THE EFFECT OF THE AIR-BROADENED LINE CENTER SHIFT ON THE CHARACTERISTICS OF OPTICAL PULSES PROPAGAITING THROUGH THE ATMOSPHERE

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The influence of the air-broadened absorption line center shift on the parameters of coherent optical Gaussian pulses resonantly absorbed over vertical atmospheric paths is examined. The calculations were carried out for the H_2O line at 0,69438 μm. The above effect was found to be dramatically dependent on the pulse spectrum to the absorption line width ratio and the pulse frequency detuning from the resonance line frequency.

The interaction of coherent optical pulses with a resonantly absorbing gas medium depends on the detuning Δ of the pulse frequency from resonance and the pulse spectrum to the absorption line width ratio, Ω/ψ[1]. For inhomogeneous, e.g. vertical, atmospheric paths, the absorption line shape, width and center frequency vary with height. This will lead to further changes temporal and energy properties of radiation propagating through the atmosphere[2–4].

This paper considers the effect of the airbroadened line center shift on the characteristics of coherent optical Gaussian pulses propagating vertically through the atmosphere.

The atmosphere is assumed to be an inhomogeneous plane-layer medium. A standard atmospheric statistical model is adopted for describing its thermodynamic parameters. The calculations were made for an isolated vapor absorption line centered at 0.69438 μm. The pathlength is taken to be 10 km, i.e. the portion of the atmosphere where the H_2O absorption is found to dominate.

The radiation field in the medium is given as[4]

$$\varepsilon(h,t) = 1/2 \int_{\infty}^{\infty} d\nu\, A(\nu) \times$$

$$\times \exp\left\{-ik \int_0^h dh' \left[n_0 + 2\pi S\, N(h')\, G(\nu,h')\right] + i\nu t\right\} \qquad (1)$$

where $\varepsilon(h, t)$ is the slowly varying complex optical wave amplitude, $A(\nu)$ is the Fourier transform of the pulse amplitude at the starting point of the atmospheric path, $k = w/c$; n_0 is the nonresonance part of the refractive index; S is the line intensity per an absorbing gas molecule; $N(h)$ is the absorbed concentration per unit volume; $\mathrm{Jm}G(\nu, h)$ and $\mathrm{Re}G(\nu, h)$ describe the absorption line shape and the resonance part of the refractive index (the region of abnormal dispersion).

Integral (1) was calculated by substituting a periodic function with a period $\gg \Omega$ for the integrand and then using a FFT algorithm.

Figure 1 shows the calculated Gaussian pulse distortion for $\kappa = \Omega/\gamma(0) = 0.3$. In this case the interaction conditions vary from quasistationary on the Earth's surface ($\kappa < 1$) to nonstationary at a height of 10 km ($\kappa > 1$). As seen from Figure 1, for $h = 0$ and $\Delta = 0$ the pulse shape is very sensitive to the air-broadened absorption line shift. The line-center shift with height causes a weaker pulse absorption, the pulse shape being much less affected.

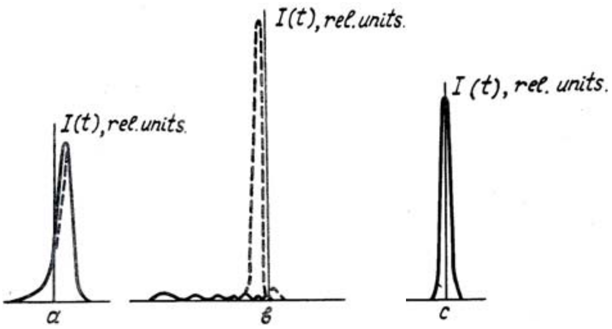

FIG. 1. The coherent Gaussian pulse distort ion over the vertical atmospheric path in midlatitude summer conditions for $\Omega/\gamma(0) = 0.3$ with (----) and without (——) air-broadened line-center shift: (a) $\Delta = -0.1$ cm^{-1}; (b) $\Delta = 0$ cm^{-1}; (c) the initial pulse shape.

The calculation of the Gaussian pulse distortion is illustrated in figure 2 for an essentially nonstationary interaction ($\kappa > 1$) over the entire path at

$\Omega/\varphi(0) = 3.0$. The pulse shape is seen to be practically independent of the air- broadened line shift.

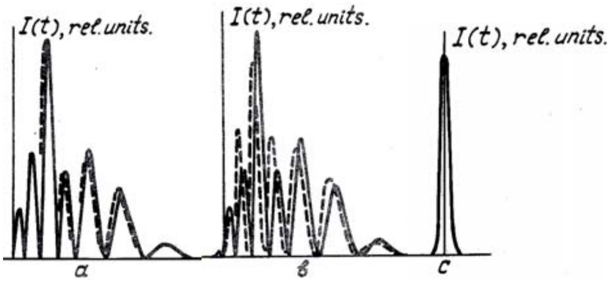

FIG. 2. The coherent Gaussian pulse distortion over the vertical atmospheric path in midlatitude summer conditions for $\Omega/\varphi(0) = 3.0$ *with (----) and without (——) air-broadened line-center shift: (a)* $\Delta = -0.1$ *cm*$^{-1}$*; (b)* $\Delta = 0$ *cm*$^{-1}$*; (c) the initial pulse shape.*

Thus, the foregoing considerations lead us to conclude that in the vertical sounding of gaseous atmospheric constituents whose absorption spectrum consists of well separated lines the optical pulses with $\Omega > \varphi$ can be conveniently used to reduce the systematic measurement error.

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