SOLITON TRANSMISSION IN INHOMOGENEOUS MEDIA WITH W-TAILORED REFRACTIVE INDEX

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In this paper , a method for soliton transmission in inhomogeneous media with W-tailored refractive index is modeled and parametrically analyzed. Two kinds of inhomogeneities are simultaneously considered : (a) Biquadratic variation of the refractive index (W-tailored radial profile),and (b) Boundary conditions of the cladded fiber.

The achievable bit rate of such important transmission was shown [1] to comfortably match with and could be made an order of magnitude better than that of the best linear transmission.

The refractive index , n , is W-tailored under the biquadratic nonlinear form,

$$n(\rho, \lambda, E) = n(\lambda)\,[1 - \alpha\rho^2 + m\alpha\rho^4] + n_2 |E|^2 \qquad (1)$$

where $\rho = r / R$ and R, λ, E, and n_2 are respectively fiber radius , carrier wavelength , electric field , and nonlinear coefficient of the refractive index. The parameters α and m control both the values of minimum and maximum refractive index and the radial position of the first ρ_{min} where :

$n_{max} = n(\lambda)(1 - \alpha + \alpha m)$, $n_{min} = n(\lambda)(1 - \alpha/4m)$, and $\rho^2_{min} = 1/2\,m$

The wave equation for the electric field, E, is given by [2]

$$\nabla^2 E - \frac{1}{c^2}\frac{\partial^2 \bar{D}_L}{\partial t^2} = \frac{2 n_2 n_0}{c^2}\frac{\partial^2}{\partial t^2}\left(|E|^2 \bar{E}\right) \qquad (2)$$

where the electric field in the fiber E (r,z,t) is given by

$$E(r,z,t) = \mathrm{Re}\,[\varphi(z,t)\, U(\rho)\, \exp[j(qz - w_0 t)]] \qquad (3)$$

where $U(\rho)$ is the solution of the steady state wave equation for the linear inhomogeneous medium ,

$$[\nabla_\perp^2 - P^2 + k_0^2(1 - 2\alpha\rho^2 + 2\alpha m\rho^4)]\, U(\rho) = 0 \qquad (4)$$

where P is the eigenvalue of the propagation constant and

$k = (w + w_o)\, n\,(w + w_o)$, $w = 2\pi c/\lambda$, and $k_o = \lim_{w \to 0} k$

the solution of Eq.(4) is assumed under the series form,

$$U(\rho) = \exp(-\rho^2/2) \sum_{i=0}^{\infty} a_{2i}\rho^{2i} \qquad (5)$$

with $a_0 = 1$. It is found that a_{2i}'s ($i > 1$) are functions of a_2, α, and m where $a_2 = 0.5 + (P^2 - k_0^2) R^2/4$

P_0^2 was calculated through the perturbation theory to the third order [3] under the form .

$$P_0^2 = k_0^2 - 2k_0\sqrt{2\alpha}/R + 2m/R^2 + 4.5m^2/R^3 k_0\sqrt{2\alpha} + 79\, m^3/8\alpha R^2 k_0^2 \qquad (7)$$

The function $\phi(z,t) = \phi(\eta)$ possesses a light solitary solution of the form

$$\phi(\eta) = \phi_o \operatorname{sech}(\eta) \qquad (8)$$

where $$\phi_o^2 = \frac{Vg^{-2} - Q\,(k_o'^2 + k_o k_o'')}{(n_2/n_0)\, k_0^2\, \tau^2\, \delta}$$

with a propagation velocity Vg ,

$$Vg = P_0 / Q\, k_o k_o' \qquad (10)$$

where $\eta = (Vg\tau - Z)/Vg\tau$, τ is the pulse duration, $k_o' k_o''$ are the derivatives of k w.r.t. w, $Q = 1 - \alpha + \frac{3}{5}\alpha m$, and δ is a function of R, α, and m,

$$\delta = \int_0^1 U(\rho)\, d\rho^2 \qquad (11)$$

It is not the same as reported by [2].

