

(19) (KR)
(12) (A)

(51) 。 Int. Cl.⁷ (11) 10-2004-0075982
G02B 6/16 (43) 2004 08 30

(21) 10-2004-7012587
(22) 2004 08 13
2004 08 13
(86) PCT/US2003/003843 (87) WO 2003/071325
(86) 2003 02 07 (87) 2003 08 28

(30) 60/357,539 2002 02 15 (US)

(71) (14831)

(72) , , 14830, , 4 가 69
 , , 14845, , 281

(74) :
(54)

, 1550nm 60μm² , 1430nm 2 3 , 1550nm
 4ps/nm - km 10ps/nm - km , 1550nm (0) 0.045ps/nm² - km
 , 1260nm .

(0)

(non-zero dispersion shifted optical fiber; NZDSF)
NZDSF

(wavelength division multiplexing system; WDM system) 1525nm 1565nm
 m C- , 1565nm 1625nm L-
 1550nm 가 , (operation window
) (0) , 4- (four-wave mixing; FWM) - (cro
 ss-phase modulation; XPM) NZDSF
 1550nm
 1550nm 100nm
 (coarse wavelength division multiplexing system; CWDM system)
) WDM 1550nm , , C- L- , S- (1450nm 155nm), 1310nm (12
 80nm 1330nm)
 orning Incorporated) SMF-28 TM 가 , 1310nm (C
 가 , 1310nm
 17ps/nm-km , NZDSF 1550nm
 . NZDSF 1550nm . NZDSF
 1500nm LEAF ? , 1590nm 0.08ps/nm-km
 Submarine LEAF ? , 1650nm 0.1ps/nm-km
 MetroCor TM , 1450nm (Lucent Corporation) Truew
 ave RS TM , NZDSF 1310nm 가 , NZ
 DSF 가 1260nm (cable cutoff wavelength)

1550nm 1550nm 60 μm^2 , 1430nm (0)
 , 1550nm 4ps/nm-km 10ps/nm-km , 1550nm 0.045ps/nm² -
 km 1260nm
 , 1550nm 58 μm^2 , 55 μm^2
 m , 1350nm 1430nm , 1370nm 1410nm
 , 1550nm 5ps/nm-km 9ps/nm-km ,
 6ps/nm-km 8ps/nm-km
 , 1530nm 3ps/nm-km 7ps/nm-km ,
 1530nm 4ps/nm-km 6ps/nm-km
 1550nm 0.042ps/nm² -km , 0.040ps
 /nm² -km , 0.038ps/nm² -km
 1550nm 0.020ps/nm² -km , 1550nm 0.030
 ps/nm² -km
 , 1200nm 1240nm , 1220nm ,
 m 1610nm 1650nm , 1630nm
 500nm , LP01 . 2m 1
 3500nm ,

4000nm .

1310nm
- km , 0ps/nm - km Ops/nm - km , 0ps/nm - km - 7.5ps/nm
1310nm
1310nm Ops/nm - km - 6ps/nm - km
1310nm - 4ps/nm - km - 5ps/nm - km
7.5ps/nm - km .

1550nm
0.22dB/km , 0.21dB/km , 0.23dB/km , 0.20dB/km

1383nm
0.4dB/km 0.6dB/km , 0.5dB/km
1310nm 0.1dB/km , 1383nm
1383nm 1310nm 0.05dB/km
1383nm 1310nm
1310nm
1550nm 0.1ps/km^{1/2}
0.06ps/km^{1/2} , 0.04ps/km^{1/2}
0.03ps/km^{1/2} .

1600nm 25dB/km
15dB/km 1550nm 10dB/km 20dB/km , 15dB/km
10dB/km

1550nm
1.5dB/m 1dB/m .

X , 1,MA
2,MIN 1 %(r) ; 1 ,
3,MAX 2 %(r) ; 1
2 c %(r) 3 %(r) 2 ;
1 2 1

% , 1,MAX 0.4% 0.7% , 1,MAX 0.45% 0.65
1,MAX 0.5% 0.65% .

3μm 6μm , 3μm 5μm

1 6 가 , 2 4 .
-0.05% -0.35% , -0.1% -0.30% , 가
2,NIN
-0.14% -0.25% . 0.55% 0.95%
1,MAX 2,NIN
0.45% 1.05% ,

1 5μm 9μm ,
6μm 8μm , 3.5μm 7.5μm
가 1 4μm 8μm

1 1.5μm 4.5μm , 2μm 4μm

6 μ m , 1 4 μ m 6.5 μ m 가 , 4.5 μ m

3,MAX 0.1% 0.3% , 0.15% 0.3% .
 1,MAX 3,MAX 0.1% 0.6% , 0.15% 0
 .5% , 1,MAX , 1,MAX 3,MAX .

2 1 , 9 μ m 15 μ m
 , 10 μ m 14 μ m .

2 2 μ m 8 μ m , 3 μ m 7 μ m
 8.5 μ m . 2 3 μ m 9 μ m , 3.5 μ m 가
 . 7.5 μ m , 4 μ m 8 μ m , 8 μ m 10 μ m

2 , 2
 3 , 3 4,MIN 2 4 %(r)
 25% 3 , 2,MIN -0.05% -0.3% , -0.1% , -0.

2,MIN 4,MIN . , 2,MIN 4,MIN .
 2,MIN 4,MIN .

3 9 μ m 15 μ m 10 μ m 12 μ m 20 μ m
 . , 3 14 μ m 13 μ m 18 μ m

3 1.5 μ m 7 μ m 가 , 2 μ m 6 μ m

3 11 μ m 18 μ m 가 , 12 μ m
 16 μ m .

2 , 1 , 1 2
 , 2 , r_{c,min} 1 . 0.3 0.2 0.45
 r₁ / r_{c,min} , r_{c,min} 1 0.3 0.65 r₂ / r_{c,min}

2 3
 . 3 .

1, 2 3 0.2 0.3 r₁ / r_{c,min} , 1
 0.35 , 0.55 r₃ / r_{c,min} . r₂ / r_{c,min} 가 , 2 0.7 0.8
 5

1260nm 1650nm 1260nm 1650nm
 . , 131

0nm 1550nm .

1			.
2			.
3			.
4			.
5			.
6		7	.
7		가	.
8			.
9			.
10			.
11			.
12			.
13			.
14			.
15			.
16			.
17			.
18			.
19			.
20			.
21			.
22	21		.
23			.
24	23		.
25	23		.
26			.

27

LP01

28

1550nm

29

30

가

(refractive index profile)'

(relative refractive index percent)'

$$\Delta\% = 100 \times \frac{n_i^2 - n_c^2}{2n_i^2}$$

 n_i

(annular region)

 i

(segment)

(depressed region)

 n_c

(cladding region)

(depressed index)

(downdopant)'

 SiO_2

가

가

가

가

(material dispersion),

(dispersion)'
(waveguide dispersion)
(0)(chromatic dispersion)'
(inter-modal dispersion)

(effective area)'

$$A_{eff} = \frac{2\pi \left(\int_0^r E^2 r dr \right)^2}{\int_0^r E^4 r dr}$$

0, E

(-profile)'

(r)%

$$\Delta(r)\% = \Delta(r_0) \left(1 - \left[\frac{|r - r_0|}{(r_1 - r_0)} \right]^{\alpha} \right)$$

 r_0

(r)%가

 r_1

(r)%가 0

 r_i, r_f r_i

-

 r_f

-

(mode field diameter; MFD)

2 (Peterman method)

$$2w = MFD$$

$$w^2 = \frac{2 \int E^2 r dr}{\int \left[\frac{dE}{dr} \right]^2 r dr}$$

0

(bend resistance)

(lateral load microbend test)

(lateral)

(#70 wire mesh)가

. 70

30N

가가 dB/m

, 70N

가

가

(pin array)

가

가

10

5mm

가

0.67mm

가

(theoretical fiber cutoff wavelength),

(theoretical fiber cutoff)',

(theoretical cutoff)'

(Single Mode Fiber Optics, Jeunhomme, 39page 44p

age, Marcel Dekker, New York, 1990)

가

LP11 LP02

. LP11 LP02

(fiber cutoff wavelength)', '2m

(2m fiber cutoff)'

(measured cutoff)'

EIA-TIA-455-80)

. FOTP-80

2m

FOTP-80(

(cabled cutoff wavelength),

(cabled cutoff)'

FOTP

EIA-TIA

(EIA-TIA Fiber Optics Standard),

(Electronics Industry Alliance-Telecommunications Industry Association Fiber Optics Standard)

