Pump power induced dispersion shift in the germano-silicate optical fiber incorporated with Si nanocrystals

Hye Jin Cho[1], Pramod R. Watekar[1], and Won-Taek Han[1,2]

1: School of Information and Mechatronics

2: School of Photon Science and Technology

Gwangju Institute of Science and Technology (GIST), Republic of Korea

Tel : 062-970-2221, Fax : 062-970-2299, E-mail : wthan@gist.ac.kr

Abstract The chromatic dispersion of the germano-silicate optical fiber incorporated with Si nanocrystals was determined with the aid of simulation and demonstrated using experiments, which showed dependence of the launched power and the pump wavelength due to optical nonlinearity of the fiber.

Introduction

The chromatic dispersion, also known as group velocity dispersion (GVD) controls the broadening of ultrafast pulses, the phase matching of parametric processes, and the generation of temporal optical solitons(1). Recently, the efforts to change chromatic dispersion by changing core diameter(2) or the refractive index of the core surround(3), or using the air cladding type(4) have been reported.

In the present communication, we propose a new method to shift the dispersion property of optical fiber by changing the launched power into the optical fiber incorporated with Si nanocrystals (Si-nc).(5)

Results

The germano-silicate optical fiber incorporated with Si-nc which was fabricated by the modified chemical vapor deposition (MCVD) and the fiber drawing process.(5) The equivalent refractive index profile of the fiber was fed to the FiberCAD code to calculate the dispersion characteristics of the fiber. To estimate the relationship between pump power and refractive index (and thereby dispersion), we used the following relationship between the refractive index n and pump power P:

$$n = n_0 + n_2 \cdot I = n_0 + \left(\frac{n_2}{A_{eff}} \right) \cdot P .$$

To investigate effect of pump power on refractive index, all the parameters expect P and n were fixed, i.e., $n_0 = 1.455$, $n_2 = 5.7\times10^{-20}$, and $A_{eff} = 55.85\mu m^2$. The change in n with variation of pump power P was used to calculate the variation of zero-dispersion wavelength, λ_0. The result is shown in Fig 1 and the computed λ_0 for each case are shown in Table 1. The estimated λ_0 was found to change from 1435.7 to 1277.7 nm when the n was varied from 1.45 to 1.47. The λ_0 was found to be dependent on n and decrease as the pump power was increased. As listed in Table 1, it is found that if refractive index of the core is changed, the shift in the zero dispersion wavelength can be achieved. This indicates the possibility of a zero dispersion wavelength shift if the refractive index of the core is changed with the pump power. This modification in the refractive index of the core of optical fiber with applied pump power can be achieved utilizing the nonlinear optical properties of the fiber.

The chromatic dispersion of the Si-nc doped fiber was measured experimentally with optical dispersion analyzer (AGILENT, optical dispersion analyzer 86038A). The tunable laser source was used as a pump source at room temperature with the pump power ranging from -9 dBm to -3 dBm. The length of the fiber under test was 166 m. Fig. 2 shows the measured chromatic dispersion of the fiber. Although the full wavelength range of the optical dispersion analyzer system was from 1520 to 1610 nm, the zero-dispersion wavelength λ_0 could be expected through the obtained data. Both linear fitting and polynomial fitting were used to calculate "the estimated λ_0", and the calculation from the both methods resulted in the same value of λ_0. The results are summarized in Table 2 and λ_0 was found to shift with fluctuation of ~1.8 nm while the pump power varied from -9 to -3 dBm. The zero-dispersion wavelength difference $\Delta\lambda_0$ estimated using the measured dispersion characteristics is also shown in Table 2, where the zero dispersion at -9 dBm was taken as the reference. As shown in Table 2, the zero dispersion wavelength shift was very small because the applied pump power was just -3 dBm and it didn't have big impact to change the $\Delta\lambda_0$ as we show in the following.

The refractive index difference Δn and the zero-dispersion wavelength difference $\Delta\lambda_0$ were estimated from the simulation while the pump power was varied from 0 to 40 dBm using the resonant and non-resonant optical nonlinearity, separately. In the case of resonant optical nonlinearity, the value of n_2 was 2.0×10^{-15}, while it was 5.7×10^{-20} for non-resonant n_2. As shown in Table 3 and Table 4, $\Delta n_{reonant}$ was much larger than $\Delta n_{non\text{-}resonant}$ and $\Delta\lambda_0$ calculated with resonant optical nonlinearity was more than $\Delta\lambda_0$ calculated using non-resonant optical nonlinearity. Therefore, pump wavelength should be concerned to control λ_0 more efficiently.

