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Long Period Fiber Grating (LPFG) and to Study the Effect of Coupling Length on Its Different Modes

Ms. Himani Dua[1], Mr. Puneet Sehgal[2]

Department of Instrumentation, Assistant Professor, Shaheed Rajguru College of Applied Sciences for Women, University of Delhi, India[1]

Department of Electronics, Assistant Professor, A.R.S.D. College, University of Delhi, India[2]

Abstract: As we already know that optical fiber communication is now a days used in the world's communication network. Optical fiber can be used as a medium for telecommunication over long distances and networking of respective signals as it is light weight and can be bundled in the form of cables. Fiber optics is the only technique known today to have the power to meet the strong demands for flexibility and high bandwidth posed by the rapidly growing communication networks. The optical systems were primarily used in point-to-point long distance links [10]. As long period grating (LPG) is an important component of optical fiber communication system, thus, long period grating can be designed in a effective manner to use it as a important tool to sense the refractive index of any medium. In this paper we have studied about in depth concepts of Long period grating (LPG) and coupled mode equations have been solved for long period grating to analyze the grating structures that exhibit attractive optical properties that make them suitable for optical communication system as a wavelength filter. At the end, we have studied the effect of coupling length on exchange of power and its variation between the core mode and different cladding modes at λ =1.55μm for a specific set of parameters defined under the observation for a fiber.

Keywords: Optical Fiber, Communication network, Long Period Grating, Coupled Mode analysis, cladding modes, coupling length.

I. INTRODUCTION

Fiber gratings are often classified as fiber Bragg gratings (FBGs) or long-period gratings (LPGs), according to grating period. LPGs typically have a grating period in the range of from 100 μm to 1 mm, whereas FBGs have a sub-micron period. A long-period fiber grating (LPG), which couples light from a fundamental guided core mode into co-propagating cladding modes at various wavelengths, was first reported by Vengsarkar and co-workers in1996 [1].LPGs have also been used as gain-flattening filters for erbium-doped fiber amplifiers [2], and as optical fiber polarizer's [3].

LPGs have a number of unique advantages such as the fact that simple techniques are required to fabricate them, their compact construction (they are intrinsic fibre devices) and non-conducting (dielectric) structure that is immune to electromagnetic interference (EMI). LPGs have a number of unique advantages such as the fact that simple techniques are required to fabricate them, their compact construction (they are intrinsic fibre devices) and non conducting (dielectric) structure that is immune to electromagnetic interference (EMI) [4]. Long period gratings are periodic photo-induced devices which couple light from core mode to various cladding modes of a single mode fiber. The cladding modes are quickly attenuated and this result in series of loss bands in the transmission spectra of the grating as shown in Fig 1 below. Each of these loss bands corresponds to coupling to distinct cladding modes [5].

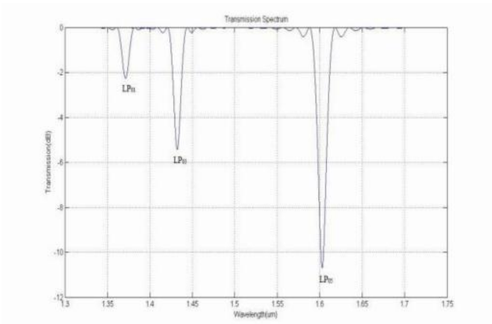

Fig 1: Transmission spectra of long period grating[5]

The phase matching condition between the fundamental mode and the forward propagating cladding mode for the long-period grating (LPG), is given by [6]

$$\lambda_0 = \left(n_{eff}^{co} - n_{eff}^{cl,\mathrm{m}}\right)\Lambda$$

Where λ_{res} *is* the resonance wavelength, n_{co} is the effective refractive index of the core mode and $n_{cl,m}$ is the effective index of the m^{th} cladding mode[9]. Λ is the grating period which is much longer for co propagating coupling at a given wavelength than for the counter propagating coupling [7]. Thus, the rejection wavelengths of LPG are sensitive to such environmental changes [8].

