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Laser meter of aerosol microparticles parameters during their spontaneous transformation

A laser dual-wavelength analyzer microparticle (LDAM) based on the diagnostic method [1] is considered. Moving microparticles are irradiated by two pairs of coherent beams at long λ_1 and λ_2. The LDAM uses two anti-phase spatial filtering units of the scattered radiation at both wavelengths λ_1, and λ_2, whose outputs are connected to the inputs of a digital particle analyzer.

In the work [3] the spontaneous formation of H_2O_2 was first established, observed when spraying water microdroplets with a diameter of 1 μm to 20 μm. It is important to note that hydrogen peroxide is used not only as a disinfectant, but also in many other areas, such as metal processing, bleaching cellulose and textiles, and in the mining industry. The chemistry of aqueous microdroplets is at the stage of active development. Let us give some examples that confirm this: reduction of chlorogold acid ($H[AuCl_4]$) to gold nanoparticles [4], reduction of a number of different carboxylic acids [5] and formation of hydrogen peroxide [3, 6].

To study objects of microdroplet chemistry, mass spectrometry, fluorescence microscopy, and NMR research methods are mainly used.

In this paper we consider a laser dual-wavelength microparticle analyzer, which allows, in contrast to classical methods, to observe in real time the spontaneous transformation of both water microparticles, for example, into H_2O_2 and other aerosol transformations.

In the LDAM scheme with symmetrical reception relative to the *OYZ* plane (Fig. 1), passing through the *OZ* scheme axis and located perpendicular to the beam plane, the scattered radiation is received by the diaphragm within the spatial region limited by the opening, which has an axis of symmetry oriented in the *OYZ* plane. In this case, the plane OY_3Z_3, in which the axis of symmetry of the receiving diaphragm lies, coincides with the plane *OYZ*. If the axis of the receiving optics does not coincide with the axis of the *OZ* cheme and makes some angle with it, then in this version of the LDAM it is possible to achieve a higher spatial resolution, especially at small angles `γ between the probing beams. At that, when receiving backscattered radiation, the optical block of LDAM has a more compact design in comparison with the LDAM scheme, in which symmetric reception relative to the plane of the probing beams is realized. The peculiarities of the spatial structure of the high-frequency signal and the method of calculation of its main parameters for the LDAM scheme with symmetric reception of scattered radiation relative to the OYZ plane at different states of polarization of the probing beams are considered:

1) the beams have linear coordinated states of polarization with the direction of oscillation of the electric vectors perpendicular to the *OYZ* plane, or have linear

polarizations with the direction of oscillation of the electric vectors in the *OYZ* plane*;*

2) the first probing beam has right-circular (left-circular) polarization, and the second probing beam has left-circular (right-circular) polarization (Fig. 1);

3) The probing beams have linear polarizations, with the first linearly polarized beam having azimuth "α" (or "$-\alpha$"), and the second beam "$-\alpha$" (or "α").

At symmetric reception of scattered radiation relative to the *OYZ* plane, the spatial structure of the high-frequency signal has certain symmetry properties [7].

It should be noted that for all the above considered states of polarization of probing beams, when a monodisperse particle flux with specified parameters is used as scattering centers in the LDAM scheme, the phase components of the high-frequency signal determined by scattering effects are equal to $\Phi_\partial = 0°$ or $\Phi_\partial = 180°$ [8], it is possible, on the basis of the investigated dependences of the high-frequency signal parameters on the change of the angle between the probing beams γ and the receiving aperture α, to identify the spatial regions of reception for which the high-frequency signals will be in-phase, i.e., to realize the spatial filtering of the scattered radiation [9], which provides a high degree of phase matching of the mixed scattered beams.

Based on the considered theory of calculating the parameters of the high-frequency signal of the LDAM, taking into account the symmetry properties of the spatial structure of the signal, an application program for calculating on a computer the LDAM schemes implementing symmetrical reception of scattered radiation relative to the *OYZ* plane is developed. The results of computer calculation of the LDAM scheme with symmetric reception with respect to *OYZ* at different polarizations of the probing beams are analyzed.