The peak power P_0 is given by [1]

$$P_0 = \tfrac{1}{2} Vg\,\epsilon_0 n_0^2\, S\, \phi_o^2$$

where ϵ_0 is the permittivity of free space and S is the cross sectional area of the fiber core .

A sample of the calculations based on this model will be discussed. The variations of the peak power P_o and the group velocity Vg with the parameter α at different values of m and the assumed set of parameters are displayed respectively in Figs.1 and 2. From these figures and the other obtained data, it is found that both P_o and Vg possess exponential correlations with the parameter α. The results clarified in Fig.3, where the radius R appears as a parameter, assert that, at any assumed set of parameters , there is a threshold value α_{th} to achieve a stable soliton transmission where α_{th} increases as the fiber radius increases , Fig. 4.

In conclusion, to design a W-tailored refractive index fiber for stable soliton transmission of high bit rate , minimum power and high group velocity, the parameter α must be of minimum value while the parameter m must be of maximum value .

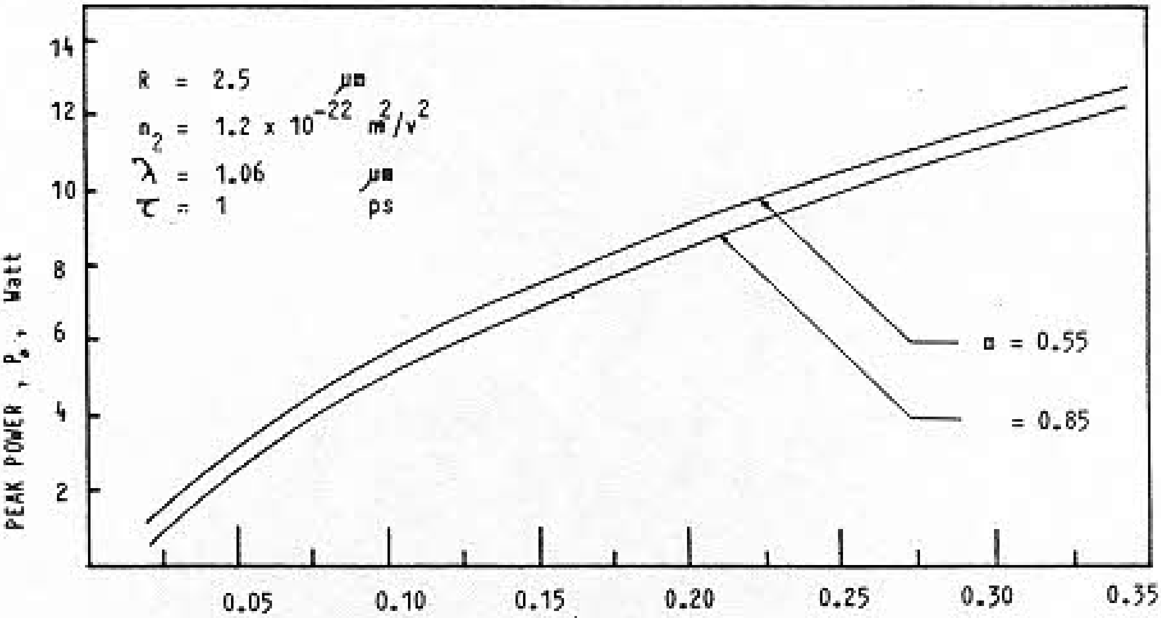

Fig.1. Variation of P_o with α for different values of m and the assumed set of other parameters .