EIA-445

(EIA-445 Fiber Optic Test Procedure)

EIA-455-170

'FOPT-170'

(waveguide fiber telecommunications link),

(link)

fier),
er),

(optical attenuator),

(optical isolator),

(optical switch),

(optical ampli
(optical filt

(multiplexing or demultiplexing device)

가

(inter-connected link)

(span)

(physical)' 가 (optical)'
99%

(vapor deposition process)
(outside vapor deposition; OVD)
(laydown), (consolidation) (draw)
(modified chemical vapor deposition; MCV
D) (vapor axial deposition; VAD)
OVD, VAD MCVD

1 (central region)(1 ; 4), (4)
1 (first annular region)(2 ; 6), 1 (6)
2 (second annular region)(3 ; 8), 2 (8)
(outer annular cladding region) (cladding) (clad layer)(14)
(optical waveguide fiber; 2) ()

2 (1 ; 4), (4) 1
(2 ; 6), 1 (6) 2 (3
; 8), 2 (8) 3 (4 ; 10), 3
(10) (14) (3)
()

(14) (silica) (14)
(rod-in-tube)
(primary coating; P) 2 (secondary coa
tion; S) (14) 1

(14)
 $\% (r)=0$

 n_c

가

(half maximum point)

 $1, \text{MAX}$ $1, \text{MAX}$ $1/2$ $\% (r)=0$

3 (34) (36) (32) (30) (30)
(30) 2- (32) (34) (36)
(30) (34) (36)
(regenerator), (dispersion compensation module)

(repeater)

가 , (low water peak),
 , 1383nm 가
 2001 11 27 09/722,804, 200
 0 4 11 28 가 09/547,598, 2000 12 22 가 60/258,179,
 2001 2 28 가 60/275,015 ,
 4 (silica-based reaction product) (soot preform) (soot body)(21) -
 (glass-forming precursor compound) (oxidizing medium) -
 가 (moving fluid mixture)
 (porous silica body)
 OVD (bait rod)
 OVD 4
 4 (mandrel)(31)가 (handle; 33)
 35) (31) (soot-generating burner;
 (37) (31) (37) (31)
 (33) (21)
 가 (31) (31) (21)
 (31) 5 6 (21) (center
 line hole; 40) (21) (downfeed device; 42) (33)
 가 (consolidation furnace; 44) (33) (40)
 가 (44) (21) (bottom plug; 46)
 가 (46) (21) (46)
 (taper) (21)
 e) (21) 가 (44) (chlorine-containing atmospher
 (21) (48) (21)
 OVD (21) 가 (40)
 00 , 가 , 15
 , 1ppb 가 OH (40)
 6 (46) (33) (
 21) (40) (open end; 64) (21) (46)
 (top plug; 60) 5 (33) (cavity)
 (40) (60) (21)
 (40) 가 (44) (60) (46) (40)
 (21) (21) (60) (46) (21)
 (40) (60) (60) (40)
 6 (60) (33) (60) (enlarged porti
 on; 62), (21) (40) (narrow portion; 64)
 , (60) (33) (elongated hollow porti
 on; 66) (66) (40) 가 ,

(40)

(60) (66) (40) 가

31ppm
5ppb

1ppb

0.5mm

200 μ m 2mm 0.2m

(60) 0.3mm 0.4mm

(66)

가

1950 2100 가 (core cane)

(overcladding portion; 82) Ri (core portion; 86) Rj (centerline axis; 28) (inner cladding portion; isometric section)

383nm (water peak) 950nm (overtone optical attenuation)가 OH

(low water peak) 1340nm 1470nm (Raman pump)

(Raman amplifier)

1550nm 1400nm 1500nm mW 1400nm 가

OH 1260nm 1650nm OH 1

383nm

OVD PMD

(polarization mode dispersion; PMD)

60/309,160 2000 4 17 PCT/US00/10303 2001 7 31 가

(An Optical Fiber and a Method for Fabricating a Low Polarization-Mode Dispersion and Low Attenuation Optical Fiber)' 2

000 4 26 09/558,770, (Low Water Peak Optical Waveguide and Method of Manufacturing Same)' 1999 4 26 가 60/1

31,033 (spinning)

PMD

8

(4)

(moat midpoint) R_{2mid}

(moat width) W₂ 가

(ring midpoint) R_{3mid} (ring width) W₂

(8)(ring)); 2 (8)

(14)

1,MAX 가 1,MAX > 3,MAX > 2,MIN , 2%(r)

2,MIN (6)

2%(r)

3,MAX (8)

3%(r)

c%(r)

2%(r)

(4) $R_{1j} (R_{1i}=0) \quad R_{1j} (\% (r) = 0\%)$

(6) $R_{2i} (\% (r) \text{ 가 }) \quad R_{2j} (\% (r) \text{ 가 })$

(8) $R_{3i} (\% (r) \text{ 가 }) \quad R_{3j} (\% (r) = 0\%)$

(half-height peak width) HHPW R_{3hhj} (peak) R_{3hhi}

(14) $R_{4i} (\% (r) \text{ 가 }) \quad R_{4j} (\% (r) = 0\%)$

(profile volume)

$$\int_{r_0}^{r_f} \Delta(r) r dr$$

$r_0 \quad r_f$ 가

(rounding) 가

(central region profile volume) (central region volume)' R_{1i}

(moat profile volume) (moat volume)' R_{2i}

(ring profile volume) (ring volume)' R_{3i}

(gutter profile volume) (gutter volume)' R_{4i}

$\% (r)=0\%$

$\% - \mu m^2$ (slope)' ps/nm² - km ps/nm - km

1 . 1 4 1 5 (1 5)
 , 8 3 1 5 1
 9 2 1 5

[1]

실시예	1	2	3	4	5
$\Delta_{1,MAX}$	0.505	0.504	0.508	0.512	0.519
R_{1j}	3.96	3.96	3.96	3.96	3.96
$R_{1,hh}$	3.4	3.4	3.4	3.4	3.4
$\Delta_{2,MIN}$	-0.45	-0.467	-0.49	-0.595	-0.713
R_{2i}	3.96	3.96	3.96	3.96	3.96
R_{2j}	6	6.05	6.15	5.8	5.6
W_2	2.04	2.09	2.19	1.84	1.64
R_{2mid}	5.0	5.0	5.1	4.9	4.8
$\Delta_{3,MAX}$	0.154	0.19	0.255	0.25	0.262
R_{3i}	6.5	6.5	6.65	6.4	6.65
R_{3j}	13.1	11.85	10.75	9.45	9
R_{3hh}	7.6	7.4	7.4	7.05	6.7
R_{3hhj}	12	11	10	9.35	8.5
R_{3hhmid}	9.8	9.2	8.7	8.2	7.6
R_{4i}	14	12.9	11.3	10.4	9
$HHPW_3$	8	6.9	5.15	4.6	3.4
$\Delta_{4,MIN}$	-0.22	-0.15	-0.09	-0.05	0
R_{4j}	18.3	17.1	15.6	13.7	
W_4	4.3	4.2	4.3	3.3	
R_{4mid}	16.2	15	13.5	12.1	
중심 영역 부피	2.75	2.75	2.77	2.8	2.84
모우트 부피	-4.1	-4.4	-4.91	-4.75	-4.81
링 부피	6.74	6.22	5.92	4.74	3.54
거터 부피	-14.2	-8.97	-4.84	-1.81	0
총 프로파일 부피	-8.8	-4.4	-1.1	1.0	1.6

[2]

실시예	1	2	3	4	5
1310nm에서 분산	-1.2	-1.4	-1.1	-1.2	-1.3
1400nm에서 분산	3.4	3.1	3.3	3.2	3.4
1530nm에서 분산	6.5	6	6.2	6.1	6.45
1550nm에서 분산	6.7	6.2	6.4	6.3	6.4
1625nm에서 분산	6.9	6.4	6.7	6.5	6.8
1550nm에서 기울기	0.0067	0.0067	0.0071	0.0069	0.0073
1400nm에서 기울기	0.039	0.037	0.037	0.037	0.038
λ_0	1313	1316	1310	1314	1308
1550nm에서 A_{eff}	47.1	47.4	47.3	45.9	44.2
1550nm에서 MFD	7.7	7.7	7.65	7.6	7.5
1310nm에서 MFD	6.7	6.7	6.7	6.6	6.5
1550nm에서 편 배열	9.6	11.2	11.4	11.2	11.1
1550nm에서 측면 부하	0.76	0.83	0.85	0.71	0.54
1550nm에서 감쇠	0.206	0.207	0.207	0.210	0.212
LP02 차단	1603	1584	1605	1596	1601
케이블 차단	1203	1184	1205	1196	1201
LP01 차단	2767	2913	3500	4881	5000
1550nm에서 κ	1000	925	901	913	877