Since the chromatic dispersion is a result of the group velocity being a function of the wavelength, the refractive index of the Si-nc fiber affects the zero-dispersion wavelength λ_0 because it is directly related to the group delay inside the core of the fiber. Therefore, changing the refractive index using the launched power can be the new method to control the zero-dispersion wavelength of the fiber. Evidently, the both numerical and experimental results show the refractive index can be controlled successfully by the launched power, thereby controlling the λ_0.

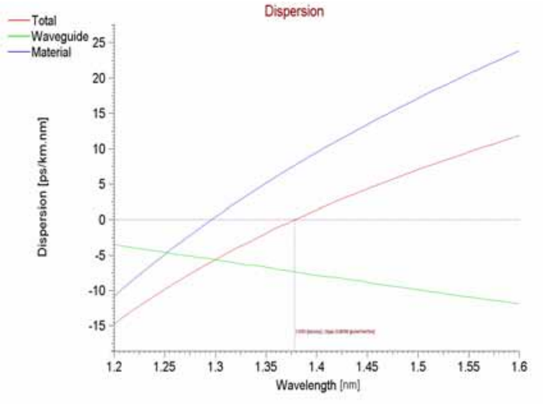

Figure 1. Chromatic dispersion in case of n=1.455

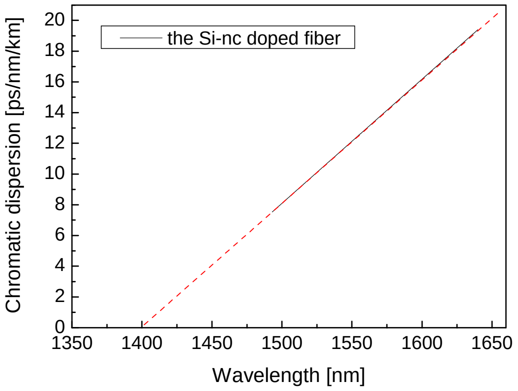

Figure 2. Chromatic dispersion in case of P = -3 dBm

Table 1. The calculated λ_0 from the simulation

n	1.47	1.455	1.4533	1.45
Calculated λ_0 [nm]	1277.7	1373.8	1400.4	1435.7

Table 2. The estimated λ_0 from the measurement

Pump power	[dBm]	-3	-5	-7	-9
Estimated λ_0	[nm]	1399.7	1398.79	1399.97	1400.6
$\Delta\lambda_0$	[nm]	0.9	1.81	0.63	0

Table 3. The estimated Δn and Δλ_0 from the simulation while the pump power ranges from 0 to 40 dBm in case of resonant optical nonlinearity

Pump power	[dBm]	40	30	20	10	0
Δn	[$\times10^{-5}$]	358.102	35.8102	3.58102	0.358102	0.0358102
$\Delta\lambda_0$	[nm]	-44.6	-5.1	-0.7	0.1	-0.2

Table 4. The estimated Δn and Δλ_0 from the simulation while the pump power ranges from 0 to 40 dBm in case of non-resonant optical nonlinearity

Pump power	[dBm]	40	30	20	10	0
Δn	[$\times10^{-9}$]	102.059	10.2059	1.02059	0.102059	0.0102059
$\Delta\lambda_0$	[nm]	0.1	-0.1	0.3	-0.2	-0.2

Conclusion

The chromatic dispersion of the germano-silicate optical fiber incorporated with Si nanocrystals upon pumping was investigated through the simulation and measurement. The zero-dispersion wavelength λ_0 was found to shift by 1.8 nm while the pump power varied from –9 to -3 dBm.

Acknowledgements

This work was supported by the Brain Korea-21 Information Technology Project, Ministry of Education and Human Resources Development, by the National Core Research Center (NCRC) for Hybrid Materials Solution of Pusan National University, by the GIST Top Brand Project (Photonics 2020), Ministry of Science and Technology, South Korea.

References

1. M. A. Foster, et al., *Opt. Express* **16,** 1300 (2008)
2. Y. Akasaka, et al., European Conference on Optical Communication, paper TuP, **2** 221 (1996)
3. R. Amezcua-Correa, et al., *Opt. Express* **15,** 17577 (2007)
4. T. Nagashima, et al., European Conference on Optical Communication, We. 1.3.2 (2006)
5. S. Moon, et al., *Electron. Lett.* **43**, 85-87 (2007).