論 文
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초고속 광통신을 위한 16-Channel AWG 파장다중화기의 설계에 관한 연구

A Study on the Design of 16-Channel AWG Wavelength Division Multiplexer for Super High-Speed Optical Communication

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Abstract - Various methods for analyze optical components which are necessary before the fabrication of optical circuit component and as its applications, designing method of Wavelength Division Multiplexer(WDM) filter using arrayed-waveguide grating(AWG) is paper. In the case of analyzing uniform optical waveguide, effective index method(EIM), harmonic expansion method are used, and in the case of non-uniform optical waveguide, beam propagation method(BPM) are used.

In this paper, to use arrayed-waveguide grating as WDM filter of centered wavelength of 1.55㎛ and wavelength spacing of 0.8㎚, all of the parameter of AWG is calculated by the HEM and the BPM using EIM. As a result of calculation, free spectral range is 12.8㎚, focal length 9336.55㎛, path difference 129.36㎛ and the number of slab waveguide 91 when the distance of core center to center on row land circle is 20㎛.

Key Words : Wavelength Division Multiplexer, arrayed-waveguide grating, beam propagation method, global position system, fiber-to-the-home

1. Introduction

Development of super high-speed, high-capacity anger, transfer communication that demand increases rapidly rawly with miniaturization, satellite communication, global position system(GPS) terminal, light weight anger of wireless communication terminal, miniaturization, 100㎓ danger high-speed element technology that enable multi-function anger of super high-speed Information network system essential that is speak can.

Also, integrate information of various form of voice that is required on information-oriented society, data, reflex etc. and construction of optical bandwidth optical subscriber net based on fiber-to-the-home(FTTH) is essential to transmit. World communication industries are forecasting increase of big-bang transmission speed according to development of internet, multimedia service etc.

Each countries are real condition that is supporting construction of super-highway information network by central government undertaking in dimension of native country competitive power enlargement along with this. Technology of communications that it transmits information of super high-speed high-capacity substantially that become head of a family groundwork in these super high-speed info-communications base environment construction is optical transmission technology, because most of current optical transmission system consist of electron element, is real condition that is not taking advantage of broad sense optical bandwidth and high-speed properly by handling after convert optical signal to electricity signal. Therefore, research about new transmission technology by development and this of optical element that can process optical signal just as it is gone vigorously.

If various kinds transmission speed increase methods to use wide bandwidth of optical fiber enough effectively in this real had been presented and divide greatly this, method that increase the speed of electronic circuit, method that make short pulse optically and this does multiplex, mark division multiplex method, multiplex method to do space quantity, and can speak as multiplex way back to do wave length quantity that transmit through one optical fiber because binding various kinds other conclusion of state examination[1].

To commercialize send-receive device to the speed of 2.5Gbps until present about speed increase of electronic circuit of these, succeeded, and develop by purpose to commercialize send-receive device of 10Gbps worldwide present. After the concept of WDM transmission

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technology comes out first time before several years only, research is gone worldwide and main subject of study and development connected with current optical communication system is focused to if can make fast and noiseless wavelength conversion device with problem of if can make optic amplifier that heighten transmission speed, or can use wavelength channels of how large number in WDM system than increase not relay transmission distance, and have how wide bandwidth simply in single link. Here, have high capacity into expense that is less constructing communication network that take advantage of enough several advantages that physical characteristic of optical signal and WDM mode offer by some method going forward more here, and research and development for optical communication net that compose network that softness is in use also because is unrelated in protocol is gone very fast.

Optical communication net construction technology that do with WDM transmission mode and this is no longer next generation technology and got into technology that embodiment is available in present but there are problems that must solve yet to embody economical and various optical communication network more. That is, enable WDM transmission, and various kinds technologies are required to take advantage of enough the function.

MUX and DEMUX, optical filter that crosstalk is less etc. that gains are high and unite or separate flat optic amplifier, laser that keep correct conclusion of state examination, several wavelength are required by element, and variation technology, single channel breakup compensation technology to do super high-speed more etc. to transmit market place are required.

In this paper, designs 16 channels arrayed-waveguide grating(AWG) multiplex filter that was used by WDM optical element by proportion function unfolding law department 2 dimensions FD-BPM and analyzed optical transmission special quality.

