# LETTERS TO THE EDITOR

## A PLANE SYMMETRIC UNIVERSE FILLED WITH STIFF MATTER

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RECENTLY considerable interest has been created in the study of equation of state[1] $\rho = p$ for the matter content of the universe in its early stages. In this note, considering a special case of the perfect fluid distribution discussed for the Marder metric by Singh and Abdussattar[2] with metric potentials $A = B$ and equation of state $\rho = p$ for stiff matter, a cosmological model is obtained as

$$ds^2 = (1 + at)^{2\beta}\{dt^2 - dx^2 - dy^2\} - (1 + at)^{2-2\beta}\, dz^2 \quad (1)$$

where $a$ is an arbitrary constant and $\beta$ is a positive number less than 2. The distribution in the model is given by

$$8\pi p = 8\pi\rho = \frac{a^2\beta(2-\beta)}{(1+at)^2(\beta+1)}. \quad (2)$$

The coordinate system turns out to be comoving with $v_4 = (1 + at)^{\beta}$. The flow vector $v_i$ satisfies the equations of the geodesics $v^i{}_{ij}v^j = 0$ and hence the lines of flow are geodesics. The universe described above is irrotational but not shear free. The surviving components of the shear tensor $\sigma_{ij}$ and the scalar of expansion $\theta$[3] for the model are given by

$$\sigma_{11} = \sigma_{22} = \frac{a(1-2\beta)}{3(1+at)^{1-\beta}},$$

$$\sigma_{33} = \frac{2a(2\beta-1)}{3(1+at)^{3\beta-1}}, \quad (3)$$

and $$\theta = \frac{a(\beta+1)}{(1+at)^{\beta+1}}. \quad (4)$$

If we take $a$ as a positive constant, $\theta$ is always positive. Therefore the universe is expanding with time. From (2) and (4) we see that when $t$ tends to zero

$$\rho(=p) \to \frac{a^2\beta(2-\beta)}{8\pi} \quad \text{and} \quad \theta \to a(\beta+1)$$

and when $t$ tends to infinity $\rho(=p)$ and $\theta$ tend to zero. That is, $\rho(=p)$ and $\theta$ are decreasing functions of time and the rate of expansion of the universe is large in the beginning. From the physical components of the non-vanishing Riemann curvature tensor for the metric (1) we find that the model is asymptotically flat. The model admits a four-parameter group of motions. Petrov-Pirani classification of the model reveals that it is of Petrov type I-D. If we take $\beta = 0$ the space time is flat. For $\beta = \frac{1}{2}$ we get the conformally flat metric with

$$8\pi p = 8\pi\rho = \frac{3a^2}{4(1+at)^3}$$

and for $\beta = 2$ we have $R_{ij} = 0$, $R_{hijk} \neq 0$. By a suitable transformation the line-element in geodesic form can be written as

$$ds^2 = dT^2 - T^{2\beta/(\beta+1)}(dX^2 + dY^2) - T^{(2-2\beta)/(\beta+1)}\, dz^2. \quad (5)$$

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## BACK SCATTERED *m*-LINES

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THE observation of back-scattered *m*-lines and its use in locating the mode angles in thin film optical wave guides are presented. Observation is made on solution deposited polystyrene thin films using a prism coupler.

Thin films of polystyrene are formed on ultrasonically cleaned glass slides (index = 1·513) by spin-coating. Films are cured at about 120° C to remove stress birefringence[1]. The thickness of the films thus formed were such that these were capable of supporting only $TE_0$ and $TM_0$ modes. The film is clamped with a symmetric EDF glass prism (index = 1·698) to couple the light in and out of the film to observe *m*-lines[2]. A patch is observed at the centre portion of the prism base. This portion is the coupling region,

where the gap is suitable for coupling a narrow beam of light into the film. Light from a He–Ne laser is focussed on to the prism coupler (Fig. 1). When the light is incident on the coupling region and the angle of incidence is adjusted to couple the light into a mode, strong coupling takes place. To observe weak coupling, light is focussed to the edge of the coupling region. Since unpolarised light is used in this study, both the $TE_0$ and $TM_0$ mode lines were observed simultaneously very close to each other. When a polariser is introduced in the light path, depending upon the polarisation, either $TE_0$ or $TM_0$ or both the mode lines were observed.

Now, if the light is focussed on to the far end of the coupling region, the light, that is back scattered in the film, couples back into the prism and comes out to form faint back scattered *m*-lines on a screen (screen A) that is introduced on the incident light path with a pinhole at centre. Fig. 1 *a* shows the schematic diagram of the arrangement. Light, getting back scattered from the mode in which the beam essentially enters, comes out along the same path in which it is incident. Hence the corresponding mode line falls right across the pinhole (Fig. 2). If the angle of incidence is now altered even very slightly, this line moves away from the pinhole. One can locate the coupling angle with ease and also accurately. This gives one great confidence in determining the mode angles.

