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June 9, 2009

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To: VSRT Group

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Subject: Measurement of the electron temperature opacity and polarization of a CFL.

A variation of the method calibrating the 2 element interferometer described in memo #26 can be used to measure the opacity and electron temperature of a CFL. First we need to measure the opacity of the CFL. To make this measurement we model the CFL (GE27w) as 8 cylinders 9cm long by 1 cm in diameter. These cylinders are arranged in a circle of 4 cm in diameter. The lamp geometry effects the overall polarization of the lamp which depends on the viewing angle because the microwave radiation is produced when an electron is rapidly decelerated and accelerated when it collides with the glass wall. As a result the source is unpolarized when viewed and "end on" and becomes linearly polarized when viewed from the side. This can be tested using the wire grid polarizer described in memo #32. The direction of linear polarization is with the electric field vector normal to the wall. The total flux, in both polarizations is given by

$1+\cos^2\theta$ (see appendix)

where θ is the angle with respect to the axis of the CFL. The opacity when viewed from the side, can be measured by comparing the fringe amplitude of 2 lamps, placed so that the signal from one lamp has to propagate through the other, with the fringe amplitude of 2 lamps.

In this case

$$T_1 = T_E\left(1-e^{-\tau}\right)$$
$$T_2 = T_E\left(1-e^{-\tau}\right)\left(e^{-\tau}+1\right)$$

where T_E = electron temperature

τ = opacity of a single CFL viewed from the side

T_1 = fringe amplitude with one CFL

T_2 = fringe amplitude with two CFLs

Solving the above we obtain

$$\tau = -\log_e\left(T_2/T_1 - 1\right)$$

The next step is to compare the fringe amplitude of the CFL with an absorber against cold sky. This has to be done against cold sky as an absorber at ambient temperature in a room at ambient temperature will be invisible and produce no fringes. As in memo #26 the angular sizes or the absorber need to be taken into account. In addition, if circularly polarized LNBFs are used the polarization needs to be taken into account as the CFL has to be viewed from the side since we can only measure the opacity from the side.

The single CFL side view opacity is about 0.5 from which we estimate an end view opacity of about 1 or greater so that the end view close to being optically thick. Comparison of a CFL with an absorber to obtain the electron temperature will be made this spring.

Appendix

The radiation field due to the collision of an electron with the wall of the tube is given (from Jackson, "Classical Electrodynamics" eqn 14.18)

$$\vec{E} = (e/c)\left[\frac{\vec{n}\times\left(\vec{n}\times\vec{\dot{\beta}}\right)}{R}\right]$$

where e = electron charge

c = velocity of light

$\vec{n}$ = vector towards the observer

R = distance to the observer

$\vec{\dot{\beta}}$ = normalized acceleration vector

$\vec{E}$ = electric field vector at the observer

In simpler terms this formula says the radiation from the accelerated electrons is equivalent to that from a short dipoles whose elements are oriented normal to the walls of the fluorescent lamp. A short dipole generates linear polarization whose orientation is in the direction of the dipole. i.e. A horizontal dipole produces horizontal polarization. The radiated power is proportional to $\sin^2(\theta)$ where θ is the angle with respect to the axis of the dipole.

If a linear tube of a fluorescent lamp is observed with a circular polarized LNBF in the direction of the tube all the electrons random polarization which is received by the LNBF. In the direction perpendicular to the tube the polarization from each electron is linear normal to the tube but the average power is $\overline{\sin^2(\theta)}$ or ½ the power viewed "end on". The following table summarizes:

LNBF pol	LNBF locations	Power
RCP or LCP	End on	1
RCP or LCP	Perpendicular	0.5
Linear	End on	0.5
Linear parallel to tube	Perpendicular	0
Linear perpendicular	Perpendicular	0.5
Linear any direction	End on	0.5

A more complete analysis.

When a more complete analysis was made it was found that the power from the CFL for the 2 linear polarizations are:

$$P_H = \left[\sin^2\alpha\cos\phi - \sin\beta\sin\alpha\cos\alpha\sin\phi\right]^2$$

$$P_V = \left[\sin^2\alpha\sin\phi\cos\theta + \cos\beta\sin\alpha\cos\alpha\sin\theta - \sin\beta\sin\alpha\cos\alpha\cos\theta\right]^2$$

where $\alpha = \cos^{-1}\left(\sin\phi\sin\theta\right)$

$\beta = \tan^{1}\left(-\cos\phi\tan\theta\right)$

θ = angle between the antenna and the axis of the linear CFL

ϕ = angle of electron acceleration with respect to the horizontal looking along the CFL axis as seen by the antenna at $\theta = 0$

P_H = power in horizontal polarization

P_V = power in vertical polarization

The table given the calculated values of P_V and P_H as a function of θ when averaged over $0 \le \phi < 360$.

θ	P_H	P_V
0	0.50	0.50
10	0.50	0.50
20	0.49	0.50
30	0.48	0.50
40	0.44	0.50
50	0.36	0.50
60	0.25	0.50
70	0.13	0.50
80	0.04	0.50
90	0	0.50