As mentioned earlier a long period fiber grating is formed typically by introducing a periodic refractive index modulation in the core of the optical fiber. LPG couples an incident fundamental core mode (LP_{01}) to forward propagating cladding modes (LP_{0m}) when the phase

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matching conditions are satisfied. The cladding modes are lossy and can be easily attenuated by introducing a bend. Hence, the guided core mode can be phase matched to a co-propagating LP_{02}, LP_{03} cladding modes and many more for a specific grating period. The pictorial description implies that for a given λ_0, depending on the periodicity Λ one can induce mode coupling between the fundamental core mode and several different cladding modes. The table below defines the various parameters for the fiber under our study and defines the grating period and propagation constant for coupling to various cladding modes [9].

Fiber Parameters	Values
Core refractive index (n_1) *Cladding refractive index* (n_2) *Core radius* (a_{co}) Cladding radius (a_{cl})	*1.46* *1.45* *4.1μm* 62.5μm
Grating Parameters	value
Refractive index modulation Δn	0.0001

Table1: Parameters of Optical Fiber under consideration [9] In Table 1, we consider a fiber of parameters n_1 = 1.46, n_2= 1.45, n_3= 1.0 (air), a_{co}= 4.1μm and a_{cl} = 62.5 μm to calculate n_{eff} using both three layer model and two layer model. The effective indices for fiber with refractive index profile and first order perturbation compared with the fiber at λ= 1.55μm is tabulated in below Table 2.

Lp0,m mode	Effective index (n_{eff})	Propagation constant(μm^{-1}) $\beta = 2\Pi n_{eff} / \lambda_0$	Grating period (μm) $\Lambda = \frac{\lambda_0}{\left(n_{eff}^{co} - n_{eff}^{cl,m}\right)}$
0,1	1.445311	5.8550955	
0,2	1.4422254	5.84101287	577.92520
0,3	1.4420450	5.84028225	540.89070
0,4	1.4417421	5.8390555	488.38507
0,5	1.4413200	5.837346	430.18667
0,6	1.4407817	5.8316589	373.40997
0,7	1.4401302	5.83252731	321.92948
0,8	1.4385006	5.82592743	277.1771
0,9	1.4385006	5.82592743	239.16961
0,10	1.4375285	5.82199043	207.2592
0,11	1.436458	5.80765490	180.58145
0,12	1.4352800	5.81288400	158.58145
0,13	1.4340027	5.80771093	139.5413
0,14	1.4326197	5.80210979	123.73955
0,15	1.4311267	5.79606314	110.31837
0,16	1.4295201	5.78955641	98.839032
0,17	1.4277974	5.78257947	88.933480

Table 2: The effective indices for fiber with refractive index profile and first order perturbation compared with the fiber at λ= 1.55μm. Thus , it can be seen that for cladding modes , the propagation constants and modal fields obtained using two layer model significantly differ from that obtained using three layer model.

II. COUPLED MODE THEORY FOR LONG PERIOD FIBER GRATINGS (LPFG)

As discussed earlier LPG is formed by introducing a periodic refractive index modulation in the optical fiber with periodicity of 100μm to 1000μm[11].It is a device based on coupling between the propagating core mode and co-propagating cladding modes. The core cladding mode interactions in a fiber grating can be understood by treating the coupling among the core mode and the multiple cladding modes [11]. The most popular method for studying power exchange between core and cladding modes of a long period grating is the coupled mode theory. Coupled mode theory is essentially a perturbation analysis which assumes that the modal fields of the original fiber remain unchanged in the presence of the small periodic index variations [11]. This approach leads to first order coupled differential equations for the *z*-dependent amplitudes of the coupled core and cladding modes. In most cases, the individual resonances are sufficiently narrow and spectrally well-separated so that coupling between the core mode and a single cladding mode well describes the transmission spectrum in a specified band of wavelengths. For such cases, a simple two-mode coupled mode theory is employed . For cases, where the core mode-cladding mode resonances overlap one another or a large number of resonances fall in the specified spectral band, all the cladding modes which are resonant in the band must be included simultaneously in the coupled mode theory. We first present the simple two-mode coupled mode theory which leads to analytical solutions of the differential equations presented in this Section.