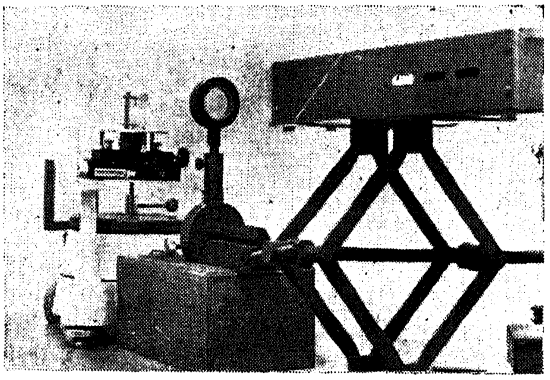

FIG. 1. Experimental set-up for the study of light propagation in thin film optical waveguides.

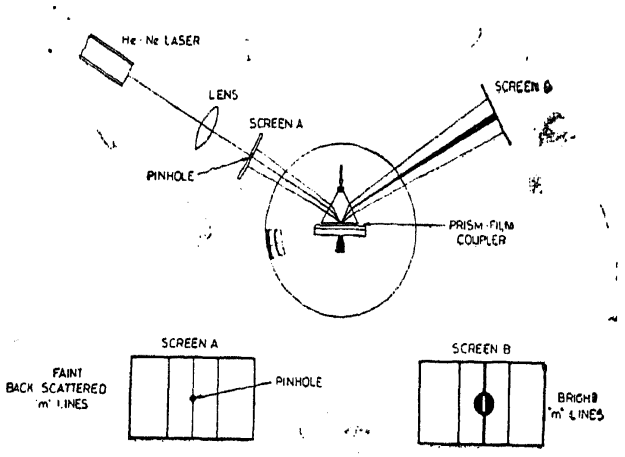


FIG. 1 *a*. Schematic diagram of observation of back scattered *m*-lines.

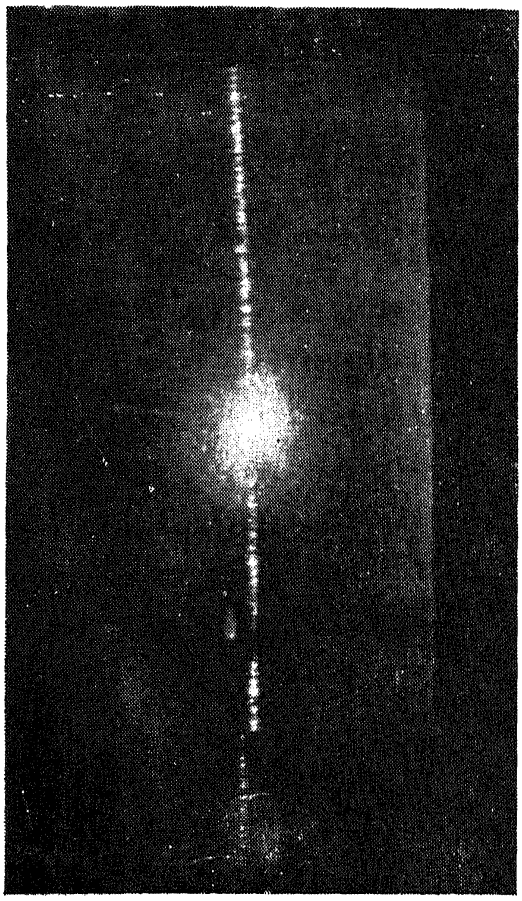

FIG. 2. Back scattered *m*-line falling across pinhole.

From the measured coupling angles, the refractive index and thickness were calculated using the known relationship between these quantities[3]. By computation, refractive index for which the calculated thickness is same for both the $TE_0$ and $TM_0$ modes for the observed coupling angles, is determined. The refractive index thus determined, the corresponding thickness and the observed mode angles for different films formed under similar conditions are given in Table I.

TABLE I

| Film No. | Angle of incidence on Prism* $TE_0$ mode | Angle of incidence on Prism* $TM_0$ mode | Film index for $\lambda$=6328 Å | Film thickness Å |
|---|---|---|---|---|
| 1. | 34° 14′ | 33° 16′ | 1·5830 | 4648 |
| 2. | 34° 15′ | 33° 17′ | 1·5830 | 4658 |
| 3. | 33° 43′ | 32° 44′ | 1·5835 | 4307 |
| 4. | 34° 52′ | 33° 55′ | 1·5840 | 4980 |
| 5. | 34° 42′ | 33° 44′ | 1·5840 | 4872 |

* Angle of prism face used for coupling = 45° 13′.