6 10

3 6 9 10 11 8 4 6 10 10

[3]

실시예	6	7	8	9	10
$\Delta_{1,MAX}$	0.501	0.502	0.502	0.506	0.513
R_{1j}	3.95	3.95	3.95	3.95	3.95
$R_{1,hh}$	3.4	3.4	3.4	3.4	3.4
$\Delta_{2,MIN}$	-0.35	-0.35	-0.36	-0.42	-0.56
R_{2i}	3.95	3.95	3.95	3.95	3.95
R_{2j}	6	6.25	6.05	5.95	5.5
W_2	2.1	2.3	2.1	2	1.6
R_{2mid}	5.0	5.1	5.0	5.0	4.7
$\Delta_{3,MAX}$	0.15	0.2	0.2	0.2	0.2
R_{3i}	6.55	6.65	6.65	6.4	6.3
R_{3j}	13.05	12.15	11.75	11	9.5
R_{3hhi}	7.6	7.6	7.5	7.2	6.9
R_{3hhj}	12	11.2	10.9	10.2	8.7
R_{3hhmid}	9.8	9.4	9.2	8.7	7.9
R_{4i}	14.3	12.7	12.3	11.7	9.5
$HHPW_3$	8.3	6.45	6.25	5.75	4
$\Delta_{4,MIN}$	-0.22	-0.18	-0.12	-0.12	0
R_{4j}	18.5	16.9	16.5	13.9	
W_4	4.2	4.2	4.2	2.2	
R_{4mid}	16.4	14.8	14.4	12.8	
중심 영역 부피	2.73	2.73	2.73	2.76	2.8
모우트 부피	-3.19	-3.72	-3.61	-3.71	-3.55
링 부피	6.65	6.85	6.25	5.26	3.3
거터 부피	-14.4	-10.62	-6.89	-3.07	0
총 프로파일 부피	-8.21	-4.76	-1.52	1.24	2.55

[4]

실시예	6	7	8	9	10
1310nm에서 분산	-2.4	-2.37	-2.33	-2.26	-2.34
1400nm에서 분산	2.3	2.42	2.27	2.33	2.25
1530nm에서 분산	6	6	5.8	6	6
1550nm에서 분산	6.3	6.28	6.23	6.39	6.38
1625nm에서 분산	7.4	7.5	7.4	7.6	7.5
1550nm에서 기울기	0.016	0.016	0.017	0.017	0.017
1400nm에서 기울기	0.041	0.040	0.040	0.040	0.041
λ_0	1344	1340	1343	1342	1345
1550nm에서 A_{eff}	49.9	49.7	49.8	48.7	47.3
1550nm에서 MFD	8	7.95	7.95	7.86	7.74
1310nm에서 MFD	6.9	6.85	6.85	6.8	6.7
1550nm에서 편 배열	7.9	8.5	9.1	9.6	9.6
1550nm에서 측면 부하	0.71	0.75	0.77	0.67	0.5
1550nm에서 감쇠	0.204	0.204	0.205	0.206	0.209
LP02 차단	1607	1606	1604	1593	1602
케이블 차단	1207	1206	1204	1193	1202
LP01 차단	3050	3123	3744	5000	5000
1550nm에서 κ	394	393	366	376	375

11 15

5 11 15 (11 15)
 11 14 5
 15 5 12 13 6 11 15

[5]

실시예	11	12	13	14	15
$\Delta_{1,MAX}$	0.51	0.51	0.51	0.513	0.519
R_{1j}	3.8	3.83	3.83	3.83	3.8
$R_{1,hh}$	3.25	3.25	3.27	3.27	3.27
$\Delta_{2,MIN}$	-0.212	-0.23	-0.243	-0.263	-0.34
R_{2i}	3.8	3.83	3.83	3.83	3.8
R_{2j}	6.2	6.6	6.75	6.83	6.78
W_2	2.4	2.8	2.9	3	3.0
R_{2mid}	5	5.2	5.3	5.3	5.3
$\Delta_{3,MAX}$	0.135	0.18	0.18	0.18	0.17
R_{3i}	6.8	6.9	6.8	6.65	6.3
R_{3j}	13.15	12.25	11.95	11.55	10
R_{3hhi}	7.1	7.6	7.4	7.3	6.9
R_{3hhj}	12.8	11.6	11.2	10.8	9.3
R_{3hhmid}	9.9	9.6	9.3	9	8.1
R_{4i}	13.2	12.4	12	11.7	10.2
HHPW ₃	7	5.8	5.25	4.9	3.4
$\Delta_{4,MIN}$	-0.22	-0.21	-0.16	-0.16	0
R_{4j}	16.6	15.6	15.2	14.1	
W_4	3.4	3.2	3.2	2.4	
R_{4mid}	14.9	14	13.6	12.9	
중심 영역 부피	2.49	2.53	2.54	2.55	2.57
모우트 부피	-2.81	-3	-3.06	-3.03	-2.89
링 부피	7.1	6.75	6.23	5.54	3.29
거터 부피	-7.83	-6.9	-4.87	-2.48	0
총 프로파일 부피	-1.05	-0.62	0.84	2.52	2.97

[6]

실시예	11	12	13	14	15
1310nm에서 분산	-3.7	-3.5	-3.4	-3.5	-3.5
1400nm에서 분산	1.25	1.44	1.4	1.43	1.41
1530nm에서 분산	5.7	5.8	5.8	5.8	5.9
1550nm에서 분산	6.2	6.3	6.3	6.3	6.4
1625nm에서 분산	7.9	8.1	8	8.1	8.1
1550nm에서 기울기	0.0243	0.0243	0.0244	0.0244	0.0247
1400nm에서 기울기	0.045	0.044	0.044	0.044	0.045
λ_0	1372	1367	1368	1368	1369
1550nm에서 A_{eff}	51.1	51	50.8	50.2	48.8
1550nm에서 MFD	8.15	8.1	8.1	8.05	7.95
1310nm에서 MFD	7	6.95	6.95	6.9	6.8
1550nm에서 편 배열	10.2	9.7	10	9.9	10
1550nm에서 측면 부하	0.83	0.81	0.79	0.71	0.51
1550nm에서 감쇠	0.201	0.202	0.202	0.202	0.204
LP02 차단	1596	1602	1596	1601	1598
케이블 차단	1196	1202	1196	1201	1198
LP01 차단	4116	4217	4960	5000	5000
1550nm에서 κ	255	259	258	258	259

16 20

7 16 20 (16 20)
 16 19 7
 , 14 18
 20 7 15 8 16 20

[7]

실시예	16	17	18	19	20
$\Delta_{1,MAX}$	0.518	0.518	0.52	0.522	0.526
R_{4j}	3.88	3.88	3.88	3.88	3.88
$R_{4,hh}$	3.18	3.18	3.18	3.18	3.18
$\Delta_{2,MIN}$	-0.18	-0.185	-0.199	-0.22	-0.26
R_{2i}	3.88	3.88	3.88	3.88	3.88
R_{2j}	7.26	7.14	6.98	6.73	6.43
W_2	3.38	3.26	3.1	2.85	2.55
R_{2mid}	5.57	5.51	5.43	5.305	5.155
$\Delta_{3,MAX}$	0.22	0.213	0.22	0.21	0.203
R_{3i}	7.3	7.15	7.05	6.85	6.5
R_{3j}	11.8	11.7	11.4	10.75	9.75
R_{3hh}	7.76	7.75	7.73	7.61	7.08
R_{3hhj}	11.42	11.03	10.66	10.03	9.11
R_{3hhmid}	9.6	9.4	9.2	8.8	8.1
R_{4i}	11.8	11.7	11.4	10.85	10.1
HHPW ₃	4.5	4.6	4.4	4.1	3.7
$\Delta_{4,MIN}$	-0.22	-0.16	-0.22	-0.1	0
R_{4j}	15	15	13.7	12.9	
W_4	3.2	3.3	2.3	2.1	
R_{4mid}	13.4	13.4	12.6	11.9	
중심 영역 부피	2.48	2.47	2.48	2.49	2.51
모우트 부피	-2.92	-2.78	-2.7	-2.51	-2.54
링 부피	7.27	6.41	5.86	4.57	3.35
거터 부피	-7.37	-5.43	-3.79	-1.64	0
총 프로파일 부피	-0.54	0.67	1.85	2.91	3.32