2. Theory of Wavelength Division Multiplexer arrayed waveguide

WDM of fanaticism lake is method necessary to increase transmission capacity of optical signal. Wavelength Division Multiplexer is main element for such system. PLC that compose from luminous intensity welsh onion on board realization and mass productivity and side of miniaturization has better advantage than optical element of bulk form such as grating in manufacture of Wavelength Division multiplexer, lenses. Some PLC multiplexer had been manufactured based on diffraction grating. Diffraction grating is formed in countenance from slab optical waveguide. Optical system is similar with general spectrometer thing, and smallest wavelength space of multiplexer is limited by degree of several ㎚ [2-4].

AWG to foundation a integrated optics N×N Wavelength Division Multiplexer one of main element of WDM optical system be . Multiplexer is consisted of AWG, input/output waveguide, and focus Slab waveguide[5-6].

AWG is linked with two Slab waveguide, and is consisted of waveguide that adjoin and that have a moment of length by good hand's value regularly arranged waveguide. Because moment of this length produces result of wavelength relativity that wavefront tips, intent light depends on frequency to output Slab waveguide. That is, as well as point that arrayed waveguide acts like diffraction grating and arrayed waveguide acts in high diffraction difference has bigger wavelength resolution than 1㎚ in spite of(degree of ㎝) its small whole size, multiplexer holds other arresting prognostication. Because transmission form is grating by arrayed waveguide, have plural input and plural output waveguide. N×N wave length/frequency multiplexer is same with Fig. 1 by arrayed waveguide that have 4 basic function that this refers N×N connection of wavelength selection.

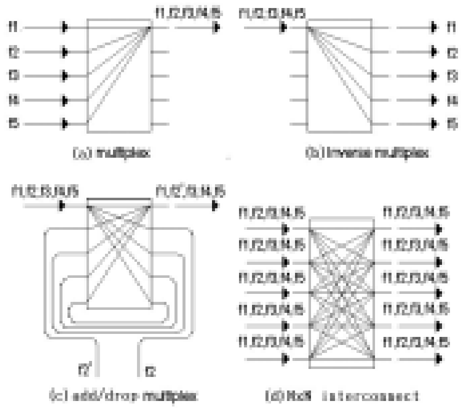


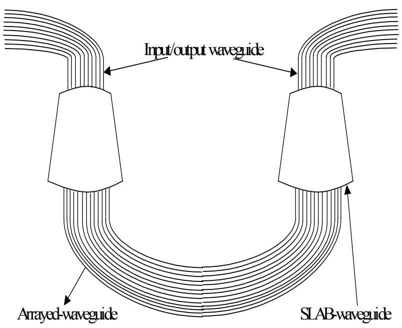
Fig. 1 Functions of N×N arrayed-waveguide grating multiplexer.

Fig. 1 (a) and (b) is simple multiplex and inverse multiplex and function of Fig. 1 (c) displays add/drop multiplex. This function is function that can do multiplex and inverse multiplex at the same time. Wavelength or frequencies more than one is inputed by each loop and drop do can . Last function is N×N full-interconnection with Fig. 1 (d).

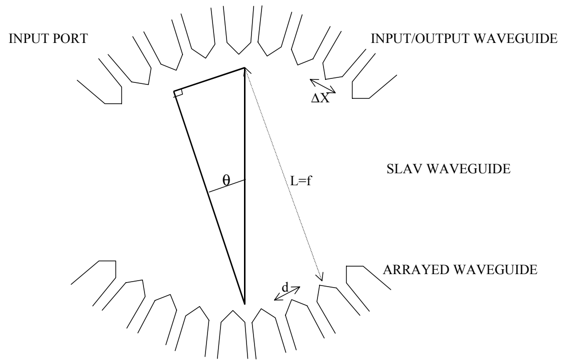
Is linked to left port that multiplex inputed to each left port frequency of done signal according to frequency demarcate and differ. N inverse multiplexer in N×N net, N multiplexer and N^2 fiber that is reported at early alternated by single multiplexer and use of this multiplexer proposed because do Saleh faith[7-8].

Multiplexer can accomplish low insertion loss department if manufacture to silica waveguide. slab optical relativity problem indeed, wavelength transfer between TE and TM-mode can be solved selecting wave plane method. Even if some methods that can remove slab optical relativity say that is, because dismissal method does not mind in level of double refraction by waveguide and can remove perfectly TE-TM transfer, it is the most superior method.

Showed Wavelength Division Multiplexer that is consisted of grating by input/output waveguide, focus Slab waveguide, and arrayed waveguide rough to Fig. 2.



