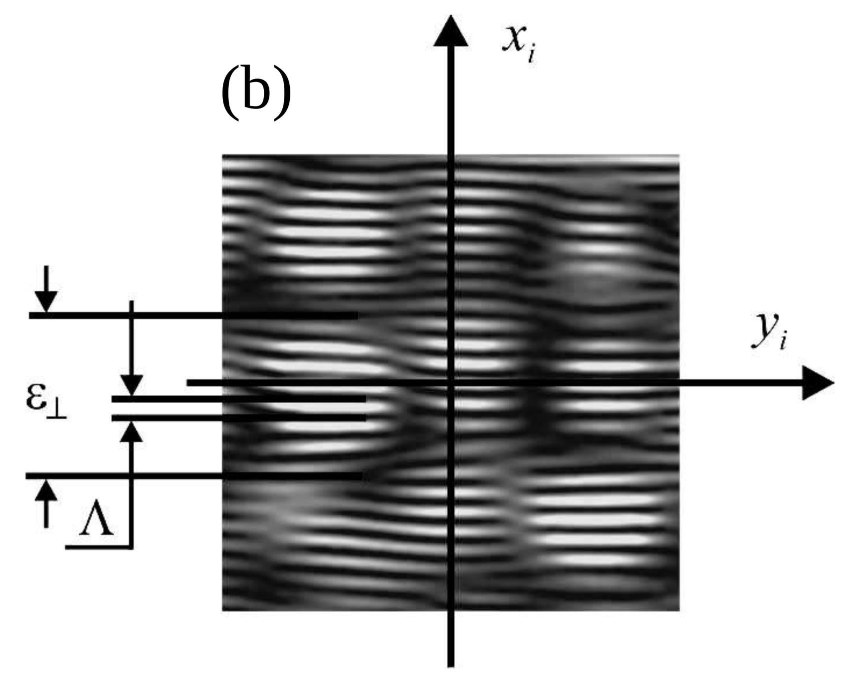


Fig. 1 Scheme of an experimental setup with a laser speckle interferometer of transverse displacements with one illuminating laser beam and with a single-lens optical imaging system of the scattering surface (a): 1 – laser, 2 – laser power supply, 3 – rotary mirror, 4 – micro lens, 5 – narrow rotating mirror, 6 – screen with three holes located on one horizontal straight line, 7 – lens, 8 – object with a scattering surface with the possibility of displacement in a horizontal direction perpendicular to the optical axis of the lens 7, 9 – digital camera, 10 – plate of a vibration-proof table, 11 – computer





(c)

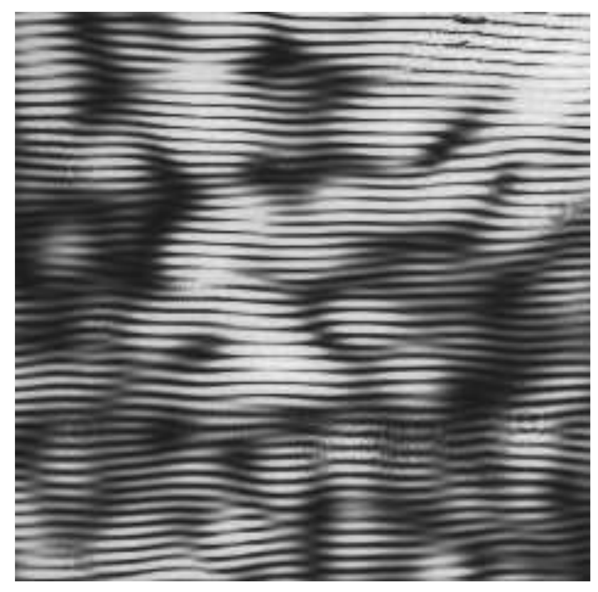


Fig. 2 Experimental setup with a laser speckle interferometer of transverse displacements with one illuminating laser beam and with a single-lens optical imaging system of the scattering surface (a): 1 – laser (He-Ne) , 2 – laser power supply, 3 – rotary mirror, 4 – micro lens, 5 – narrow rotary mirror, 6 – screen with three holes, 7 – lens, 8 – object with a scattering surface, 9 – digital camera (CCD camera), 10 – vibration proof plate. Speckles and interference fringes in the surface image: b – modeled, c – experimental