[8]

실시예	16	17	18	19	20
1310nm에서 분산	-4.2	-4.2	-4.24	-4.27	-4.33
1400nm에서 분산	0.83	0.83	0.81	0.81	0.72
1530nm에서 분산	5.7	5.7	5.7	5.8	5.7
1550nm에서 분산	6.3	6.3	6.3	6.4	6.3
1625nm에서 분산	8.6	8.5	8.6	8.6	8.4
1550nm에서 기울기	0.030	0.030	0.030	0.030	0.030
1400nm에서 기울기	0.047	0.047	0.047	0.047	0.047
λ_0	1382	1382	1383	1383	1385
1550nm에서 A_{eff}	52.9	52.7	52.3	51.6	50.8
1550nm에서 MFD	8.3	8.3	8.25	8.2	8.14
1310nm에서 MFD	7.1	7.05	7	7	6.9
1550nm에서 편 배열	10.1	10.4	10.5	10.3	10.2
1550nm에서 측면 부하	0.93	0.89	0.84	0.7	0.6
1550nm에서 감쇠	0.2003	0.2003	0.2007	0.201	0.202
LP02 차단	1609	1602	1605	1604	1598
케이블 차단	1209	1202	1205	1204	1198
LP01 차단	4308	5000	5000	5000	5000
1550nm에서 κ	210	210	210	213	210

21 25

9 21 25 (21 25)
 21 25 , 16 24 10
 21 25

[9]

실시예	21	22	23	24	25
$\Delta_{1,MAX}$	0.53	0.53	0.53	0.51	0.53
R_{1j}	4	4	4	3.9	3.65
$R_{1,hh}$	3.1	3.1	3.1	3.15	3.1
$\Delta_{2,MIN}$	-0.17	-0.16	-0.155	-0.16	-0.2
R_{2i}	4	4	4	3.9	3.65
R_{2j}	7.2	7.2	7.2	7.4	6.6
W_2	3.2	3.2	3.2	3.5	3.0
R_{2mid}	5.6	5.6	5.6	5.7	5.1
$\Delta_{3,MAX}$	0.215	0.2	0.19	0.2	0.25
R_{3i}	7.25	7.25	7.25	7.4	6.6
R_{3j}	11.8	11.85	11.9	11.9	10.6
R_{3hh}	7.65	7.65	7.65	7.7	7.05
R_{3hhj}	11.35	11.35	11.35	11.3	10
R_{3hhmid}	9.5	9.5	9.5	8.8	8.5
R_{4i}	11.8	11.9	11.9	12	10.7
$HHPW_3$	4.6	4.7	4.7	4.6	4.1
$\Delta_{4,MIN}$	-0.21	-0.12	-0.085	-0.17	-0.2
R_{4j}	15.3	16.4	17.7	16.5	14.55
W_4	3.5	4.5	5.8	4.5	
R_{4mid}	13.6	14.2	14.8	14.3	
중심 영역 부피	2.49	2.49	2.49	2.41	2.56
모우트 부피	-2.67	-2.51	-2.43	-2.48	-2.24
링 부피	7.13	6.66	6.34	6.53	5.96
거터 부피	-7.05	-6.36	-6.3	-6.07	-8.59
총 프로파일 부피	-0.1	0.3	0.1	0.4	-2.3

[10]

실시예	21	22	23	24	25
1310nm에서 분산	-4.7	-4.7	-4.7	-4.7	-5.6
1400nm에서 분산	0.4	0.5	0.6	0.5	0.1
1530nm에서 분산	5.6	5.7	5.9	5.7	4.2
1550nm에서 분산	6.3	6.4	6.6	6.4	4.9
1625nm에서 분산	8.9	8.9	9.1	9	7.8
1550nm에서 기울기	0.034	0.034	0.034	0.034	0.037
1400nm에서 기울기	0.048	0.049	0.050	0.049	0.045
λ_0	1391	1390	1388	1390	1399
1550nm에서 A_{eff}	53.7	53.8	53.7	53.8	51.2
1550nm에서 MFD	8.4	8.4	8.4	8.4	8.2
1310nm에서 MFD	7.1	7.1	7.1	7.1	6.9
1550nm에서 편 배열	9.2	8.8	8.6	9.2	2.9
1550nm에서 측면 부하	0.87	0.85	0.81	0.83	0.28
1550nm에서 감쇠	0.199	0.199	0.199	0.199	0.204
LP02 차단	1605	1609	1602	1595	1496
케이블 차단	1205	1209	1202	1195	1096
LP01 차단	4660	4991	4917	5000	3574
1550nm에서 κ	185	188	194	188	132

26 31

11

26

26
31

31

(26

31)

11

30

17

[11]

실시예	26	27	28	29	30	31
$\Delta_{1,MAX}$	0.53	0.54	0.55	0.53	0.53	0.53
R_{1j}	4	3.9	3.9	4	4	4
$R_{1,hh}$	3.3	3.1	3.1	3.1	3.1	3.1
$\Delta_{2,MIN}$	-0.17	-0.16	-0.157	-0.174	-0.185	-0.2
R_{2i}	4	3.9	3.9	4	4	4
R_{2j}	7	7.1	7	7.1	7	6.8
W_2	3	3.2	3.1	3.1	3	2.8
R_{2mid}	5.5	5.5	5.45	5.55	5.5	5.4
$\Delta_{3,MAX}$	0.21	0.215	0.205	0.212	0.213	0.206
R_{3i}	7.15	7.2	7.15	7.15	7	6.85
R_{3j}	11.7	11.2	10.75	11.75	11.35	10.95
R_{3hh}	7.9	7.8	7.8	7.8	7.55	7.45
R_{3hhj}	11.05	10.6	10.2	11.2	10.7	10.35
R_{3hhmid}	9.5	9.2	9	9.5	9.1	8.9
R_{4i}	11.8	11.25	10.85	11.8	11.4	11
HHPW ₃	4.8	4.2	3.82	4.7	4.4	4.2
$\Delta_{4,MIN}$	-0.145	-0.095	-0.05	-0.21	-0.21	-0.21
R_{4j}	15.1	14.6	14	14.6	13.7	12.9
W_4	3.3	3.4	3.2	2.8	2.3	1.9
R_{4mid}	13.5	12.9	12.4	13.2	12.6	12.0
중심 영역 부피	2.48	2.45	2.41	2.48	2.49	2.49
모우트 부피	-2.3	-2.34	-2.18	-2.45	-2.47	-2.43
링 부피	6.1	5.36	4.37	6.59	5.91	5.25
거터 부피	-4.92	-3.1	-1.55	-5.61	-3.84	-2.4
총 프로파일 부피	1.4	2.4	3.1	1.0	2.1	2.9

[12]

실시예	26	27	28	29	30	31
1310nm에서 분산	-4.7	-4.9	-5.1	-4.8	-4.8	-4.8
1400nm에서 분산	0.52	0.39	0.39	0.42	0.4	0.42
1530nm에서 분산	5.8	5.7	5.9	5.6	5.7	5.7
1550nm에서 분산	6.5	6.4	6.4	6.3	6.4	6.4
1625nm에서 분산	9	8.9	9.1	8.9	8.9	8.9
1550nm에서 기울기	0.034	0.034	0.034	0.034	0.034	0.034
1400nm에서 기울기	0.049	0.05	0.051	0.049	0.049	0.049
λ_0	1389	1392	1392	1391	1392	1391
1550nm에서 A_{eff}	53.5	52.4	51.3	53.6	53.3	52.8
1550nm에서 MFD	8.4	8.3	8.2	8.4	8.4	8.3
1310nm에서 MFD	7.1	7.05	7	7.1	7.1	7.1
1550nm에서 편 배열	9.3	9.1	9.3	9.4	9.3	9.5
1550nm에서 측면 부하	0.82	0.72	0.56	0.85	0.78	0.73
1550nm에서 감쇠	0.199	0.199	0.199	0.199	0.199	0.2
LP02 차단	1604	1602	1578	1606	1599	1605
케이블 차단	1204	1202	1178	1206	1199	1205
LP01 차단	5000	5000	5000	5000	5000	5000
1550nm에서 κ	191	188	188	185	188	188

13 32 36 (32 36)
 , 18 32 33 13 34 35
 13 , 19 35
 36 13
 , 20 14 32
 36

[13]