To begin with the coupled mode analysis for a long period grating, we consider an optical fiber with a general refractive index profile $n^2(r)$ in which there is a sinusoidal z-dependent periodic index variation $\Delta n^2(z) = \Delta n^2 \sin Kz$ in the core region. The total field at any value of z can thus be described as

$$\psi = A(z)\,\psi_{co}(r)e^{-i\beta_{co}z} + B(z)\,\psi_{cl}^{m}(r)e^{-i\beta_{cl}^{m}z} \qquad (1)$$

where $\psi_{co}(r)$ and β_{co} represent normalized modal field and propagation constant of the core mode, $\psi_{cl}^{m}(r)$ and β_{cl}^{m} represent normalized modal field and propagation constant of the phase matched cladding mode of the fiber. *A*(z) and *B*(z) are the amplitudes corresponding to core and cladding mode (where *z* is the direction of propagation). Since the modes are orthonormal and normalized for unit power, $|A(z)|^2$ and $|B(z)|^2$ directly give the power in the core mode and cladding mode respectively. In the absence of perturbation, *A* and *B* are constants and equal to their value at *z*=0; the perturbation couples power among the modes as they propagate and hence, *A* and *B* are *z*-dependent. Since $\psi_{co}(r)$ and $\psi_{cl}^{m}(r)$ are the modal fields of the fiber in the absence of any perturbation, they satisfy the following equations

$$\nabla_t^2 \Psi_{co}(r) + \left(k_0^2 n^2 - \beta_{co}^2\right)\psi_{co}(r) = 0 \qquad (2)$$

$$\nabla_t^2 \Psi_{cl}^{m}(r) + \left(k_0^2 n^2 - \beta_{cl}^{m\,2}\right)\psi_{cl}^{m}(r) = 0 \qquad (3)$$

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The total field satisfies the following wave equation

$$\nabla_t^2\psi + \frac{\partial^2\psi}{\partial z^2} + k_0^2\left(n^2 + \Delta n^2(z)\right)\psi = 0 \tag{4}$$

We now substitute the total field ψ from equation (1) into equation (4) and use the slowly varying approximation (i.e. $\lambda\frac{d^2A}{dz^2} << \frac{dA}{dz}$ *and* $\lambda\frac{d^2B}{dz^2} << \frac{dB}{dz}$) to obtain the following equation

$$-2i\beta_{co}e^{-i\beta_{co}z}\frac{dA}{dz}\psi_{co} - 2i\beta_{cl}^{m}\frac{dB}{dz}\psi_{cl}^{m}e^{-i\beta_{cl}^{m}z} + k_0^2\Delta n^2(z)\left[A(z)\psi_{co}e^{-i\beta_{co}z} + B(z)\psi_{cl}^{m}e^{-i\beta_{cl}^{m}z}\right] = 0 \tag{5}$$

where equations (2) and (3) have been used to simplify the expression. Multiplying equation (5) by $\psi_{co}(r)$, integrating over the whole cross-section of the fiber and using the orthonormality condition $\int\psi_{co}\psi_{cl}^{m}\,rdr = 0$ we get the coupled mode equation depicting evolution of modal amplitude of core mode with propagation distance, z, as

$$\frac{dA}{dz} = -i\frac{k_0^2}{2\beta_{co}}A(z)\frac{\int_0^a\psi_{co}\Delta n^2(z)\psi_{co}\,rdr}{\int_0^\infty\psi_{co}\psi_{co}\,rdr} - i\frac{k_0^2}{2\beta_{co}}e^{-i\Delta\beta z}B(z)\frac{\int_0^a\psi_{co}\Delta n^2(z)\psi_{cl}^{m}\,rdr}{\int_0^\infty\psi_{co}\psi_{co}\,rdr} \tag{6}$$

Where, $\Delta\beta = \beta_{co} - \beta_{cl}^{m}$. Similarly, by multiplying $\psi_{cl}^{m}(r)$ and integrating over the whole cross-section of the fiber we get the coupled mode equation depicting evolution of modal amplitude of cladding mode with propagation distance, z, as

$$\frac{dB}{dz} = -i\frac{k_0^2}{2\beta_{cl}^{m}}e^{-i\Delta\beta z}A(z)\frac{\int_0^a\psi_{cl}^{m}\Delta n^2(z)\psi_{co}\,rdr}{\int_0^\infty\psi_{cl}^{m}\psi_{cl}^{m}\,rdr} - i\frac{k_0^2}{2\beta_{cl}^{m}}B(z)\frac{\int_0^a\psi_{cl}^{m}\Delta n^2(z)\psi_{cl}^{m}\,rdr}{\int_0^\infty\psi_{cl}^{m}\psi_{cl}^{m}\,rdr} \tag{7}$$