(a) Waveguide layout of arrayed waveguide N×N multiplexer.



(b) Layout of neighborhood by slab waveguide.

Fig. 2 Layout of N×N arrayed-waveguide grating waveguide multiplexer.

Multiplex and inverse multiplex action are same concept except that electric wave direction of light is reverse. Done light input makes off multiplex by one public opinion by input waveguide from fiber. Light is diffracted in slab and is combined with arrangement waveguide. All arrayed waveguides locate for won in end by central input waveguide.

Radius of circle is slab's focal length L_f. Been diffracted light has same status and comes by arrayed waveguide. Arrangement waveguides are detached without that combine each other. By some two waveguide that adjoin length ΔL as difference occurs each light transmit individually by waveguide and reaches with phase difference each other from way out by waveguide . These phenomenon is as result that depend on wavelength that wavefront tips. Focus near output waveguides of light is set by output slab waveguide from grating by arrayed waveguide. Position is basing on Rowland circle structure by method such as general concave lens reflection grating system by input/output waveguide, by slab waveguide, by arrayed waveguide.

Focus position depends on wavelength because of phase shift that depend on wavelength by a path moment by arrayed waveguide. Finally, light by each output waveguide inverse multiplex do. If suppose that can express breakup special quality by handling arrangement waveguide with diffraction grating and input light entered a company by central mouth part waveguide, light which is diffracted by output slab waveguide to do to combine status of light is converged for fixed direction of angle θ that satisfy grating equation of following way (1).

$$n_s d \sin\theta + n_c \Delta L = m\lambda \qquad (1)$$

Here, n_s and n_c is validity refractive index by slab and arrayed waveguide each, and d grating distance, m is diffraction degree by arrayed waveguide and λ is wave length. θ=0 way (1) is thing which this shows that ΔL expresses bigger m value than thing of general diffraction grating. This is one of special quality of grating by arrayed waveguide.

In addition, power of lightθ=0 of near concentrate. Therefore, Focus in low θ value.

Here, define that center wavelength λ_0 satisfies way (2) in θ=0.

$$n_c \Delta L = m\lambda_0 \qquad (2)$$

When compare grating by arrayed waveguide with general diffraction grating, center conclusion of state examination corresponds in blaze conclusion of state examination.

Can appear equally with higher degree grating that have blaze of zero angle by arrayed waveguide. Also, angle breakup must consider angle of diffraction that appear differentiating way (1) at center wavelength neighborhood and truth that it is relation between conclusion of state examination and n_c changes according to wave length.

In this paper, displayed this as waveguide dispersion This waveguide dispersion is result from material by waveguide and chromatic breakup of structural breakup by waveguide and angle dispersion can appear by way (3) under this condition.

$$\frac{d\theta}{d\lambda} = \frac{m}{n_s d} \cdot \frac{n_g}{n_c} \qquad (3)$$

Here,

$$n_g = n_c - \lambda d \frac{n_c}{d\lambda}$$

n_g regards as group index.

High diffraction difference can know that is enough width get big angle breakup that have guided narrow wavelength channel space from way (3). Width narrow grating distance by arrayed waveguide unclaimed. Upside equation and ceremony for general diffraction grating and relationship difference are that $\frac{n_g}{n_c}$ of the former multiplies. This reflects effect of waveguide dispersion in angle dispersion, Usually, n_g is bigger than n_c. The most important parameter of Wavelength Division Multiplexer is netted from angle breakup and focal length L_f as wavelength channel space $\Delta\lambda$ and way of this time is same with way (4).

$$\Delta\lambda = \frac{\Delta x}{L_f}\left(\frac{d\theta}{d\lambda}\right)^{-1} = \frac{\Delta x}{L_f} \cdot \frac{n_s d}{m} \cdot \left(\frac{n_g}{n_c}\right)^{-1} \qquad (4)$$

Here, Δx is space by output waveguide.

Small Δx and d and value are required width narrow wavelength space by way (4) and these thing diffraction and grating to foundation with a multiplexer same .