실시예	32	33	34	35	36
$\Delta_{1,MAX}$	0.535	0.55	0.53	0.53	0.535
R_{1j}	4	4	3.95	3.95	4
$R_{1,hh}$	3.1	3.05	3.1	3.1	3.1
$\Delta_{2,MIN}$	-0.26	-0.203	-0.167	-0.19	-0.176
R_{2i}	4	4	3.95	3.95	4
R_{2j}	6.4	6.6	7	6.8	6.95
W_2	2.4	2.6	3.1	2.9	3.0
R_{2mid}	5.2	5.3	5.5	5.4	5.5
$\Delta_{3,MAX}$	0.222	0.2	0.234	0.294	0.214
R_{3i}	6.55	6.7	7.75	8.55	7.05
R_{3j}	9.65	9.85	11.85	11.8	11.2
R_{3hhi}	7.2	7.25	8.6	9.2	7.8
R_{3hhj}	9	9.25	11.2	11.2	10.4
R_{3hhmid}	8.1	8.25	9.9	10.2	9.1
R_{4i}	10	10.2	11.9	11.9	12.5
$HHPW_s$	3.6	3.6	4.9	5.1	5.55
$\Delta_{4,MIN}$	0	0	-0.19	-0.19	-0.19
R_{4j}			15	15	15
W_4			3.1	3.1	2.5
R_{4mid}			13.5	13.5	13.8
중심 영역 부피	2.52	2.47	2.46	2.47	2.49
모우트 부피	-2.28	-2.29	-1.95	-1.65	-2.25
링 부피	3.35	3.3	6.13	5.87	5.18
거터 부피	0	0	-5.77	-5.79	-3.41
총 프로파일 부피	3.6	3.5	0.9	0.9	2.0

[14]

실시예	32	33	34	35	36
1310nm에서 분산	-4.8	-4.9	-4.9	-4.9	-4.9
1400nm에서 분산	0.34	0.27	0.37	0.41	0.36
1530nm에서 분산	5.6	5.6	5.6	5.7	5.6
1550nm에서 분산	6.3	6.4	6.3	6.4	6.3
1625nm에서 분산	8.8	8.8	8.8	9	8.8
1550nm에서 기울기	0.034	0.033	0.034	0.034	0.034
1400nm에서 기울기	0.049	0.05	0.049	0.05	0.049
λ_0	1393	1395	1392	1392	1393
1550nm에서 A_{eff}	52.3	51	53.3	52.7	53.5
1550nm에서 MFD	8.3	8.2	8.4	8.3	8.4
1310nm에서 MFD	7	7	7.1	7.1	7.1
1550nm에서 편 배열	9.7	9.6	10	9.6	8.9
1550nm에서 측면 부하	0.62	0.55	0.87	0.81	0.79
1550nm에서 감쇠	0.201	0.2	0.199	0.199	0.199
LP02 차단	1600	1600	1601	1600	1604
케이블 차단	1200	1200	1201	1200	1204
LP01 차단	5000	5000	5000	5000	5000
1550nm에서 κ	185	194	185	188	185

37

15 37 (37) 37
 15 21
 가 21 16 22 21 ,
 ,

38

15 38 (38) 38
 15 23
 23 OVD 23
 16 24 23
 . 25 23
 OVD, PCVD, IVD, VAD MCVD ,

39

15 39 (39) 39
 15 26

[15]

실시예	37	38	39
$\Delta_{1,MAX}$	0.52	0.61	0.54
R_{1j}	3.9	4.25	4
$R_{1,hh}$	3.2	2.8	3.1
$\Delta_{2,MIN}$	-0.2	-0.2	-0.13
R_{2i}	3.9	4.25	4
R_{2j}	6	6.5	6.85
W_2	2.1	2.3	2.9
R_{2mid}	5.0	5.4	5.4
$\Delta_{3,MAX}$	0.18	0.15	0.175
R_{3i}			
R_{3j}			
$R_{3hh,i}$	7.5	7.5	8.25
$R_{3hh,j}$	9.7	9.5	11.75
$R_{3hh,mid}$	8.6	8.5	10
R_{4i}	10.3	10.1	13.85
$HHPW_3$	4.3	3.6	7
$\Delta_{4,MIN}$	0	0	-0.1
R_{4j}			18.5
W_4			4.7
R_{4mid}			16.1
중심 영역 부피	2.57	2.52	2.51
모우트 부피	-1.43	-1.79	-1.95
링 부피	3.47	2.65	6.44
거터 부피	0	0	-6.38
총 프로파일 부피	4.61	3.38	0.62

[16]

실시예	37	38	39
1310nm에서 분산		-6.8	-5.0
1550nm에서 분산	6.4	6.6	6.1
1565nm에서 분산			6.6
1625nm에서 분산			8.4
1550nm에서 기울기	0.038	0.045	0.032
1600nm에서 기울기			0.031
λ_0	<1420		
1550nm에서 A_{eff}			53.8
1310nm에서 감쇠		0.369	
1380nm에서 감쇠		0.570	
1550nm에서 감쇠		0.228	0.199
1550nm에서 MFD	7.8	8.5	8.4
1310nm에서 MFD		7.1	
1550nm에서 편 배열	1.8		7.4
1550nm에서 측면 부하 굽힘 손실(dB/m)			0.95
1550nm에서 측면 부하 굽힘 손실(dB/m)			1.85
LP11 차단	1216		
2m 측정 차단			1400
케이블 차단		1050	1250
1550nm에서 κ	170	147	190

e) , (fundamental mode)' LP01 (bend edge / 가 가
L - 1625nm

[illegible]

The diagram illustrates a network topology with nodes and links. The nodes are labeled with their data rates: 1Gbit/s, 10Gbit/s, 2Gbit/s, 40Gbit/s, and 40Gbit/s. The links are labeled with their data rates: 1Gbit/s, 10Gbit/s, 2Gbit/s, 40Gbit/s, and 40Gbit/s. The diagram shows a network structure where data flows from a source node to a destination node through various intermediate nodes and links.

(57)

1550nm	$60\mu\text{m}^{-2}$;
1430nm	(0)	;
1550nm	$4\text{ps/nm} \cdot \text{km}$	$10\text{ps/nm} \cdot \text{km}$;
1550nm	$0.045\text{ps/nm}^{-2} \cdot \text{km}$;
1260nm		;

1. 1550nm $58\mu\text{m}^2$

1 **3.** ,
1600nm 25dB/km .

1 4. , 1550nm 50μm² 55μm² .

1 5. , 1550nm 0.042ps/nm² -km .

1 6. ,
1550nm 0.038ps/nm² -km .

7.

1550nm 0.045ps/nm² - km 0.020ps/nm² - km

8.

1 ,

1220nm .

9.

1 ,

1383nm 가 0.6dB/km .

10.

1 ,

1383nm 가 0.5dB/km .

11.

1 ,

1383nm 가 0.4dB/km .

12.

1 ,

1550nm 0.06ps/km^{1/2} .

13.

1 ,

1550nm 0.04ps/km^{1/2} .

14.

1 ,

1550nm 0.03ps/km^{1/2} .

15.

1 ,

₁ %(r) ; , 1,MAX

r) 1 ; , 2,MIN 2 %(

₃ %(r) 1 2 ; , 3,MAX

2 , c %(r) ;

16.

15 ,

2 .

17.

15

1,MAX 0.4% 0.7%

18.

15

3µm 6µm

19.

15

2,MIN -0.05% -0.35%

20.

15

1 1.5µm 4.5µm 4µm 6.5µm

21.

15

3,MAX 0.1% 0.3%

22.

15

2 3µm 9µm 가 , 7.5µm 10.5µm

23.

15

2 , 2 4,MIN 4 %(r) 3

24.

23

3 1.5µm 7µm 11µm 18µm

25.

1 %(r) ; 1,MAX
(r) 1 ; 2,MIN 2 %
3 %(r) 1 2 ; 3,MAX
2 , c %(r) ; ,

1 -1.5%- μm^2 , 가 -2%- μm^2
.

26.

25 ,

1,MAX 0.4% 0.7% .

27.

25 ,

3 μm 6 μm .

28.

25 ,

3.50 μm 4.5 μm .

29.

25 ,

2,MIN -0.05% -0.35% .

30.

25 ,

1 1.5 μm 4.5 μm 4 μm 6.5 μm
.

31.

25 ,

3,MAX 0.1% 0.3% .

32.

25 ,

2 3 μm 9 μm 가 ,
7.5 μm 10.5 μm .

33.

