245(8): Photon Mass and Dispersion of Electromagnetic Radiation.

This phenomenon originates in the fact that a photon with mass obeys the Einstein field equation:

$$E^2 = c^2 p^2 + m^2 c^4 \quad -(1)$$

Now use:

$$E = \hbar\omega, \quad p = \hbar\kappa \quad -(2)$$

so

$$\hbar^2\omega^2 = c^2\hbar^2\kappa^2 + m^2c^4 \quad -(3)$$

and

$$\omega^2 = c^2\kappa^2 + \frac{m^2c^4}{\hbar^2} \quad -(4)$$

It follows that:

$$\kappa^2c^2 = \omega^2 - \frac{m^2c^4}{\hbar^2} \quad -(5)$$

and

$$\kappa^2 = \frac{1}{c^2}\left(\omega^2 - \left(\frac{mc^2}{\hbar}\right)^2\right) \quad -(6)$$

so that

$$\frac{\omega^2}{\kappa^2} = \frac{c^2\omega^2}{\omega^2 - (mc/\hbar)^2} \quad -(7)$$

The phase velocity is

$$v_p = \frac{\omega}{\kappa} = c\left(1 - \frac{1}{\omega^2}\left(\frac{mc^2}{\hbar}\right)^2\right)^{-1/2} \quad -(8)$$

$$\sim c\left(1 + \frac{1}{2\omega^2}\left(\frac{mc^2}{\hbar}\right)^2\right)$$

2) The group velocity is:

$$V_g = \frac{d\omega}{dk} = c\left(1 - \left(\frac{mc^2}{\hbar}\right)^2 \cdot \frac{1}{\omega^2}\right)^{1/2}$$

$$\sim c\left(1 - \frac{1}{2\omega^2}\left(\frac{mc^2}{\hbar}\right)^2\right) \quad -(9)$$

If there is a finite photon mass the group velocity will differ from the phase velocity of light.

For two wave packets with different propagating frequencies ω_1 and ω_2 there is a velocity difference:

$$\frac{\Delta v}{c} = \frac{1}{c}\left(V_{g1} - V_{g2}\right) \quad -(10)$$

$$\sim \frac{1}{2}\left(\frac{mc}{\hbar}\right)^2\left(\frac{1}{\omega_2^2} - \frac{1}{\omega_1^2}\right)$$

If these two waves move through the same distance L, the time interval is:

$$\Delta t = L\left(\frac{1}{V_{g1}} - \frac{1}{V_{g2}}\right) \quad -(11)$$

In the history of photon mass physics these results have been used to measure m. However, in the theory of UFT 245 the photon mass is defined through:

$$j^\mu = -\frac{R}{\mu_0} A^\mu \quad -(12)$$

i.e by

$$\rho = -R\epsilon_0 \phi \quad -(13)$$

and

$$\underline{J} = -\frac{R}{\mu_0} \underline{A} \quad -(14)$$

where

$$R = \left(\frac{mc}{\hbar}\right)^2 \quad -(15)$$

If it is assumed that R is positive valued:

$$\left(\frac{mc}{\hbar}\right)^2 = \epsilon_0 \left|\frac{\rho}{\phi}\right| \quad -(16)$$

i.e

$$\boxed{m^2 = \left(\frac{\hbar}{c}\right)^2 \epsilon_0 \left|\frac{\rho}{\phi}\right|} \quad -(17)$$

The experimentally measured dispersion of light is such that m^2 is very small, which means that

$$\rho << \phi \quad -(18)$$

in the vacuum.