In an earlier publication[4] it is mentioned that one requires skill and experience to determine mode angles of a thin film, while observing *m*-lines. But the observation of back scattered *m*-lines as used in our study enables one to locate the angle at which coupling takes place easily and confidently. So, we feel that this technique offers a significant improvement in measurement of mode angles of thin film optical waveguides.

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## EXCITED STATE DIPOLE MOMENT OF ACRIDINE ORANGE

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In a previous note, the effect of solvent on the polarization of fluorescence of acridine orange was reported[1]. The effect of solvent on excitation and fluorescence spectra of acridine orange has further been investigated to obtain information about the change in dipole moment of the molecule on excitation from the ground state to the next higher singlet state. The excited state dipole moment can be estimated by measuring Stoke's shift in different solvents and making use of the following theoretical relations given by Bakshiev[2] and Chamma and Viallet[3].

Bakshiev's formula is :

$$\bar{\nu}_a - \bar{\nu}_f = \frac{2\Delta\mu^2}{\bar{a}^3 hc}\left(\frac{D-1}{D+2} - \frac{n^2-1}{n^2+2}\right)\frac{2n^2+1}{n^2+2} = \frac{2\Delta\mu^2}{\bar{a}^3 hc} F_1(D, n) \qquad (1)$$

where $(\Delta\mu)^2 \approx (\mu_e - \mu_g)^2$. (Kawski *et al.*[4]), $\mu_e$ and $\mu_g$ are dipole moment in the ground and excited emitting state, '$a$' is the Onsager cavity radius, '$D$' and '$n$' are the solvents, dielectric constants and refractive index.

Chamma and Viallet's[3] formula is :

$$\frac{\bar{\nu}_a + \bar{\nu}_f}{2} = \frac{-2(\mu_e^2 - \mu_g^2)}{\bar{a}^3 hc}\left[\frac{2n^2+1}{2(n^2+2)}\left(\frac{D-1}{D+2} - \frac{n^2-1}{n^2+2}\right) + \frac{3}{2}\frac{(n^4-1)}{(n^2+2)^3}\right] = \frac{-2(\mu_e^2 - \mu_g^2)}{\bar{a}^3 hc} F_2(D, n). \qquad (2)$$

Stoke shift $\bar{\nu}_a - \bar{\nu}_f$ and $\bar{\nu}_a + \bar{\nu}_f/2$ in a series of solvents are plotted according to eqs. (1) and (2), yielding slopes $S_1$ and $S_2$, which then given the value of $\Delta\mu$ as equations (1) and (2) can be used simultaneously.

In the present investigation, the absorption and fluorescence frequency shifts are measured for Acridine Orange in different solvents for a constant concentration $\sim 10^{-6}$ g/cc at temperature 25° C using Aminco Bowman spectrophotofluorometer. Acridine orange used was of spectroscopic grade purity and the solvents used were of AR quality obtained from BDH/EM and were further checked by absorption studies for any possible contamination. The concentration was kept low to minimise reabsorption of the emitted light and the possible changes in the wavelength due to inner filter effect. The entrance and exit slits of the spectrophotofluorometer were adjusted to give a reasonably good signal for detection and also a good resolution. For absorption and emission wavelengths the accuracy of wavelength measured is of the order of $\pm 2$ nm. The effect of scattering and background for each solvent was checked separately using pure solvent in the cuvette and was found to be less than 0·5%. Necessary corrections for the nonuniform spectral emission of xenon lamp and nonlinear response of the photomultiplier tube (IP 21) were applied[5-6]. The peak absorption and emission wavelengths were located and the results are given in Table I.

Plots of $\bar{\nu}_a - \bar{\nu}_f$ versus $F_1$ and $\bar{\nu}_a + \bar{\nu}_f/2$ versus $F_2$ are shown in Figs. 1 and 2. As these plots are linear, they lend support to the Bakshiev's and Chamma, Viallets theory[2,3] as given in relations (1) and (2). The slopes of these lines in Fig. (1) and Fig. (2) are $S_1 = 1859{\cdot}55$ and $S_2 = -1974{\cdot}34$ respectively (using least square fit method). With these values of $S_1$ and $S_2$ and using the equations (1) and (2), the estimated value for the excited state dipole moment of acridine molecule is

$$\mu_e \sim 33\,\mu_g.$$

The solvent perturbation data given in Table I along with Kasha's test[7], is helpful in identifying whether the transition is $n \rightarrow \pi^*$ or $\pi \rightarrow \pi^*$. As the