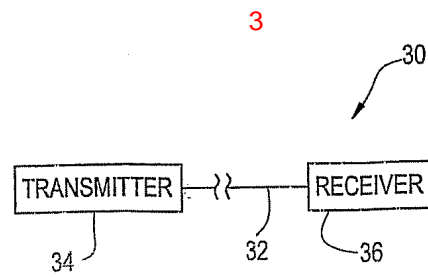
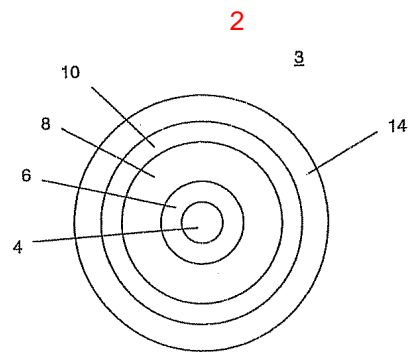
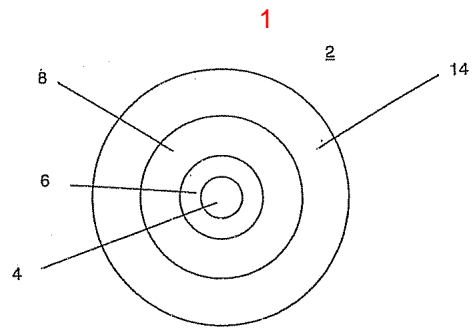
25 ,

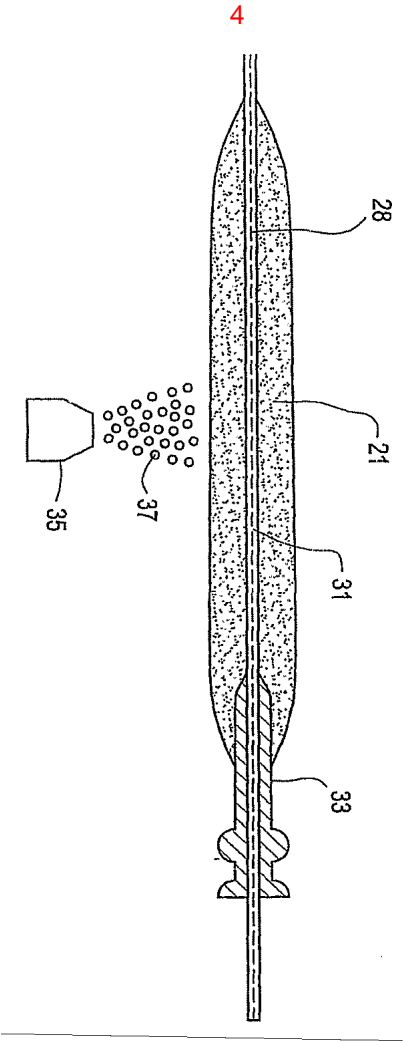
2 , 2 ,
4,MIN 4 %(r) 3
.

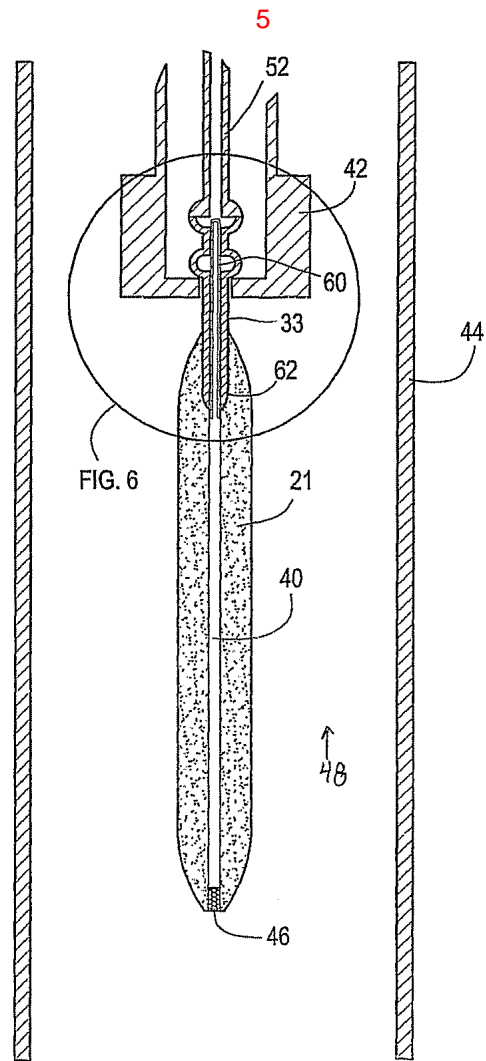
34.

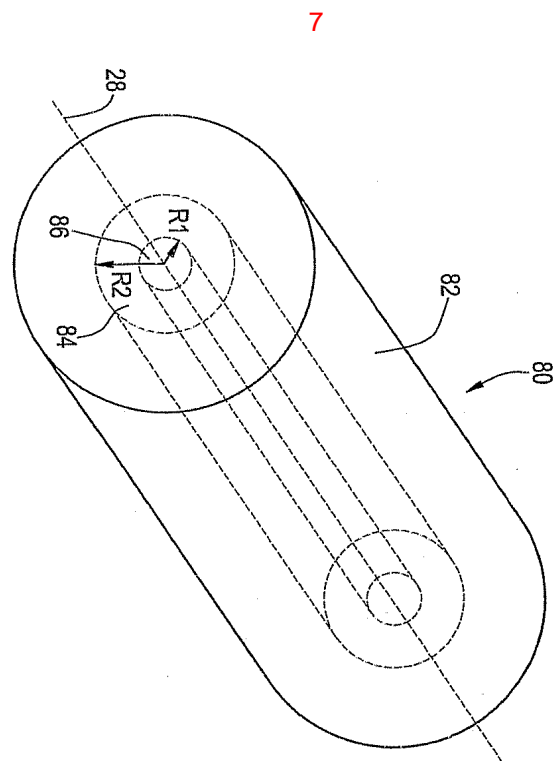
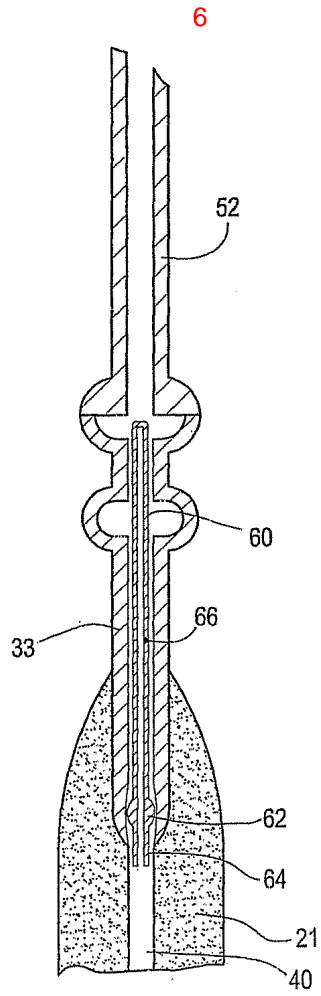
33 ,

3 1.5 μm 7 μm 11 μm 18 μm
.