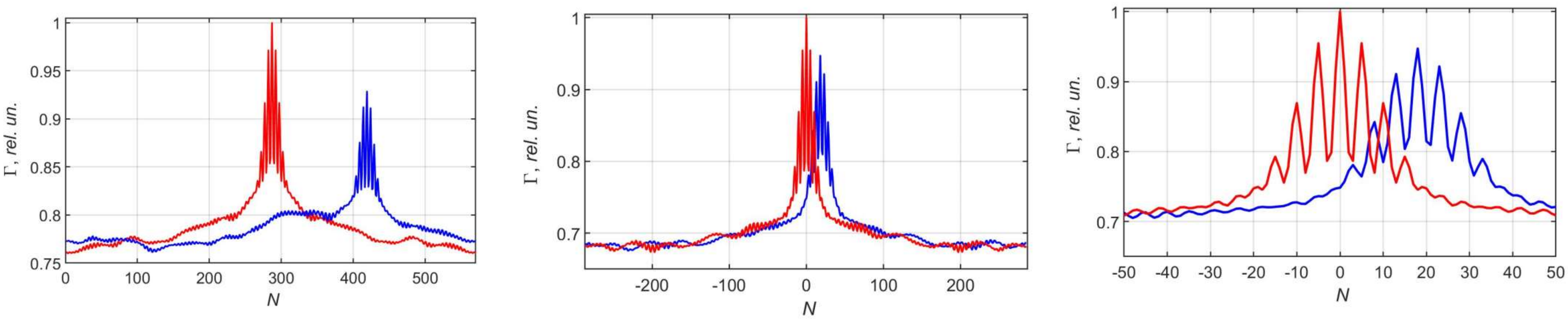


Fig. 3 Graphs of the cross-correlation functions of speckle-modulated images with interference fringes that have experienced mutual displacement. The numbers of samples – frames of recorded images - are postponed along the abscissa axis

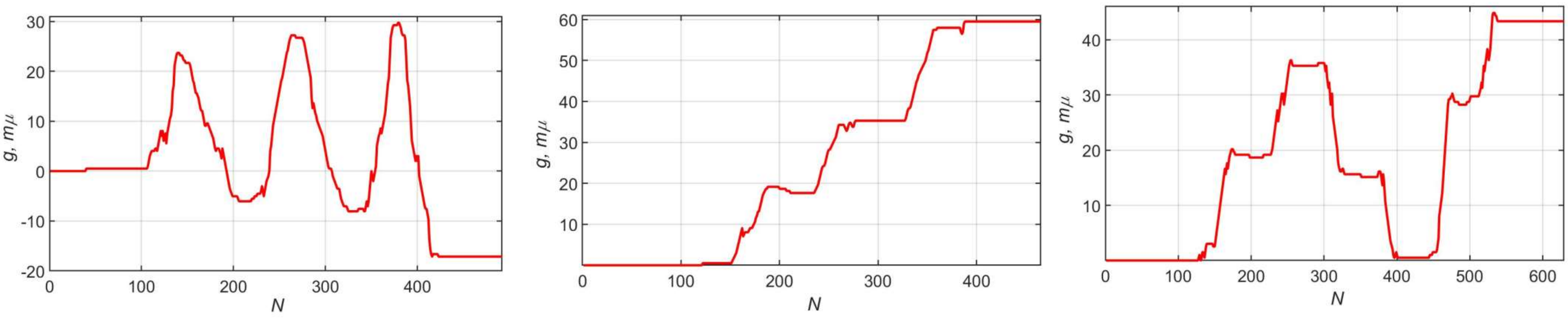


Fig. 4 Graphs of the continuous alternating signs lateral displacement g(t) of an object with a scattering surface, correlatively reconstructed from a series of speckle-modulated interferograms recorded by a digital camera in the recording mode of a sequence of frames with a frequency of 26 frames/sec. The numbers of samples – frames of recorded images - are postponed along the abscissa axis

The effect of the same joint displacement of the speckle structure and interference fringes from a physical point of view is due to the fact that both the speckle structure and the fringes are actually two structural components of the image field of the shifting surface of the object. Therefore, both of these structures are displaced by the same amount when the surface is displaced. Therefore, it is possible to use a correlation method for determining the displacement of the entire image of the illuminated part of the scattering surface. This correlation method was used by us in the experimental part of the work, in relation to the speckle interferometer under consideration with one illuminating beam and a single-lens interferometer signal generation system.This effect is also of great practical importance for the method of processing the measuring signal of a speckle interferometer in determining the parameters of the scattering surface displacement.