ADAPTIVE SYSTEM FOR LASER BEAM FORMING IN ATMOSPHERE WITH THE USE OF INCOHERENT IMAGES AS THE REFERENCE SOURCES

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INTRODUCTION

A radical means of dealing with these undesirable effects is to use various adaptive methods [1] which allow one at least in principle to almost completely eliminate the influence of the inhomogeneities of the medium. The essence of these methods reduces to controlling the initial distribution of the beam field on the basis of information about the instantaneous distribution of inhomogeneities of the medium in which the beam is propagating. We shall describe some very simple variants ([3], 1982) of the applications of adaptive control of beam parameters based on the principle of reciprocity of the propagation of radiation in an inhomogeneous medium. We use a fast speed intensity analyzer as for wave front sensor. The information on the distribution of inhomogeneities of the medium in the propagation path is obtained from the distribution of the intensity in the image plane of the object. We can see that the intensity of the reflected signal (or its functional) fluctuates as the square of the intensity of the field on the object so that maximization of the received signal maximizes also the intensity on the object.

USE OF THE RECIPROCITY PRINCIPLE TO CONTROL THE PARAMETERS OF AN OPTICAL BEAM

Here we present some of the simplest applications [1, 2] of adaptive control of beam parameters, based on the reciprocity principle applied to propagation in an inhomogeneous medium. Here information on the distribution of inhomogeneities in the medium along the propagation path is extracted from the intensity distribution in the image plane.

We introduce the Cartesian [2] coordinate system \((x, \rho)\) such that the \(x\) axis points in the direction of propagation of the beam. Let the initial distribution of the beam field \(U_0(\rho)\) be prescribed in the \(x = 0\) plane. The field at the point \((L, R)\) of the inhomogeneous medium can be written in the form

\[
U_b(L, R) = \iint d^2 \rho U_0(\rho) G(L, R; 0, \rho),
\]

(1)

where \(G(L, R; 0, \rho)\) is the Green's function of the problem or, equivalently, the field of the spherical wave at the point \((0, \rho)\) of the inhomogeneous medium, created by a point source located at the point \((L, R)\). The radiant intensity at that point then has the form

\[
I_b(L, R) = \iint d^2 \rho d^2 R_2 \Gamma_0(0, \rho_1 \rho_2) G(L, R; 0, \rho_1) G^*(L, R; 0, \rho_2),
\]

(2)

where \(\Gamma_0(0, \rho_1 \rho_2) = \langle U_0(\rho_1) U_0^*(\rho_2) \rangle\) is the initial value of the beam coherence function. In the case of a partially coherent beam \(\Gamma_0(0, \rho_1 \rho_2) = \langle U_0(\rho_1) U_0^*(\rho_2) \rangle\), where the averaging is carried out over the random fluctuations of the source (here it is understood that \(I_b(L, R)\) is also averaged over the fluctuations of the source).

By virtue of the reciprocity principle

\[
G_0(x_0, \rho_0; x, \rho) = G_0(x, \rho; x_0, \rho_0).
\]

(3)

Then, comparing (1) and (3), taking (4) and (6) into account, one can easily see that upon fulfillment of the condition

\[
U_0(\rho) = q - k \frac{1}{2 \pi i} A(\rho, L) \exp\left(ikl + i \frac{k \rho^2}{2l} - i k \rho_0 \right),
\]

(4)

where \(q = \text{const}\), the field of the coherent beam at the point \((L, R)\) coincides to within a constant factor with the intensity of the radiation from the point source at the point \(r\) in the plane \(x = -l\), i.e.,

\[
U_b(L, R) = C I_{\text{im}} (-l, r).
\]

(5)

What is more, (4) does not depend on the position of the source (i.e., on either \(L\) or \(R\)) and the parameters \((l, r)\) can be chosen quite arbitrarily on the basis of convenience. Similarly, from (2) and (3) upon fulfillment of the condition

\[
\Gamma_0(0, \rho_1 \rho_2) = \frac{k^2}{4 \pi^2 l^2} A(\rho_1) A(\rho_2) \exp[i S(\rho_1) - S(\rho_2)] +
\]

\[
+ i \frac{k}{2l} (\rho_1^2 - \rho_2^2) - i \frac{k}{l} \rho_1 \rho_2,
\]

(6)

we find that the beam intensity at the point \((L, R)\) coincides to within a constant factor with the intensity of the radiation from the point source at the point \(r\) in the plane \(x = -l\):

\[
I_b(L, R) = C^2 l^2 I_{\text{im}} (-l, r).
\]

(7)
Also, it is not hard to see that for a coherent beam, for which \[ \Gamma_0(\rho_1, \rho_2) = U_0(\rho_1)U_0^*(\rho_2), \] fulfillment of condition (4) also leads to (7). Relations (4)-(7) are thus an exact consequence of the reciprocity principle (6) and mean that the field from the point source located at the point \( (L, R) \) in the inhomogeneous medium having passed through an opening with amplitude-phase transmission coefficient \( A(r) \exp(iS(r)) \) and being observed at the point \( (-l, r) \) coincides with the field from a point source located at the point \( (-l, r) \) which has passed through the same opening and is being observed at the point \( (L, R) \) of the inhomogeneous medium. In all of this the initial distribution of the beam field \( U_0(\rho) \) is treated as the result of the passage of a spherical wave created by a source located in the region \( x < 0 \) through a screen with some chosen value of the amplitude-phase transmission coefficient.

Equality (7) together with condition (6) makes it possible to obtain information about the instantaneous values of the intensity fluctuations of the beam field at some remote point of the inhomogeneous medium on the basis of intensity measurements at an appropriately chosen point located behind the optical system.

In this case we may to use our knowledge for image correction systems [4, 5] to task for laser beam focusing on the distant targets.

REFERENCES

5. V.P.Lukin, B.V.Fortes, Partial correction for turbulent distortions in telescope, Applied Optics, V.37, No.21, 1998.