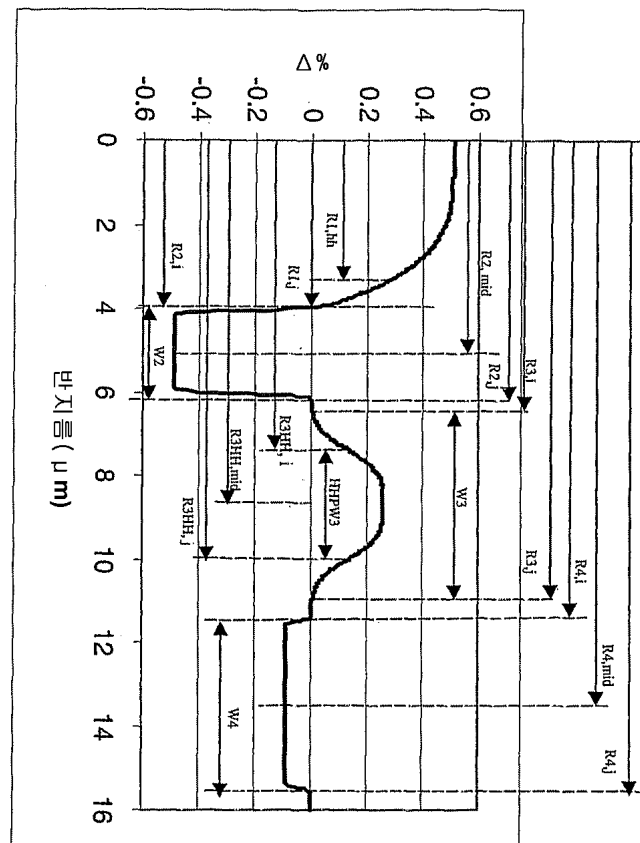




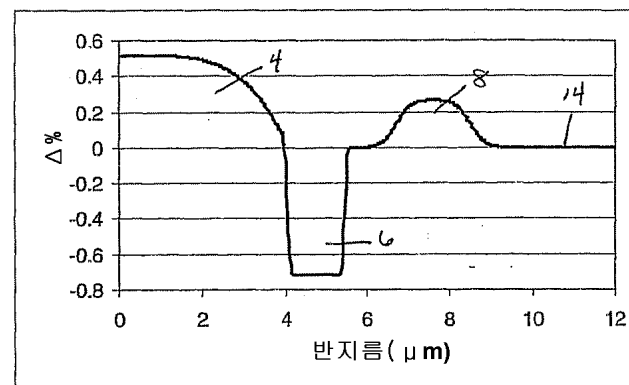




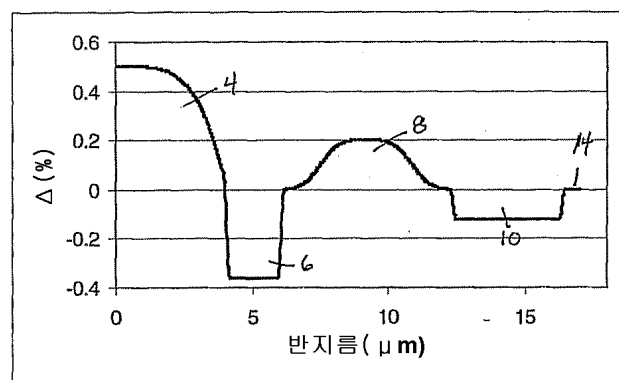
8



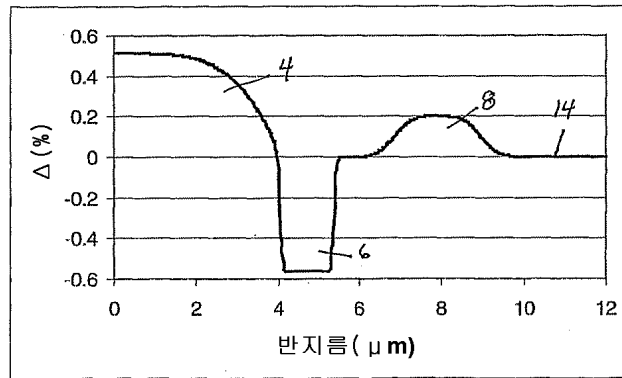
9



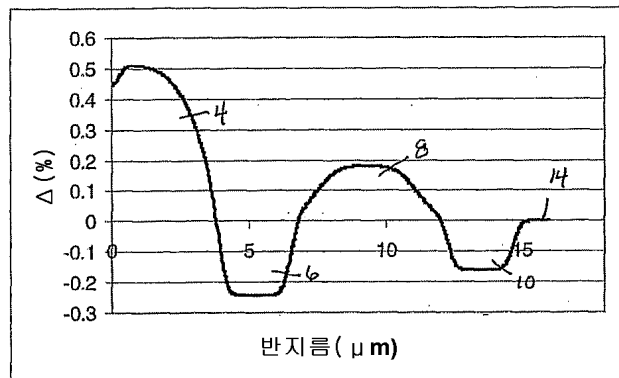
10



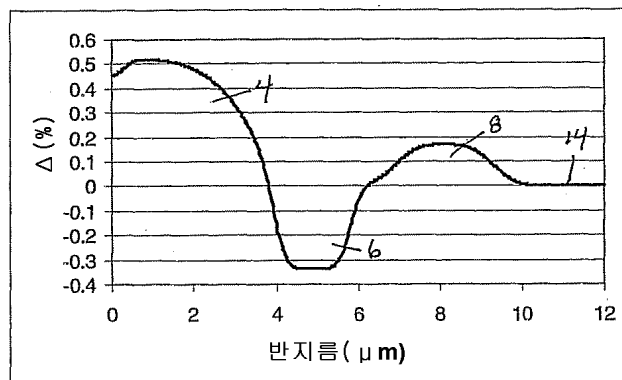
11



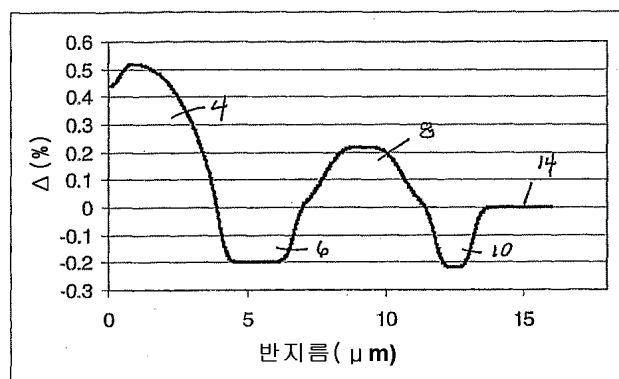
12



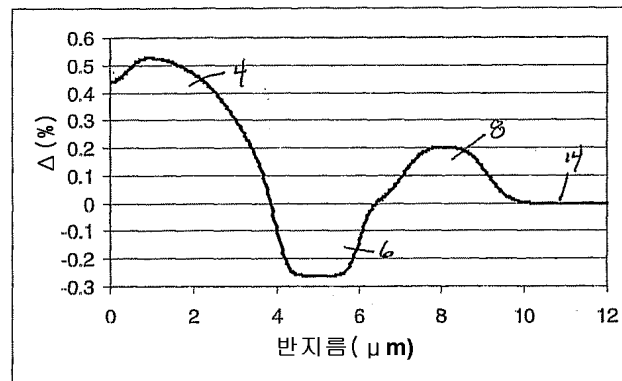
13



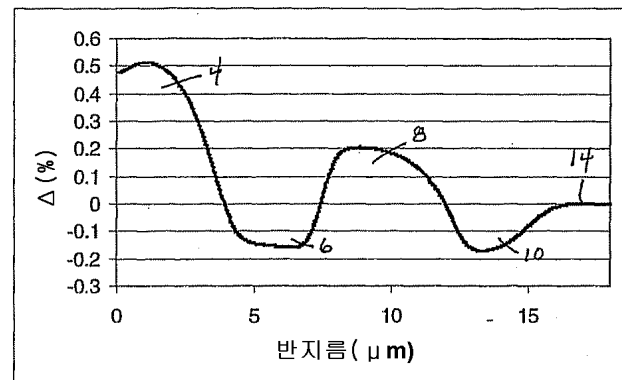
14



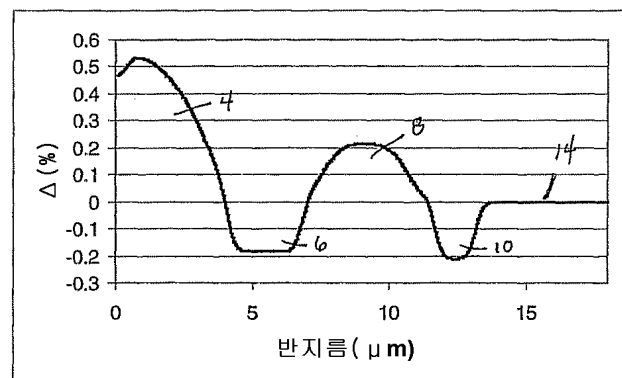
15



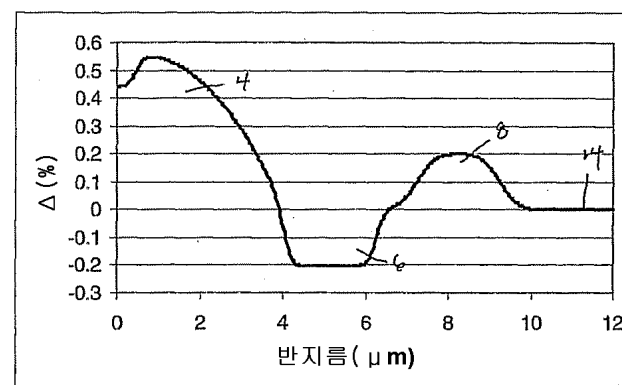
16