Equations (6) and (7) can be further simplified by defining of coupling coefficients $\kappa_{11}, \kappa_{12}, \kappa_{21}$ and κ_{22} as

$$\kappa_{11} = \frac{k_0^2}{4\beta_{co}}\frac{\int_0^a\psi_{co}\Delta n^2\psi_{co}\,rdr}{\int_0^\infty\psi_{co}\psi_{co}\,rdr} \qquad \kappa_{12} = \frac{k_0^2}{4\beta_{co}}\frac{\int_0^a\psi_{co}\Delta n^2\psi_{cl}^{m}\,rdr}{\int_0^\infty\psi_{co}\psi_{co}\,rdr} \tag{8}$$

$$\kappa_{21} = \frac{k_0^2}{4\beta_{cl}^{m}}\frac{\int_0^a\psi_{cl}^{m}\Delta n^2\psi_{co}\,rdr}{\int_0^\infty\psi_{cl}^{m}\psi_{cl}^{m}\,rdr} \qquad \kappa_{22} = \frac{k_0^2}{4\beta_{cl}^{m}}\frac{\int_0^a\psi_{cl}^{m*}\Delta n^2\psi_{cl}^{m}\,rdr}{\int_0^\infty\psi_{cl}^{m}\psi_{cl}^{m}\,rdr}$$

With $\Delta n^2(z) = \Delta n^2\sin Kz$. The equations (6) and (7) can now be expressed as

$$\frac{dA}{dz} = -2i\kappa_{11}A(z)\sin(Kz) - 2i\kappa_{12}B(z)e^{i\Delta\beta z}\sin(Kz) \tag{9}$$

$$\frac{dB}{dz} = -2i\kappa_{22}B(z)\sin(Kz) - 2i\kappa_{21}A(z)e^{-i\Delta\beta z}\sin(Kz) \tag{10}$$

In order to understand the physical significance of the self coupling coefficients κ_{11}, κ_{22}, we now define a new setof variables, $a(z) = A(z)e^{-i\beta_{co}z}$ and $b(z) = B(z)e^{-i\beta_{cl}^{m}z}$ and rewrite the coupled mode equations in terms of $a(z)$ and $b(z)$ as

$$\frac{da}{dz} = -i\left(\beta_{co} + 2\kappa_{11}\sin(Kz)\right)a - 2i\kappa_{12}\sin(Kz)b \tag{11}$$

$$\frac{db}{dz} = -i\left(\beta_{cl}^{m} + 2\kappa_{22}\sin(Kz)\right)b - 2i\kappa_{21}\sin(Kz)a \tag{12}$$

As can be seen from equations (11) and (12) $2\kappa_{11}\sin(Kz)$ and $2\kappa_{22}\sin(Kz)$ are the small first order perturbation corrections ($\Delta n \sim 10^{-4}$) to the propagation constants β_{co} and β_{cl}^{m} of the core mode and cladding mode of m^{th} order respectively due to presence of perturbation. Hence, in order to simplify the algebra to obtain analytical solution, κ_{11} and κ_{22} are neglected in comparison to the propagation constants β_{co} and β_{cl}^{m}. Incorporating this and substituting $\sin(Kz) = \frac{1}{2i}\left[\exp(iKz) - \exp(-iKz)\right]$ one can rewrite equations (11) and (12) as

$$\frac{dA}{dz} = -\kappa_{12}B(z)e^{i(\Delta\beta+K)z} + \kappa_{12}B(z)e^{i(\Delta\beta-K)z} \tag{13}$$

$$\frac{dB}{dz} = -\kappa_{21}A(z)e^{-i(\Delta\beta-K)z} + \kappa_{21}A(z)e^{-i(\Delta\beta+K)z} \tag{14}$$

