Numerical Research of Multimode Light Flux Distribution in Model Depressive Midium

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This work is done in framework of project INTAS 00118 for the program ALICE [1]. The method purposed here may be used in the system of monitoring of relative displacements of registration chambers in ALICE.

The idea to use correlated beam of light in monitoring puposes was not successful. The chambers produce heat during their work, thus settling temperature gradient in the air. The light beam distributing in the air with temperature gradient is deflected from its initial direction due to dispersion effect and it is impossible to define which part of registred by photosensor displacement is a result of mechanical displacement of the chamber itself, and which part is due to dispersion effect. In this situation it is hard to get desired precision of monitoring.

We offer to use spatially combined multimode light beams for this purpposes. Again, due to dispersion effect monochromatic light beams spatially combined in the begining will be detected in different points on photo sensor. The difference between coordinates of that points bears information about the state of the medium (in our case - air with temperature gradient). Knowing the change in sensing points coordinates and in the distance between them we can easily define the above mentioned parts of registred displacement. Assuming that the dispersion effect is due to unhomogeneous temperature distribution, we can use following empiric expression for deflection idex [2]

$$n(\lambda,\, T) = 1 + 10^{-6}\left[\frac{77.6p}{T} + \frac{0.584p}{T\lambda^2} - 0.06p_w\right], \tag{1}$$

where λ is the wave lenght, p - air pressure, p_w - parcial pressure of water vapor in the air.

Numerical research is done for 3 different wave lenghts and for 3 models of dispersive medium described below.

1. Vertical homogeneous strip.

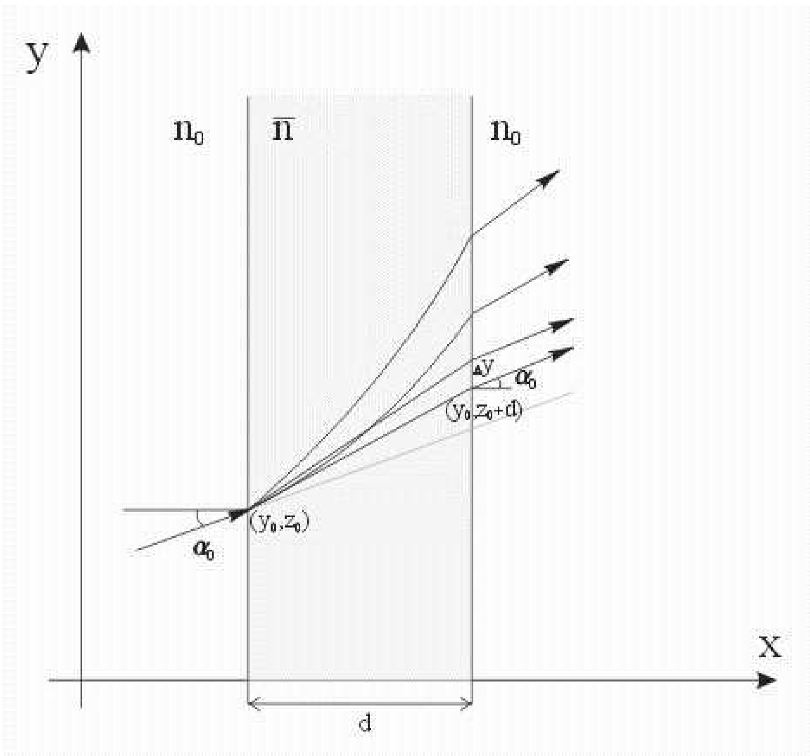
Let us consider the heated area as a vertical strip with width d. Margins of the strip are parallel planes, and the temperature T between the planes is distributed homogeneously and exceeds the temperature T_0 of the environmetn (pic. 1). Deflection $\triangle y$ of the beam from its initial direction may be calculated by equation

$$\triangle y(\lambda) = d\left(\frac{n_0 \sin\alpha_0}{\sqrt{n^2(\lambda) - n_0^2 \sin\alpha_0}} - tg\alpha_0\right) \tag{2}$$

Results of the calculations for 3 different wave lenghts $\lambda_1 = 0.25\mu$, $\lambda_2 = 0.45\mu$, $\lambda_3 = 0.85\mu$, for distances d between the planes and for the difference in temperatures $\triangle T$ are brought in table 1.

Table 1.

	$\triangle T = 5^0$		$\triangle T = 15^0$		$\triangle T = 25^0$	
d (cm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)
100	0.37	0.48	1.05	1.4	1.71	2.26
200	0.54	0.72	1.59	2.1	2.56	3.39
300	0.73	0.96	2.12	2.8	3.42	4.52
400	0.91	1.2	2.65	3.5	4.27	5.65
500	1.1	1.45	3.17	4.2	5.13	6.77



Pic. 1.