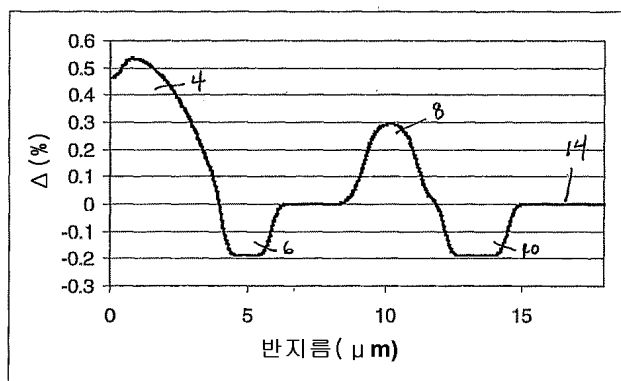
17



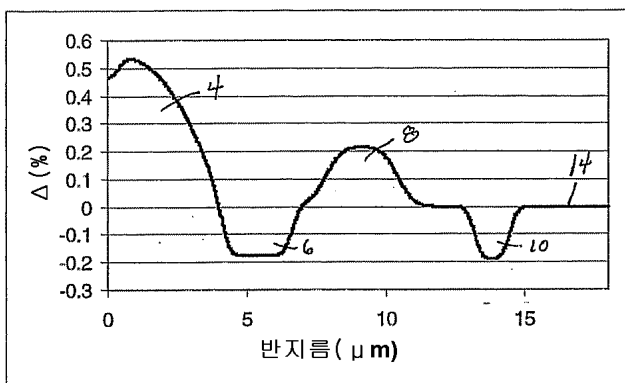
18



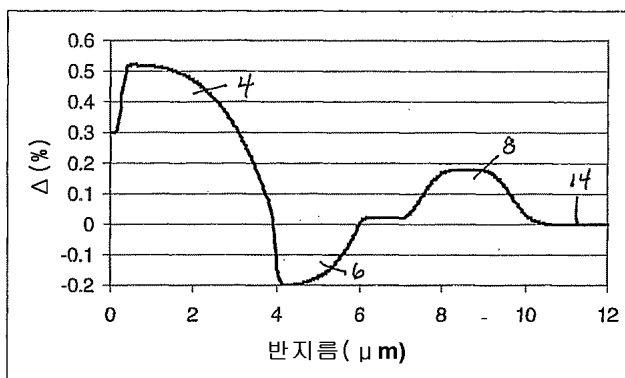
19



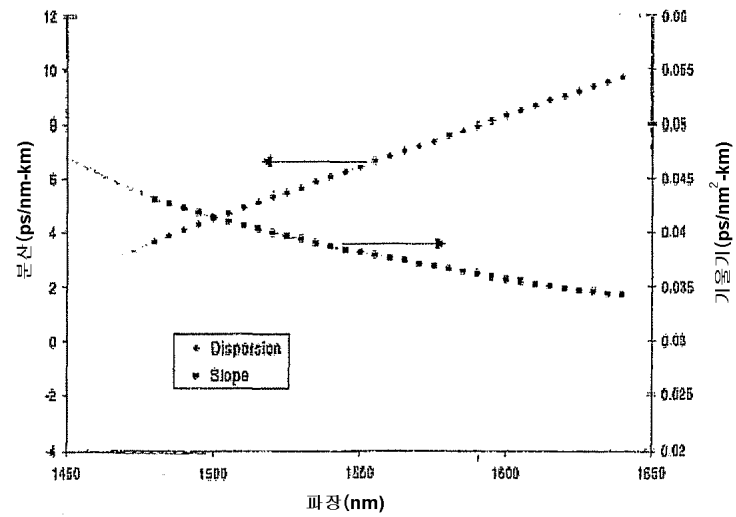
20



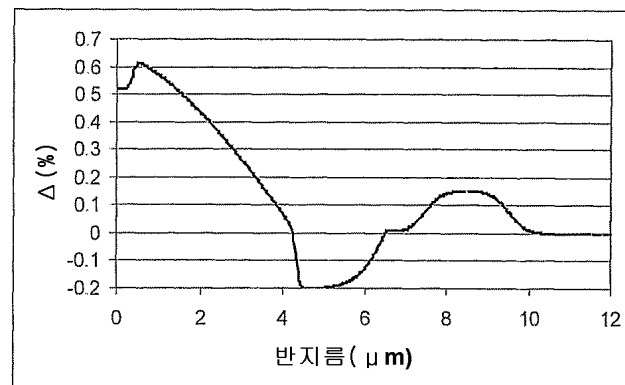
21



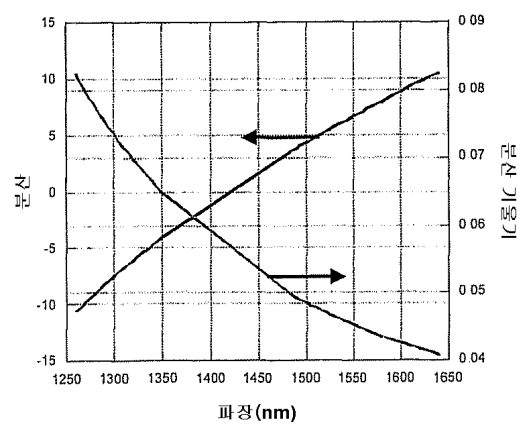
22



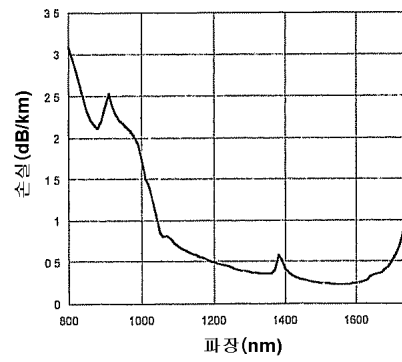
23



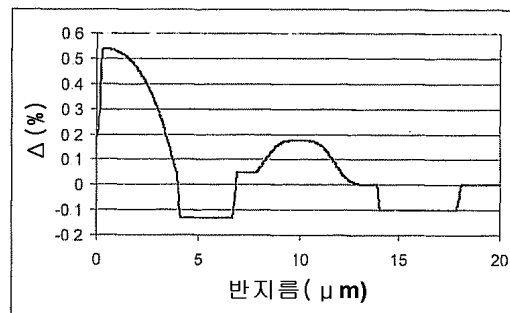
24



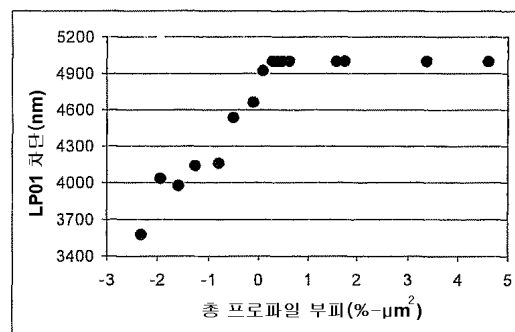
25



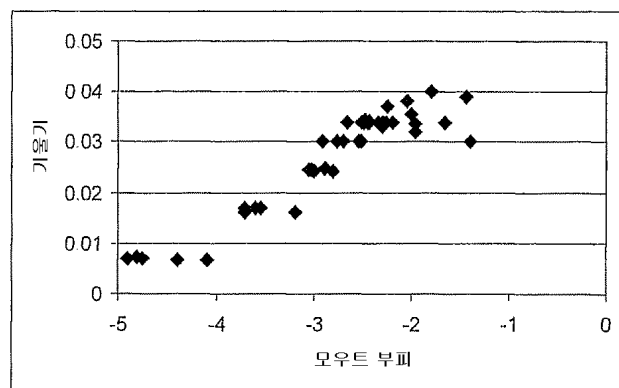
26



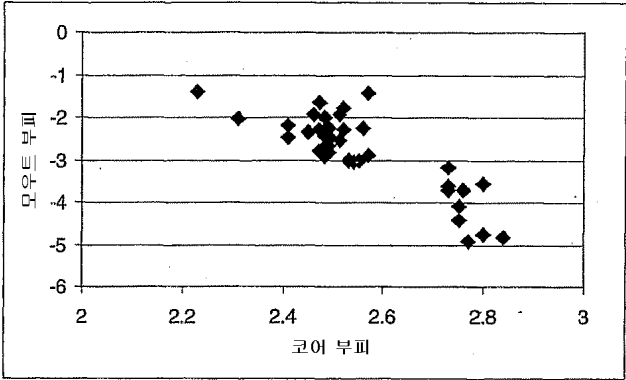
27



28



29



30