For weak perturbations, κ_{12} and κ_{21} are small and hence, the typical length scale over which the mode amplitudes change appreciably ~ $1/\kappa_{12} \approx 1/\kappa_{21}$, which is large. If we integrate equations (13) and (14) over a short length L, we obtain

$$A\left(z+\frac{L}{2}\right) - A\left(z-\frac{L}{2}\right) = -2i\kappa_{12}Be^{i(\Delta\beta+K)z}\left[\frac{\sin((\Delta\beta+K)L/2)}{(\Delta\beta+K)}\right] + 2i\kappa_{12}Be^{i(\Delta\beta-K)z}\left[\frac{\sin((\Delta\beta-K)L/2)}{(\Delta\beta-K)}\right] \tag{15}$$

$$B\left(z+\frac{L}{2}\right) - B\left(z-\frac{L}{2}\right) = -2i\kappa_{21}Ae^{-i(\Delta\beta+K)z}\left[\frac{\sin((\Delta\beta+K)L/2)}{(\Delta\beta+K)}\right] + 2i\kappa_{21}Ae^{-i(\Delta\beta-K)z}\left[\frac{\sin((\Delta\beta-K)L/2)}{(\Delta\beta-K)}\right]$$

In order to estimate the magnitude of each term in equations (15) and (16), we use the typical values of propagation constants for LP_{01} and LP_{09} modes as given in Table 1.2,

$\Delta\beta = \beta_{co} - \beta_{cl}^{0,9} = 5.8550955 - 5.82592743 = .02916807\,\mu m^{-1}$ at $\lambda_0 = 1.55\,\mu m$. We choose $\Delta\beta$ to satisfy the phase matching condition, i.e., $\Delta\beta = K$ and $L = 53\times10^{-6}$ m leading to

$$\left|\frac{\sin((\Delta\beta-K)L/2)}{(\Delta\beta-K)}\right| \approx \frac{L}{2} = 26.91\times10^{-6}\text{ m}$$

$$\left|\frac{\sin((\Delta\beta+K)L/2)}{(\Delta\beta+K)}\right| \le \frac{1}{(\Delta\beta+K)} \approx \frac{1}{2\Delta\beta} \approx 17\times10^{-6}\text{ m}$$

Thus, for $\Delta\beta \approx K$, the contribution can be

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ignored. The evolution of amplitude of core and cladding modes with z can now be expressed as

$$\frac{dA}{dz} = \kappa_{12} B(z) e^{i(\Delta\beta - K)z} = \kappa_{12} B(z) e^{i\Gamma z} \tag{16}$$

$$\frac{dB}{dz} = -\kappa_{21} A(z) e^{-i(\Delta\beta - K)z} = -\kappa_{21} A(z) e^{-i\Gamma z} \tag{17}$$

where Γ is known as detuning or phase mismatch factor defined as

$$\Gamma = \Delta\beta - \frac{2\pi}{\Lambda} \tag{18}$$

Differentiating equation (23) with respect to z and substituting equation (24), the following second order differential equation is obtained

$$\frac{d^2 A}{dz^2} - i\Gamma \frac{dA}{dz} + \kappa^2 A = 0 \tag{19}$$

Where, $\kappa = \sqrt{\kappa_{12}\kappa_{21}}$.

Using the boundary conditions that $A(z=0)=A_0$ and $B(z=0)=B_0$, we obtain the following analytical solutions for $A(z)$ and $B(z)$

$$A(z) = e^{i\frac{\Gamma z}{2}} \left[A_0 \left(cos(\gamma z) - i \frac{\Gamma}{2\gamma} sin(\gamma z) \right) + B_0 \left(i \frac{\kappa}{\gamma} sin(\gamma z) \right) \right] \tag{20}$$

$$B(z) = e^{-i\frac{\Gamma z}{2}} \left[A_0 \left(i \frac{\kappa}{\gamma} sin(\gamma z) \right) + B_0 \left(cos(\gamma z) + i \frac{\Gamma}{2\gamma} sin(\gamma z) \right) \right] \tag{21}$$