In the mean time, waveguides should be detached each other because there is no interaction each other. Space is proportional to spot size by waveguide by smallest waveguide. So, high rate refractive index moment overtopping wave that have small spot size has advantage that width offer as rate refractive index moment waveguide daytime to accomplish narrow channel space. Way (5) satisfied order and center wavelength exist much free spectral range(FSR) these wave lengths inter space be . Approximative FSR to have big m cost is same with way (5) from way (2).

$$FSR = \frac{\lambda_0}{m} \cdot \left(\frac{n_g}{n_c}\right)^{-1} \qquad (5)$$

Maximum wavelength channel number m depends on FSR. Multiplex because band width $M\Delta\lambda$ of done light must become more narrow-band frequency modulation than FSR to prevent that is piled up of degree in spectrum extent m with way (6) limit .

$$M < \frac{\lambda_0}{m\Delta\lambda}\left(\frac{n_g}{n_c}\right)^{-1} = \frac{FSR}{\Delta\lambda} \qquad (6)$$

Number of wavelength channel increases from way (6), m should be small. Wavelength Division Multiplexer has layout by symmetry waveguide, and focal length is same by input and output slab waveguide. Therefore, two slab waveguides compose 1:1 image-formation system. Mode field pattern is transmitted by output waveguide without blurring if there is enough spectrum frequency by input waveguide.

This is netted by numerical aperture (NA) uses bigger arrayed waveguide than thing by NA input/output waveguide. That is, it is that should be lived long by enough arrayed waveguide. In this case, because light which focus is set to output slab has same field pattern exactly with field by output waveguide, union that is most before efficiency with output waveguide is netted.

If move is insufficient by waveguide, spot size of light which is set to output slab is big more by output waveguide. Imperfect union of this spot size must be enough arrayed waveguide to increase insertion loss department and receive all light powers that is diffracted by enough NA input slab waveguide because generate crosstalk for next time channel.

3. transmission special quality and design of wavelength division multiplexer AWG 16 channels

Calculated validity refractive index using proportion function Unfolding law by Slab waveguide of Wavelength Division Multiplexer and channel waveguide by 16 channels arrayed waveguide. To input variable does a refractive index moment between core layer and cladding layer so that become 0.75% in wavelength1.55㎛ of freedom space, refractive index 1.455 of core layer, cladding layer and refractive index of shock-absorbing layer calculated because do by 1.444 and did calculation area by with 50㎛ × 50㎛ Fig. 3. Mode index by core thickness could know that amount to multiplex mode in case thickness of core is more than medicine 4.6㎛ from Fig. 3 by Slab waveguide in wave length1.55㎛.

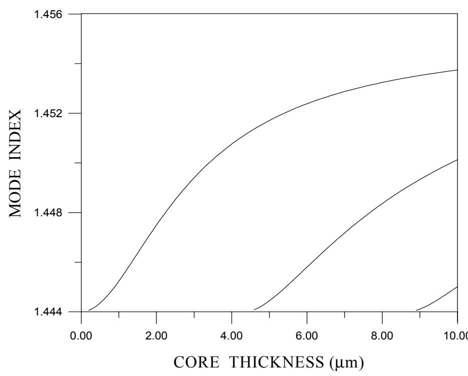


Fig. 3 Mode index with core thickness of slab waveguide.

Also, in case core thickness is 4㎛ in wavelength1.55㎛, mode index by core width could know that is same with Fig. 4 and when is width of core more than about 5.8㎛, amount to multiplex mode by channel waveguide.

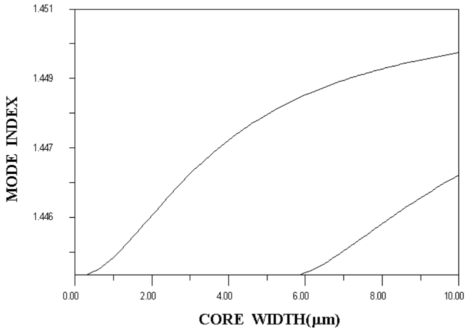


Fig. 4 Mode index with core width of channel waveguide in case core thickness 4㎛.

In case core thickness is 6㎛ in wavelength1.55㎛, mode index by core width could know that is same with Fig. 5 and when is width of core more than about 5.3㎛, amount to multiplex mode by channel waveguide. Did section of core layer of 16 channels AWG Wavelength Division Multiplexer by 4㎛×4㎛ and 6㎛×6㎛, and supposed that cladding layer is protecting infinitely in surroundings.