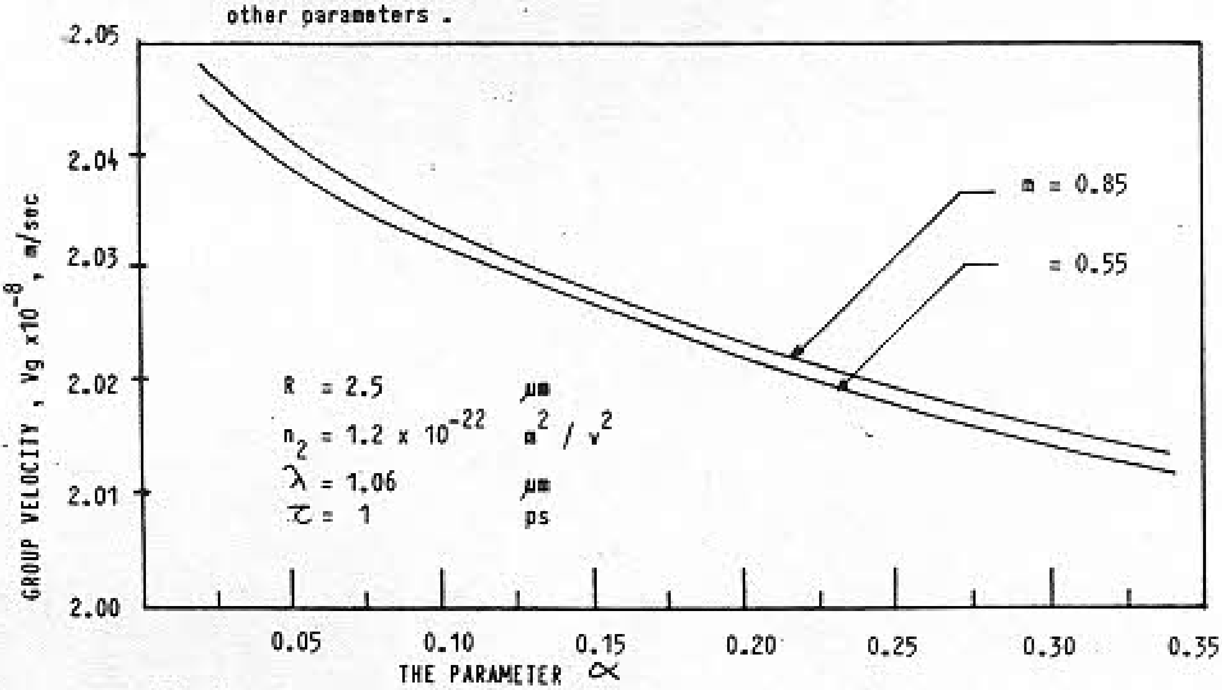

Fig.2. Variation of Vg with α for different values of m and the assumed set of other parameters .

[1] A. Hasegawa and Y. Kodama, Proc. IEEE, Vol. 69,No 9,PP. 1145 - 1150 , Sep. 1981.
[2] M. Jain and N. Tzoar , J. Appl. Phys.,Vol. 49, No.9,PP. 4649 - 4654 , Sep. 1978.
[3] G. Jacobsen and J.J.R. Hansen, Appl. Opt.,Vol.18, No. 16, PP. 2837 - 2842, 15 Aug. 1979 .