2. Vertical temperature gradient model.

Now let us consider an interval $[0,\ d]$ in the direction of OZ axis with constant temperature gradient g_z in the same direction (OZ). Spliting $[0,\ d]$ into layares of width dz and with constant deflection index n_i for $[z_i,\ z_i+dz]$ layer, we will have

$$\begin{cases} n_0 \sin\alpha_0 & = & n_i(z_i,\ y_i)\sin\beta_i(z_i,\ y_i) \\ dz & = & ctg\beta \cdot dy \end{cases} \tag{3}$$

For $n(\lambda,\ T)$ deflection index we can use following equation

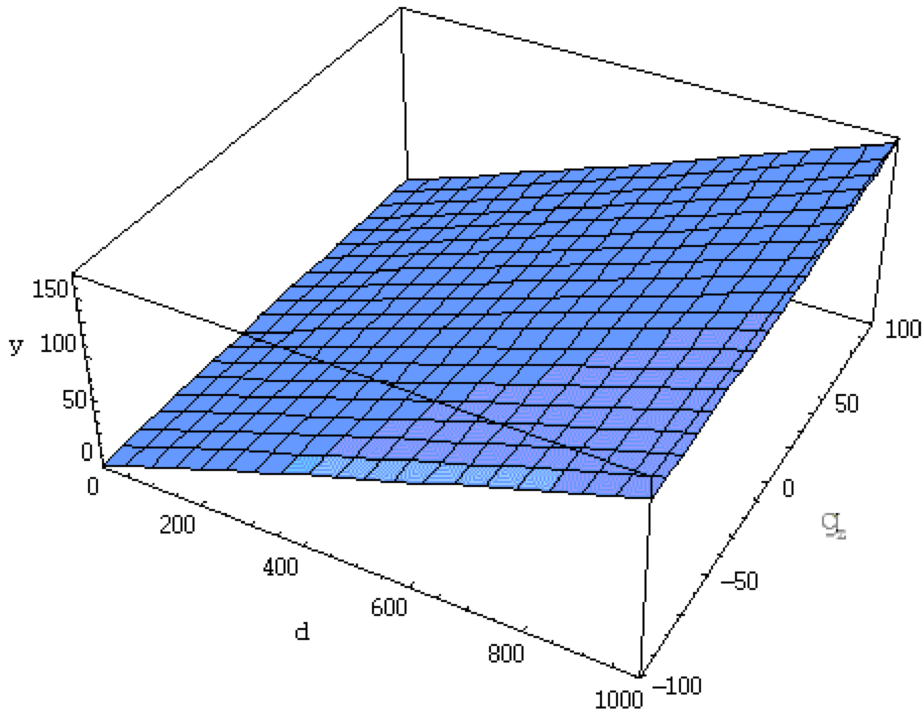
$$n\left(T(y),\ \lambda\right) = \bar{n} + \left.\frac{\partial n}{\partial T}\right|_{(0,\ 0)} \frac{\partial T}{\partial y} = \bar{n} - \frac{f(0,\ 0)\varphi_\lambda g_y y}{T} - \frac{f(0,\ 0)\varphi_\lambda g_z z}{T}, \tag{4}$$

where $\bar{n} = 1 + f[T(0,\ 0)]\varphi(\lambda)$ is deflection index of first layer, and $\varphi_\lambda \equiv \varphi(\lambda) = \left(77.6 - \frac{0.584}{\lambda^2}\right)$. For vertical gradient model in (4) we can put $g_y = 0$ (no temperature gradient in direction of OY), we will get

$$y = \frac{c_0 T^2 10^6}{P_0 \cdot \varphi_\lambda \cdot g_z}\left[arcch\frac{\bar{n}}{c_0} - arcch\frac{\bar{n} - \dfrac{10^{-6}P_0\cdot\varphi_\lambda\cdot g_z}{T^2}z}{c_0}\right], \tag{5}$$

where $c_0 \equiv n_0 \sin\alpha_0$.

Results of calculations are brought in Table 2, for 3 different wave leghts ($\lambda_1 = 0.25\mu$, $\lambda_2 = 0.45\mu$, $\lambda_3 = 0.85\mu$). Dependence of the beam deflection from the width of heated area and gradient magnitude is brought in Pic. 2.



Pic. 2.

Table 2.