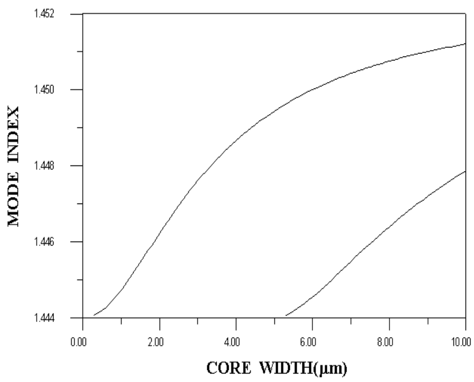


Fig. 5 Mode index with core width of channel waveguide in case core thickness 6㎛.

Calculated Far field by channel waveguide to decide number by arrayed waveguide.

Fig. 6 could know that angle that amount to $1/e^2$ of maximum amplitude as that calculate Far field in broad sense slab waveguide that pass channel waveguide is about 7 ˚.

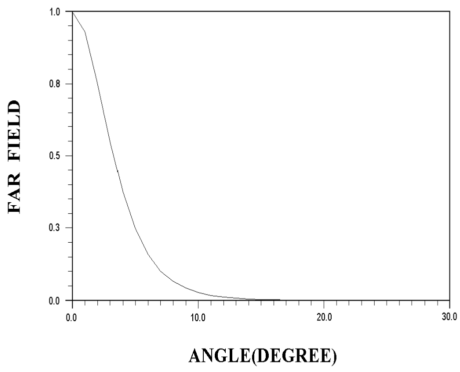


Fig. 6 The far field in slab waveguide of optical through the channel waveguide.

In case section of core layer is 4㎛×4㎛ in center wavelength1.55㎛, come two wave

lengths that is 1.54㎛ to decide group index ng and calculated mode index in 1.55㎛.

Mode index was each 1.447447, 1.447428 by channel waveguide calculation result 1.54 and optical of 1.55㎛ wavelength $\Delta\lambda$ and group index was 1.450365.

In case do wavelength space by 0.8㎚ (frequency interval 100㎓) and did channel improvement of mouth/output by 16, freedom frequency area (Free Spectral Range ; FSR) was 12.8㎚. If yield diffraction degree m hereafter, m are 121. If save Focal length L_f from way (4), it is 5982.73 ㎛. AWG Multiplexer's center wavelength λ_o 1.55㎛ to be imposed nc and ng decide. If yield arrayed waveguides path difference using way (2), it is 129.57㎛. Because appropriate cylinder length unites both hereupon in Rowland circle, it is 1461.87㎛. Number was about 73 by necessary whole channel waveguide because decided by core by arrayed waveguide and center distance 20㎛ between core.

Also, in case section of core layer is 6㎛×6㎛, come two wave lengths that is 1.54㎛ to decide group index ng and calculated mode index in 1.55㎛. Mode index was each 1.44985394, 1.44981286 by channel waveguide calculation result 1.54 and optical of 1.55㎛ wavelength and group index was 1.456187. Because do wavelength space $\Delta\lambda$ by 0.8㎚ (frequency interval 100㎓) and did channel improvement of mouth/output by 16, freedom frequency area was 12.8㎚. If yield diffraction degree m hereafter, m are 121. If save Focal length L_f from way (4), it was 9336.55㎛.

AWG Multiplexer center wavelength λ_o 1.55㎛ to be imposed nc and ng decide .

If yield arrangement waveguides path difference using way (2), it is 129.36㎛.

Because cylinder length in Rowland circle unites both, it was 2281㎛.

Number was about 91 by necessary whole channel waveguide because decided by core by arrayed waveguide and center distance 20㎛ between core. Result of something wrong designed 16 channels AWG Wavelength Division Multiplexer by proportion function Unfolding law, but this method can not confirm existence and nonexistence of whether optical behaves to design along progress direction. Therefore, explain method to analyze AWG Wavelength Division Multiplexer using BPM that is method that showed broad sense conduct visually and presented BPM calculation result. Must divide 16 channels AWG Wavelength Division Multiplexer by 3 steps to do simulation by BPM and achieve.