Where $\gamma = \sqrt{\frac{\Gamma^2}{4} + \kappa^2}$. We assume that unit power is initially launched only in the core mode, i.e., $A(z=0)=1$ and $B(z=0)=0$ and the above equations reduce to a following simplified form

$$A(z) = e^{i\frac{\Gamma z}{2}} \left(\cos(\gamma z) - i \frac{\Gamma}{2\gamma} \sin(\gamma z) \right) \tag{22}$$

$$B(z) = e^{-i\frac{\Gamma z}{2}} \left(i \frac{\kappa}{\gamma} sin(\gamma z) \right) \tag{23}$$

The power in the core mode and the cladding mode at any z can now be expressed as

$$P_{co} = A(z)A^*(z) = 1 - \frac{\kappa^2}{\gamma^2} sin^2(\gamma z) \tag{24}$$

$$P_{cl} = B(z)B^*(z) = \frac{\kappa^2}{\gamma^2} sin^2(\gamma z) \tag{25}$$

For phase matched condition, i.e., the detuning factor $\Gamma = 0$, $\gamma = \kappa$ and the power in the core mode and cladding mode can be expressed as

$$\kappa = \frac{k_0}{4} \frac{A_{cl} A_{co} 2 n_1 \Delta n}{\left(\frac{U_{co}}{a_{co}}\right)^2 - \left(\frac{U_{cl}}{a_{cl}}\right)^2} \left(\left(U_{co} J_1(U_{co}) J_0\left(U_{cl} \frac{a_{co}}{a_{cl}} \right) \right) - \left(\frac{U_{cl} a_{co}}{a_{cl}} J_0(U_{co}) J_1\left(U_{cl} \frac{a_{co}}{a_{cl}} \right) \right) \right)$$

$$P_{co} = 1 - \sin^2(\kappa z) \tag{26}$$

$$P_{cl} = sin^2(\kappa z) \tag{27}$$

As can be predicted from the above equations power is continuously exchanged between the core mode and the phase matched cladding mode. Complete power transfer from the core mode to the cladding mode takes place after a propagation distance of $z = \left(\frac{\pi}{2\kappa}\right)$ also referred to as coupling length. Hence coupling length l_c is defined as

$$l_c = \frac{\pi}{2\kappa} \tag{28}$$

III. COUPLING COEFFICIENTS $\kappa_{11}, \kappa_{12}, \kappa_{21}, \kappa_{22}$

It may be noted that $(\kappa = \kappa_{12} = \kappa_{21})$ as defined in equation using the normalization condition equation can be expressed as

$$\kappa_{12} = \kappa_{21} = \frac{k_0}{4} 2 n_1 \Delta n \int_0^a \psi_{cl}^{m} \psi_{co} r\, dr$$

$$\kappa_{11} = \frac{k_0}{4} 2 n_1 \Delta n \int_0^a \psi_{cl}^{m} \psi_{co} r\, dr ,$$

$$\kappa_{22} = \frac{k_0}{4} 2 n_1 \Delta n \int_0^a \psi_{cl}^{m} \psi_{co} r\, dr \tag{29}$$

hence, the coupling coefficient κ is a function of the index change and the modal overlap between the core guided mode and phase matched cladding mode over the region of perturbation. Since the coupling coefficient is directly proportional to the overlap integral, the modal distribution of the cladding mode will have a strong influence on its magnitude. It may be reiterated that the index modulation has no azimuthal variation, the coupling of the symmetric core guided mode can occur only to the symmetric cladding modes (l=0), since, for all other cladding modes, the overlap integral is zero. The coupling coefficient can be expressed analytically as in equation (30) below

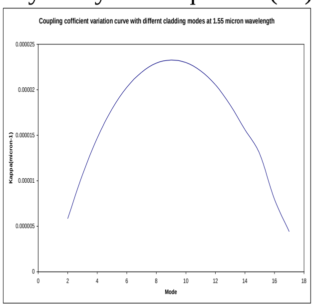

Fig2:Variation of coupling coefficient with cladding mode order for 1.55µm.