	$g_z = 1.5$ deg/cm		$g_z = 1$ deg/cm		$g_z = 5$ deg/cm	
d (cm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)
100	3.95	5.22	7.54	9.96	36.29	47.95
200	8.62	11.39	16.7	22.06	81.44	107.6
300	15.08	19.93	29.44	38.9	144.65	191.11
400	23.34	30.84	45.78	60.49	225.95	298.52
500	33.39	44.12	65.72	86.83	325.39	429.89

3. Horizontal gradient model.

In this model we will study the case when the temperature field is beeing homogeneously changed in direction of OY axis. Then horizontal layer $[y_i,\ y_i + dy]$ must have constant deflection index n_i. In this case system (3) will look like

$$\begin{cases} n_0 \sin\alpha_0 & = & n_i(z_i,\ y_i)\sin\beta_i(z_i,\ y_i) \\ dz & = & ctg\beta \cdot dy \end{cases} \tag{6}$$

and for (4)

$$n(y,\ \lambda) = \bar{n} + \frac{f(0,\ 0)\varphi_\lambda g_y y}{T}. \tag{7}$$

As a result we will get the following equation for the beam deflection

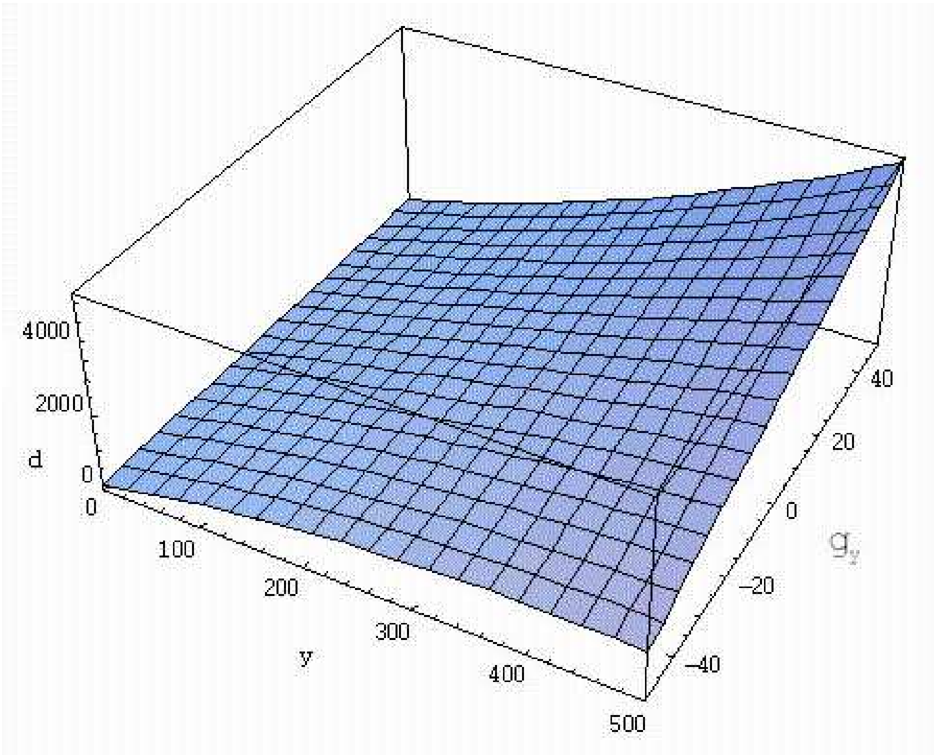
$$z = \frac{y}{\left(\frac{\bar{n}^2}{c^2} - 1\right)} + \frac{\frac{\bar{n}}{c}}{2\left(\frac{\bar{n}^2}{c^2} - 1\right)^{3/2}} \frac{P_0 10^{-6}\varphi_\lambda \cdot g_y}{c \cdot T^2} y^2. \tag{8}$$

where $c \equiv n_0 \cos\alpha_0$.

Results of calculations are brought in Table 3 again for above mentioned 3 wave lenghts, and on the Pic. 3 dependence of the beam deflection the layer's width and gradient magnitude is shown.

Table 3.

	$g_z = 1.5$ deg/cm		$g_z = 1$ deg/cm		$g_z = 5$ deg/cm	
d (cm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)	$\triangle(\lambda_1,\ \lambda_2)$ (mkm)	$\triangle(\lambda_1,\ \lambda_3)$ (mkm)
100	215.17	284.17	30.87	40.9	8.13	10.74
200	498.78	658.57	80.52	106.38	29.24	38.63
300	903.14	1192.19	153.11	202.27	61.75	81.59
400	1430.89	1888.4	248.73	328.57	105.68	139.62
500	2084.78	2750.68	367.49	485.43	161.05	212.76



Pic. 3.

References

[1] ALICE Experiment, *CERN/LHCC 95-71*, LHCC/P3, 15 Dec., 1995.

[2] Gurevich A. S. and others, *Laser radiation in turbulent atmosphere*, "Nauka" publishers, 1976, p. 277.