If suppose that there is input off in sacred ground that it is in Fig. 2 (a) left side slab waveguide and there is output ports in sacred ground that it is right side slab waveguide, optical which is entered a company on center port of input assembles keeping phase difference $k_o n_c \Delta L$ that is fixed to fame waveguide of output ports that arrayed waveguide is linked. Because space between arrangement waveguides center is away enough to is no interference mutually, when optical assembles to output ports Rowland circle, characteristic wood of plain assembles by each channel waveguide. Broad sense fixed status side that is assembled to Rowland circle must consider effect of that this tips because become original intention tangent direction necessarily. Then, is same with electric field way (7) that correct phase difference by a path purpose and tilt of dismissal if it is known that characteristic wood is $E_m^0(z,x)$ by m times channel waveguide .

$$E_m(z,x) = E_m^0(z,x)\exp(-jmk_o n_c \Delta L) \times \exp[-jk_o n_c \sin\theta(x - x_{c,m})] \quad (7)$$

Here, $x_{c,m}$ is x coordinate of center by m times channel waveguide in Rowland circle, and normal of m times dismissal that θ tips is z shaft and angle that achieve.

When correct with way (7) and section of core layer is 6 ㎛×6㎛, 16 channels AWG Wavelength Division Multiplexer by BPM simulation do. In case do to entered a company beam of center wavelength1.55㎛ in input ports of 16 channels AWG Wavelength Division Multiplexer, shape that beam that is transmitted to slab waveguide of input off is thought to optical waveguide that characteristic wood is 91 by simulation result arrayed waveguide by 2 dimensions FD-BPM using calculation result by proportion function Unfolding law that number is 91 by arrayed waveguide is same with Fig. 7 know can.

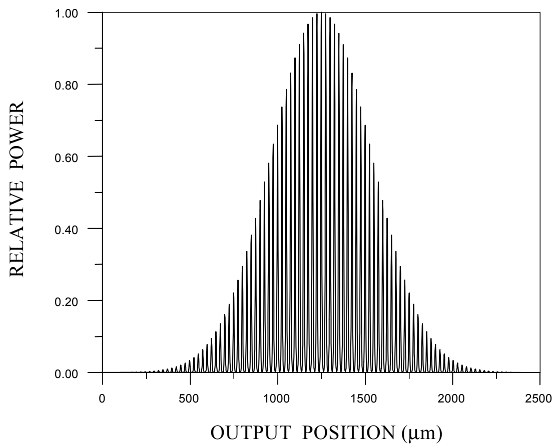


Fig. 7 Diffraction pattern of arrayed waveguide.

Fig. 8 to close of a marketplace at end by output ports fame waveguide with fixed phase difference as beam that is transmitted to slab waveguide of input off passes arrayed waveguides focusing done image appear. Middle dotted line displays center wavelength 1.55㎛ in Fig. 8 and lower part solid line displays incidence optical power of 1.55㎛ band wavelength by output ports channel waveguide.

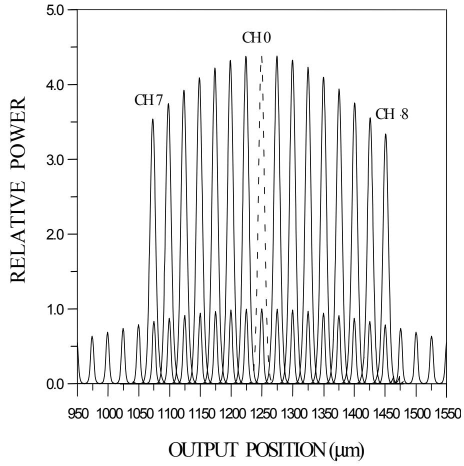


Fig. 8 Connected form to optical wavelength on the slab waveguide of output ports.

Fig. 9 certifies that each variables that save by proportion function unfolding method as that display coupling efficiency with incidence waveguide of original by ㏈ unit after beam passes taper sacred ground by output ports slab waveguide are correct. Can know that it is as each 0.8㎚ between curved lines that CH0 curved line that is painted in solid line of upper direction in Fig. 9 adjoins being center wavelength1.55㎛ difference and smallest coupling loss can know about 35 ㏈ last of the 24 hour periods if define that is their coupling loss difference when energy of wavelength that can know that is about 4 ㏈, and do not want crosstalk in specification output ports enters. 2 dimensions FD-BPM simulation did length of taper by 50㎛ and width did to become wide area 18㎛.

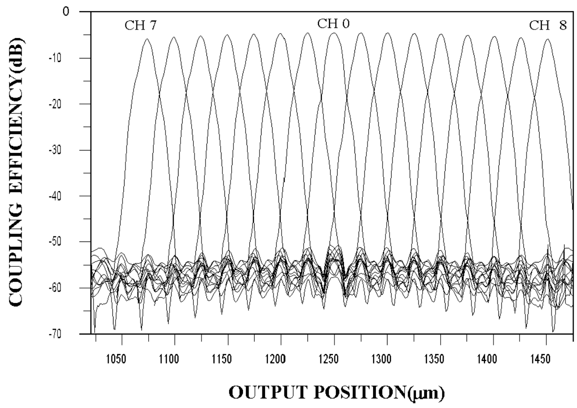


Fig. 9 A coupling efficiency incidence waveguide Original of After pass tapered region on the slab waveguide of output ports.