The results of numerical simulation show that when the LDAM scheme implements symmetric reception of scattered radiation (the first type) relative to the *OYZ* plane, a high-frequency signal is formed at the photodetector output, the phase of which can be equal to either $\Phi_\partial° = 0°$ or $\Phi_\partial° = 180°$, if the probing beams have the following polarization states: linear matched: $\alpha_1 = \alpha_2 = 0°$ or $\alpha_1 = \alpha_2 = 90°$; linear with azimuths equal in modulus but opposite in sign: $\alpha_1 = \alpha$ and $\alpha_2 = -\alpha$ (for example $\alpha_1 = 45°$ and $\alpha_2 = -45°$); mutually orthogonal circular polarizations: right-left (or left-right). Moreover, for example, if through the LDAM measurement zone formed by beams at a wavelength of $\lambda = 0{,}6328$ μm a flow of monodisperse particles with a diameter of $d_r = 3{,}78$ μm ($\dot{m} = 1{,}48$) then antiphase spatial filtering [9] will work more effectively with probing beams having horizontal polarization ($\alpha_1 = 0$; $\alpha_2 = 0$). In this case, the phase of the useful signal, as calculations show, takes on the values $\Phi_\partial° = 180°$, and the phase matching coefficient has minimal values $K_\phi = 0{,}604$.

If, under the terms of the experiment, circularly polarized probing beams need to be used in the LDAM scheme, then it is more effective to use, as calculations show, symmetrical reception of scattered radiation back, when the phase coefficient of coordination is $K_\phi = 0{,}857$ ($K_{пн} = 0{,}223$; $V = 0{,}185$). The polarization states of the probing beams are selected when implementing a specific LDAM scheme with a symmetric reception of the first type, depending on both the

parameters of the LDAM scheme and the parameters of microparticles based on numerical modeling.

The paper deals with the peculiarities of operation of a practical variant of implementation of a laser dual-wavelength microparticle analyzer (LDAM) based on the diagnostic method [1], in which the first kind of symmetric reception of scattered radiation is carried out. Moving microparticles are irradiated by two pairs of coherent probing beams, respectively, at long λ_1 and λ_2, which propagate, for example, in the horizontal plane OXZ. If a pair of probing beams at wavelength λ_1 (or λ_2) have coordinated linear polarizations with azimuths $\alpha_1 = \alpha_2 = 0$ or $\alpha_1 = \alpha_2 = 90°$; or linear polarizations, with the first beam having an arbitrary azimuth: $\alpha_1 = \alpha$ ($\alpha = 30°$), and the second beam has a linear polarization azimuth $\alpha_2 = -\alpha$ ($\alpha = -30°$), or circular mutually orthogonal polarizations, in this case, as was shown in [2], high-frequency phase-conjugate signals are formed when receiving scattered radiation in two symmetric directions relative to the OYZ plane. This is the so-called first type of symmetrical two-channel reception of scattered radiation on two photodetectors. The laser dual-wavelength microparticle analyzer also uses two optical blocks for antiphase spatial filtering of scattered radiation at both wavelengths λ_1 and λ_2, the outputs of which are connected to the inputs of the digital particle analyzer.

Conclusions

The proposed laser dual-wavelength analyzer of microparticles of two-phase flow allows at symmetric reception of scattered forward (or backward) radiation in real time to measure unambiguously and accurately the presence in the flow of the real concentration of particles of two types, which differ from each other in optical properties ($\dot{m}_1 \neq \dot{m}_2$), for example, H_2O and H_2O_2, or other microparticles, which are used, for example, to visualize aerodynamic flows in large wind tunnels equipped with laser Doppler anemometers. In addition, the LDAM can also operate effectively when the optical axis of the receiving lens lies in the *OXZ* plane and makes some angle β with the optical axis *OZ*, including when receiving backscattered radiation.

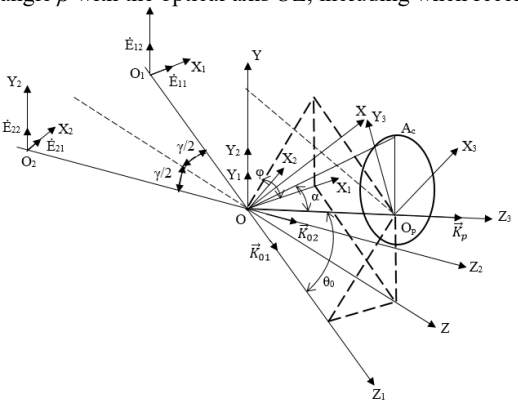

Fig. 1. Symmetrical reception of scattered radiation relative to the plane of symmetry *OYZ*

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