A LAZER STAR AS A REFERENCE RADIATION SOURCE IN FORMING NONDISTORTED AES IMAGES

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ABSTRACT. In the work, a possibility is shown of using an artificial laser source (a laser star) as a reference one to obtain an undistorted image of artificial Earth's satellites.

Key words: laser, image of AES, atmospheric turbulence.

Atmospheric turbulence and distortions, caused by it, of artificial cosmic objects' images, in particular, of artificial Earth's satellites (AES) as well as compensation methods of these distortions have been studied thoroughly and for a long time (Tatarsky, 1967; Bacoot, et al., 1977). One of compensation methods consists in obtaining images of a point source located within an isoplanatism angle Θ_0 in wich the observed object is olso found, in subsequent assessment of the wave front distortion, and then in compensations of these distortions in the obtained image of the object of interest. However, during AES observations it is intricate to find such a source (and even if it is found) its use is rather problematic. The possibility has been lately studied to use an artificial laser star (Bacoot, et al., 1995) as a reference source. The report deals with the investigation of this problem. The following questions are considered: energetics, the star's size, focal nonisoplanatism, nonpoint possible compensation methods, analysis of efficiency of using an artificial laser star (ALS) as a reference source.

Let us consider ALS as being formed due to the resonance scattering effect in a sodium mesospheric layer. At a height of 90 kms above the earth's surface the sodium atom number density is maximum and amounts to 10^3 - 10^4 cm. The resonance scattering section is - 8 10^{-12} cm^2. A relatively high sodium atom number density in the mesosphere and a large effective cross section of the back scattering make the sodium layer most suitable for forming artificial reference radiation sources.

The calculation of mean energy should be carried out in several steps. First, it is necessary to calculate the reaction of one unlabile atom per laser radiation. Then, the broadening of atomic scattering lines due to different reasons should be assessed: Doppler broadening due to atomic motion, broadening due to pulse character and partial coherence of laser radiation, broadening due to finite time of atomic passing by the laser ray. Taking account of all these factors permitted to derive a formula for energy signal received from an artificial star.

$$E = E_{rad} K \frac{NA\sigma_\rho h}{8\pi R^2} \int_0^\infty \frac{\exp(-x-\alpha^2 x^2)}{1+\beta^2 x^2} dx \qquad (1)$$

where
K is the coefficient taking into account absorption, reaction and a detector;
E is the energy received;
E_{rad} is the radiated energy;
σ_ρ is the cross section of resonance scattering $[m^2]$, $\sigma_\rho = \frac{\lambda_{nm}}{4\pi}$,
λ is the wavelength of atomic transition, λ=589 nm,
A is the area of aperture $[m^2]$,
N is the mean sodium atomic number density in a layer $[m^{-3}]$,
h is the thickness of the layer [m],
R is the distance to the layer [m]

$$\alpha^2 = \frac{1}{2\gamma^2}\left(\frac{1}{4\tau_i^2} + \frac{1}{\tau_{corr}^2} + \sigma_v^2 k^2\right), \qquad (2)$$

$$\beta^2 = \frac{1}{\gamma^2}\left(\frac{\sigma_v^2}{4\sigma^2} + \frac{\sigma_v^2}{\sigma_A^2} + \frac{k^2\sigma_v^2\sigma^2}{f^2}\right), \qquad (3)$$

τ_{corr} is the root-mean-square extension of a radiated signal correlation interval [c],
τ_i is the pulse duration [c],
γ is the natural bandwidth of atomic transition, γ=10 MHz,
σ_v is the mean-root-square scatter of velocities of atomic thermal motion (of one component), σ_v=278 m s^{-1},
$k = \frac{2pi}{\lambda_{nm}}$ is the wave number,
σ is the area of radiating aperture $[m^2]$,
f is the focal length [m]
σ_A is the root-mean-square extension of atmospheric fluctuations [m].

According to the formula obtained, calculations were made which showed that in the existing elemental fase (Zollars, 1992), and moreover in the promising one, the registering, and therefore assessment of distortions may be possible.

Calculation of geometrical dimentions of LAS under the following assumptions: - the function of a pupil $A(\vec{\rho})$ is

$$A(\vec{\rho}) = \exp^{-\frac{\vec{\rho}^2}{2\tilde{\alpha}^2}}, \tag{4}$$

where $\vec{\rho}$ - is the lateral radius-vector [m] $\tilde{\alpha}$ is the equvalent cross-section of a laser bunch at the opering [m], The function of coherence $\Gamma(\vec{\rho})$ is

$$\Gamma(\vec{\rho}) = \exp\left(-\frac{\vec{\rho}^2}{2\tilde{\beta}^2}\right), \tag{5}$$

where $\tilde{\beta}$ - the root-mean-square extention of atmospheric fluctuations [m], gives the following sizes of laser bunch cross-section at a distance z[m] over the Earth's surface d_{nn} [m]:

$$d_{LL} = \sqrt{z^2 \frac{1 + 2\left(\frac{\tilde{\alpha}}{\tilde{\beta}}\right)^2}{(k\tilde{\alpha}^2)^2} + \left(1 - \frac{z}{f}\right)^2}. \tag{6}$$

Calculations yield a result from several to tens of centimeters.

The analysis (of physico-chemical problems: nonpoints of a reference object, focal non-isoplanatism) has shown that a method of using a laser star for AES-observations can be realized. All the necessary calculations have been made at the theoretical department of Prof.P.A.Bacoot and they are to be put into practice at the Department headed by Yu.A.Medvedev in Odessa astronomical Observatory.

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