IV. COUPLING LENGTH

To signify the role of the coupling length l_c in determining the core mode power P_{co} and cladding mode power P_{cl} , we now plot curves to depict exchange of power between the core mode and the phase matched cladding mode ($\Gamma = 0$) with length of the grating. Fig2 shows the continuous exchange of power is between the core mode and different phase matched cladding mode with length for grating period which corresponds to resonant wavelength of 1.55µm. the full power from the core mode is transferred to the cladding mode. Thus, the power bounces back and forth between the core mode and the cladding mode after a spatial period $z = l_c$. If the length

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is not an integral multiple of coupling length, an incomplete exchange of power between the core mode and the phase matched cladding mode takes place even at resonant wavelength.

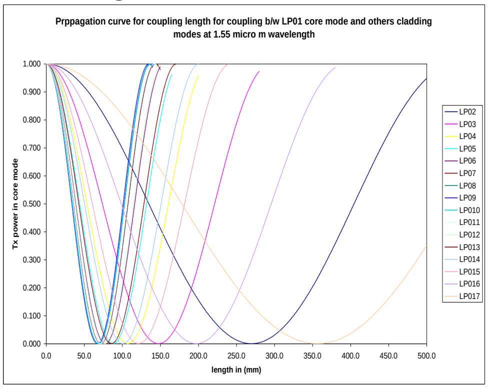

Fig3: Exchange of power and variation in coupling length between the core mode and different cladding mode at λ =1.55um for parameter defined in table1

Lp0,m mode	Grating period $\Lambda = \dfrac{\lambda_0}{\left(n_{eff}^{co} - n_{eff}^{cl,m}\right)}$	Coupling length(l_c) (in µm)	Kapppa(κ) (in µm^{-1})
0,2	577.92520	269500.00	5.83e-6
0,3	540.89070	147500.00	1.06e-5
0,4	488.38507	106950.00	1.47 e-5
0,5	430.18667	87857.00	1.79 e-5
0,6	373.40997	77532.00	2.02 e-5
0,7	321.92948	71694.00	2.19 e-5
0,8	277.1771	68528.00	2.29 e-5
0,9	239.16961	67536.00	2.32 e-5
0,10	207.2592	68300.00	2.3 e-5
0,11	180.58145	71136.00	2.21 e-5
0,12	158.58145	76440.00	2.05 e-5
0,13	139.5413	85653.00	1.83 e-5
0,14	123.73955	100620.00	1.56 e-5
0,15	110.31837	121200.00	1.3 e-5
0,16	98.839032	197064.00	7.97e-6
0,17	88.933480	356000.00	4.41e-6

Table 3: Coupling length and kappa of LPFG for coupling to different cladding modes at 1.55 µm

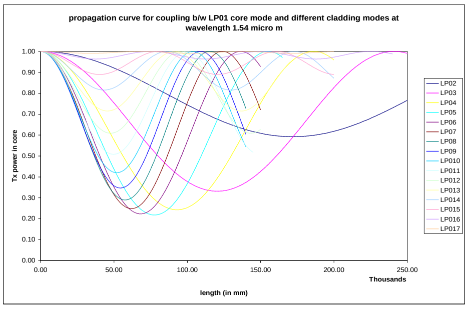

Fig4: Exchange of power and variation in coupling length between the core mode and different cladding mode at λ =1.54µm for parameter defined in table1

Thus, we can plot the propagation curve for coupling length between the LP (01) mode with other cladding modes at wavelength 1.55µm (as shown in Fig 3) and at wavelength 1.54µm (as shown in Fig 4 above) using the set of points tabulated in Table3 above. Hence, we observed that we cannot get complete power exchange from core mode to cladding mode for any length of fiber.

V. RESULT AND CONCLUSION

Thus we have studied the detailed theory of Long fiber grating (LPG) by deriving the coupled mode equations. We have analysed the Variation of coupling coefficient with cladding modes order at the wavelength 1.55µm and also plotted the propagation curve for coupling length between LP(00) mode with other cladding modes at wavelength 1.55µm and 1.54µm repectively. Thus, it can be concluded that we cannot get complete power exchange from core mode to cladding mode for any length of fiber. This analysis of LPG shows that they can be used as gain-flattening filters for erbium-doped fiber amplifiers and optical fiber polarizer's.

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