4. Conclusion

In this paper, result that design 16 channels AWG multiplexer to make use of by WDM element using validity refraction law and proportion function unfolding law that analyze optical waveguide in case of refractive index is fixed about broad sense progress direction from luminous intensity welsh onion and pencil of light electric wave method to analyze optical waveguide when refractive index distribution changes for broad sense progress direction and analyze transmission special quality is as following.

1. When it is when center wavelength of AWG multiplexer is 1.55㎛ and section of core layer is 4㎛, mode index is each 1.447447, and was 1.447428 by result channel waveguide that calculate mode index two wavelength1.54㎛ and 1.55㎛ to decide group index ng, and group index was 1.450366.

2. Can know that $1/e^2$ been angle of maximum amplitude is about 7°as result that calculated Far field by channel waveguide to decide number by arrayed waveguide.

3. It is when center wavelength of AWG multiplexer is 1.55㎛, and a path purpose of when section is 4㎛, focus 5982.73㎛, arrangement waveguides of core layer was 129.57 ㎛, and arrangement waveguides' number was 73.

4. When it is when center wavelength of AWG multiplexer is 1.55㎛ and section of core layer is 6㎛, mode index is each 1.44985394, and was 1.44981286 by result channel waveguide that calculate mode index two wavelength1.54㎛ and 1.55㎛ to decide group index ng, and group index was 1.4561868.

5. When it is when is center wavelength1.55㎛ of AWG multiplexer and section of core layer is 6㎛, focus distance is 9336.55㎛ and arrangement waveguides a path purpose was 129.36㎛, 91 arrangement waveguides numbers, crosstalk was 35 ㏈.

6. Cylinder length of case that because cylinder length unites both in Rowland circle when section of core layer is 4㎛, it is 1,461㎛ and section of core layer is 6㎛ was 2,281 ㎛.

Increase information capacity of super high-speed optical communication system my realization and large quantity productivity and aspect of integraten by calx by result such as abnormality, In case manufacture 16 channels AWG Wavelength Division Multiplexer of wavelength space 0.8㎚ (frequency space 100㎓), MUX and DEMUX that agree several wave or separate, And will can apply, and may contribute greatly in economical quantity direction optical communication net embodiment that utilization efficiency of optical signal is high on WDM/FDM element for super high-speed optical communication such as optical filter that crosstalk is less. And can apply on WDM/FDM element for super high-speed optical communication such as optical filter that crosstalk is less, Is going to contribute greatly in economical quantity direction optical communication net embodiment that utilization efficiency of optical signal is high.

5. Reference

[1] 박영일, “파장다중화 전송기술”, 정보통신 연구 제 11권 11호, 1997. 4

[2] K. Asatani. J. Lightwave Tech. vol. 7., p.1705, 1989.

[3] S. E. Miller. Bell Syst. Tech.. J. vol. 48. p. 2059, 1969.

[4] C. H. Henry, G. E. Blonder and R. E Kazarinov. J. Lightwave Tech. vol. 7., p.1530, 1989.

[5] M. Kawachi, M. Yasu, and T. Edahiro, Elect. Lett. vol. 19, p.583, 1983.

[6] H.Takahashi, Y.Hibino, I. Nishi, " Polarization- insentive arrayed- waveguide grating Wavelength Division Multiplexer on silicon", Optics Letters, vol. 17, No.7, 1992.

[7] C.H. Henry, R. F. Kazarinov, Y. Shani, R.C. Kistler, V.Pol, and K.J. Orlowsky, "Four-channel wavelength division multiplexers and bandpass filters based on elliptical Bragg reflectors," J. Lightwave Tech., vol. 8, pp. 748-755, 1990.

[8] J. B. D. Soole, A. Scherer, H. P. LeBlanc, N. C. Andreadakis, R. Bhat. and M.A.Koza, "Monolithic InP/InGaAsP/InP grating spectrometer for the 1.48-1.56 wavelength range," Appl. Phys. Lett., vol. 58, pp.1949-1951, 1991.

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