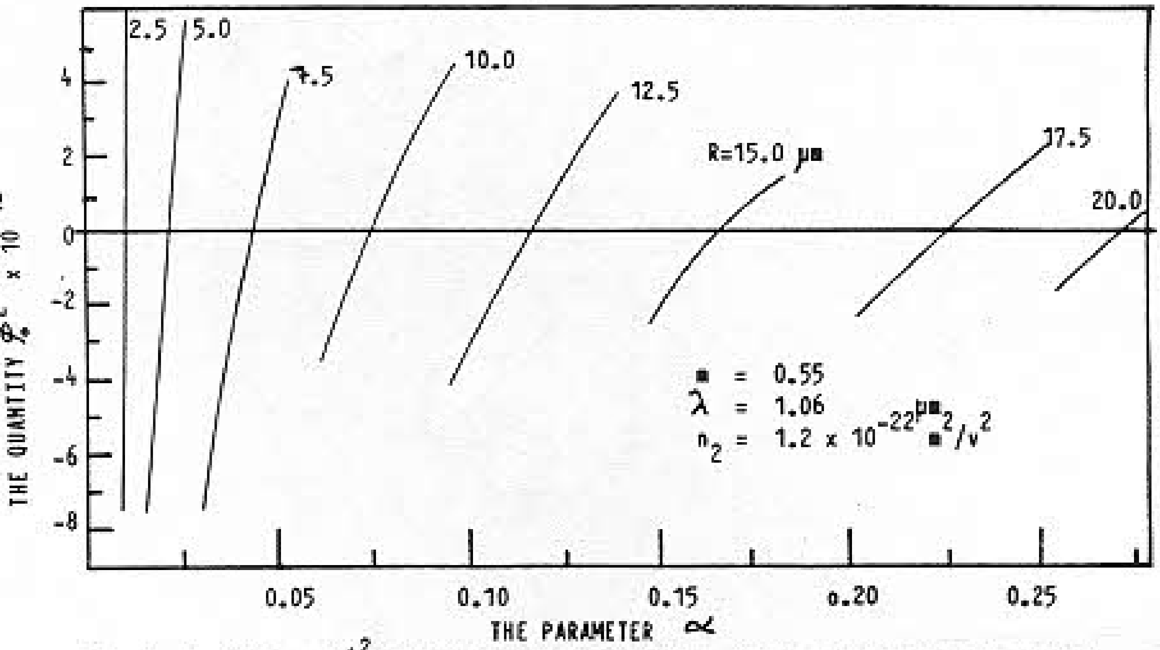

Fig.3. Variation of Φ_o^2 with α for different values of R and the assumed set of other parameters .

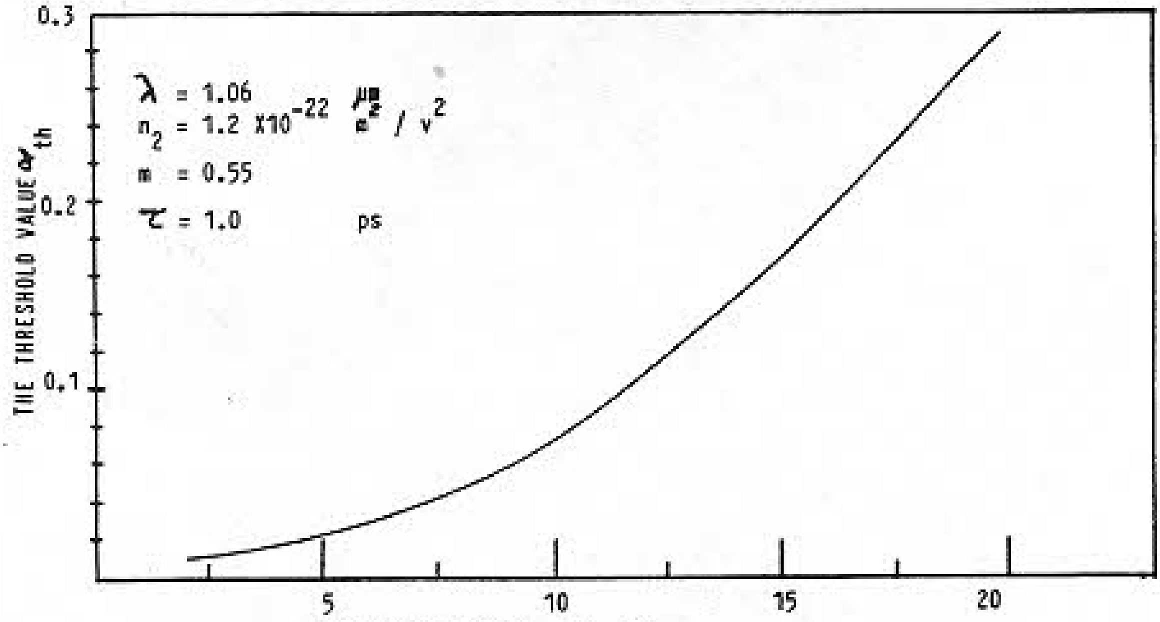

Fig.4. Variation of α_{th} with R at the assumed set of parameters .