INTERFEROMETRY WITH PATH DIFFERENCE UP TO 500 METERS THROUGH A TURBULENT ATMOSPHERE

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ABSTRACT. The present study conducts interference experiments in the atmosphere for long path differences with simultaneous recording of the laser radiation spectral composition. Experimental values are found to agree with calculated values.

It is known that the interference methods make it possible to measure dis- /139*
tances with very high precision, approaching 10^{-5} cm [1]. The use of incoherent light sources, in particular a krypton standard source, makes it possible to measure distances up to one meter using interference methods. Further increase of the measured distances is not possible because of the short source radiation coherence length ΔL, which is determined by the finite width $\Delta\nu$ of the emission line, since $\Delta L \sim 1/\Delta\nu$.

The high degree of coherence of laser radiation made it possible in the very first experiments to obtain interference patterns with high fringe visibility; in such patterns no quantitative coupling between the visibility of the interference fringes of equal thickness was observed for a path difference of 354 meters. The author of [5] suggests that further increase of the path difference is not possible because of the disturbing influence of the turbulent atmosphere. We also note that studies [2-5] really amounted simply to the statement of the possibility of observing interference patterns with high visibility. These studies did not examine the quantitative connection between the visibility of the interference pattern with the spectral composition of the laser radiation and the statistical characteristics of the atmospheric turbulence.

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* Numbers in the margin indicate pagination in the original foreign text.

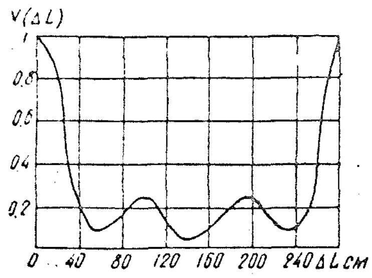

Figure 1.

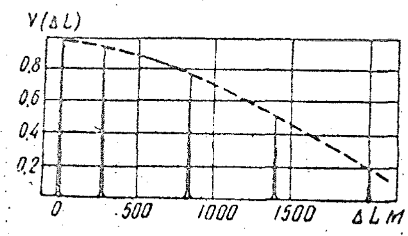

Figure 2.

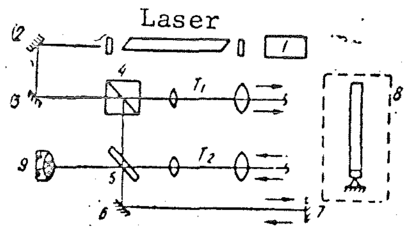

Figure 3.

An analysis of the visibility of interference fringes with account for the spectral composition of the laser radiation was made in [6]. It was shown that in the case of the presence in the laser radiation of axial modes, whose number depends on the Doppler width of the spectral line of the radiating gas and the radiation power, the visibility of the interference pattern is a periodic function of the path difference ΔL and takes a maximal value with a change of the path difference by twice the resonator length 2Z. Between the principal maxima there are secondary visibility maxima, whose number is determined by the spectral composition of the laser radiation. The total width of the principal maximum is 2Z/N. Figure 1 shows the results of our calculation of the visibility V for N = 4 over a length of one period. The envelope drawn through the points of the peripheral V maxima (Figure 2) is the visibility function for quasimonochromatic radiation. This leads to the conclusion that use of a laser radiating several frequencies in the axial mode regime makes it possible to obtain interference patterns with good visibility for suitable adjustment of ΔL. The necessity for such tuning was not mentioned and was apparently not considered in the studies [2-5].

The objective of the present study was to conduct interference experiments in the atmosphere for long path differences with simultaneous recording of the spectral composition of the laser radiation. /140

The measurements were made using a modified Michelson-Twyman-Green interferometer, shown schematically in Figure 3.

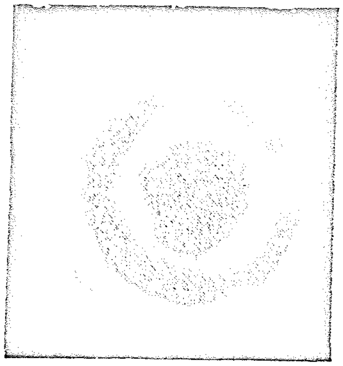

Figure 4.

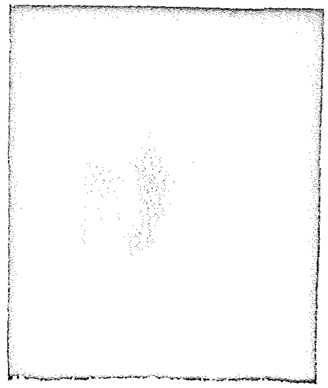

Figure 5.

The radiation source was a He-Ne laser operating in the axial mode regime. Up to eight longitudinal modes were generated simultaneously, the number of modes being recorded by the Fabry-Perot interferometer 1 with baseline length 10 cm. The laser radiation was directed by the mirrors 2, 3, and the telescope system T_1 (exit lens diameter 160 mm, magnification 50) into the atmosphere. A portion of the beam, reflected by the separating face of the cube 4, with the aid of the mirrors 6 and 7 and the semitransparent plate 5 forms a reference beam whose optical path can be altered by two meters by shifting the mirror 7. The laser beam, after traveling through the atmosphere and reflecting from the mirror 8, entered the telescope system T_2, and then fell in the focal plane of the lens 9 to form the interference pattern.

TABLE.

Exp. / Calc. l см	$\Delta L=0$		$\Delta L=200$ м	
	N	l см	N	l см
70	4	65	4	50
47	6	45	6	40
35	8	35	8	30

Most of the measurements were made in the evening and the early part of the night in October 1967 with path differences ΔL equal to 200 and 500 meters. We investigated the width l of the principal visibility maximum as a function of the number N of frequencies generated. The measurement results are shown in the table.

We see from the table that the measured widths of the principal maxima agree quite well with the calculated values.

The reduction of the width of the maximum for a path difference of 200 meters is associated with the interfering effect of the turbulent atmosphere on the coherence of the laser radiation.

As a result of the presence of the systems T_1 and T_2, it is possible to match comparatively easily the wave surfaces of the beam which has passed through the atmosphere and those of the reference beam and obtain the interference patterns of the equal-slope and equal-thickness curves. Typical equal-slope interference patterns with an adjustment of the path difference by the mirror 7 for maximal visibility near 200 and 500 meters are shown in Figures 4 and 5. We note that because of the high value of the visibility and effects associated with the uncontrollable reduction of the background blackening at the fringe minima, it was not possible to make a quantitative study of the laser radiation coherence by the photographic method.

With an increase of the path difference ΔL there is a considerable increase of the spatial instability of the interference pattern, the reason for which is the chaotic motion of this fringe system without a marked reduction of their visibility. The maximum of the fringe location fluctuations occurs in the low frequency region near 10-12 Hz.

The random shifts of the fringes are due to variation of the refraction index along the path of the radiation beam propagating in the turbulent atmosphere. The sensitivity of the interferometer to fluctuations of the refractive index was calculated from the magnitude of such shifts. For a path difference of 200 and 500 meters the sensitivity was, respectively, $3.15 \cdot 10^{-9}$ and $1.3 \cdot 10^{-9}$.

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