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Design of Low-chromatic-dispersion Weakly-coupled Few Mode Fiber

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Introduction

- Due to the exponential growth of global Internet traffic, there has been an increasing demand for larger capacity data centers interconnects.
- Mode division multiplexing (MDM) based on few mode fibers (FMF) has been widely investigated as an alternative technique to scale link capacity.
- The chromatic dispersion (CD) is still a major transmission impairment for IM/DD MDM transmission.
- FMF with both low modal crosstalk and low CD level is highly welcomed.

Design Principles

- Based on first order perturbation theory, mode effective index of LP_{mn} can be expressed as:

$$\mathrm{n}_{\mathrm{eff},mn} = \mathrm{n}_{0,\mathrm{eff},mn} + \int_0^{\mathrm{r_{core}}} \Delta \mathrm{n}(r) I_{mn}(r) r dr$$

where the $\Delta n(r)$ is the refractive index change from the initial fiber, the $n_{0,\mathrm{eff},mn}$ and $I_{mn}(r)$ represent mode effective refractive index and normalized radial intensity distribution of LP_{mn} in the initial fiber.

- The mode effective refractive index difference between LP_{mn} and LP_{pq} is calculated with the formula:

$$\Delta \mathrm{n}_{\mathrm{eff},mn,pq} = \Delta \mathrm{n}_{0,\mathrm{eff},mn,pq} + \sum_{j=1}^{N} \Delta \mathrm{n}(j) \mathrm{A}_{\mathrm{r},mn,pq}(j)$$

$$\mathrm{A}_{mn,pq}(r) = [\mathrm{I}_{mn}(r) - \mathrm{I}_{pq}(r)]r$$

where j means the index of rings along the radial, N is the number of rings, $\Delta n(j)$ represents the refractive index changes at the j-th ring

- Using three-point numerical differentiation, the chromatic dispersion of LP_{mn} at wavelength λ can be expressed as:

$$\mathrm{D}_{mn}(\lambda) = \mathrm{D}_{0,mn}(\lambda) - \frac{\lambda}{c\Delta\lambda^2} \sum_{j=1}^{N} \Delta \mathrm{n}(j) \mathrm{B}_{\mathrm{r},mn}(j)$$

- By using heuristic searching, $\Delta n(j)$ can be optimized for specific mode refractive index differences and chromatic dispersion.

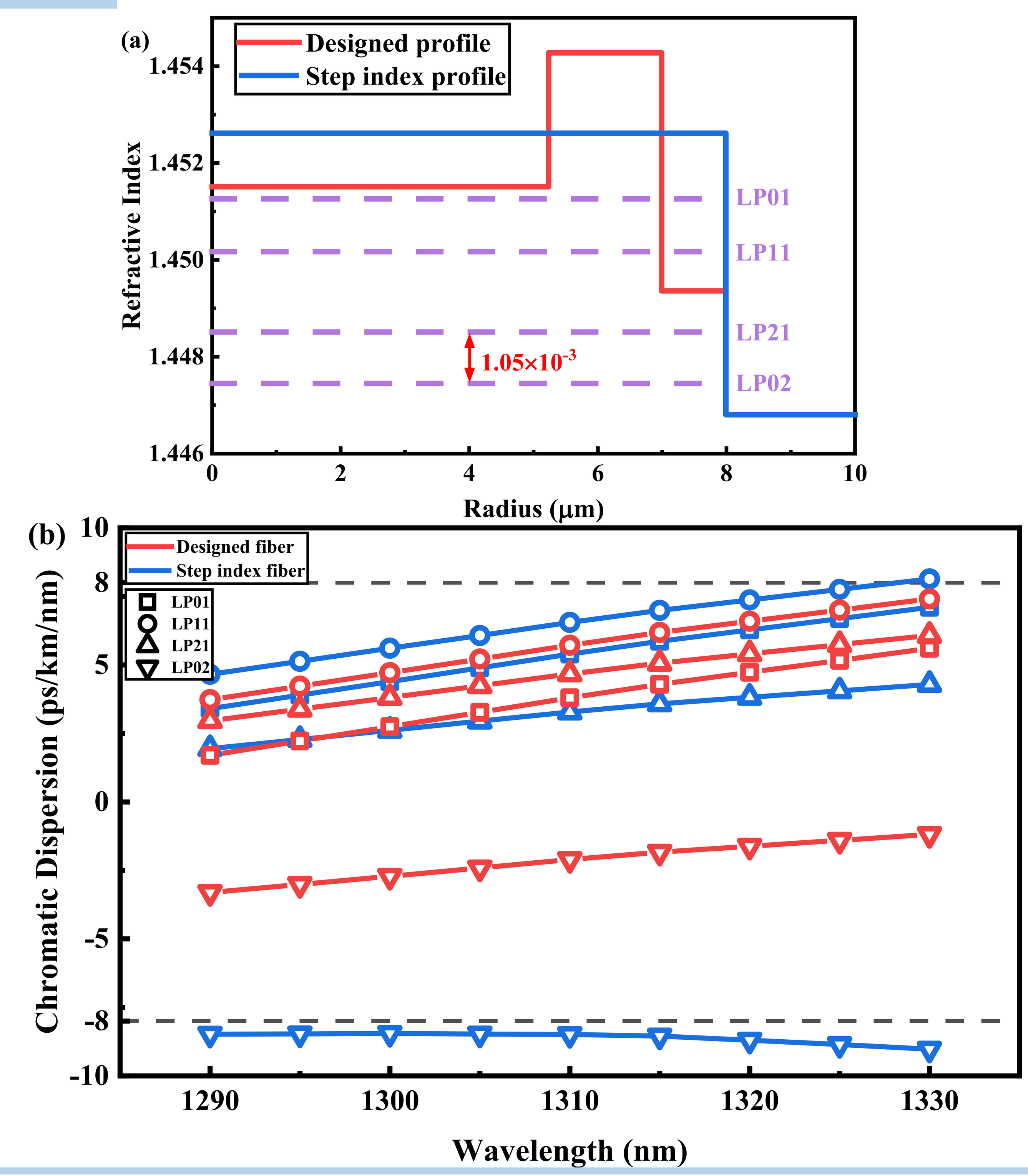
Conclusion

- We propose a low-chromatic-dispersion (CD) weakly-coupled FMF design method.
- Two low-chromatic-dispersion weakly-coupled FMFs supporting 4 modes and 7 modes respectively have been designed. The min$|\Delta n_{\mathrm{eff}}|$ of two fibers are 1.05×10^{-3} and 0.89×10^{-3} , and the $|D|$ of each supporting modes is lesser than 8 ps/km/nm over wavelength 1290nm to 1330nm.
- With the optimization method, this work can be extended for supporting more modes.

Simulation Results

4-mode FMF

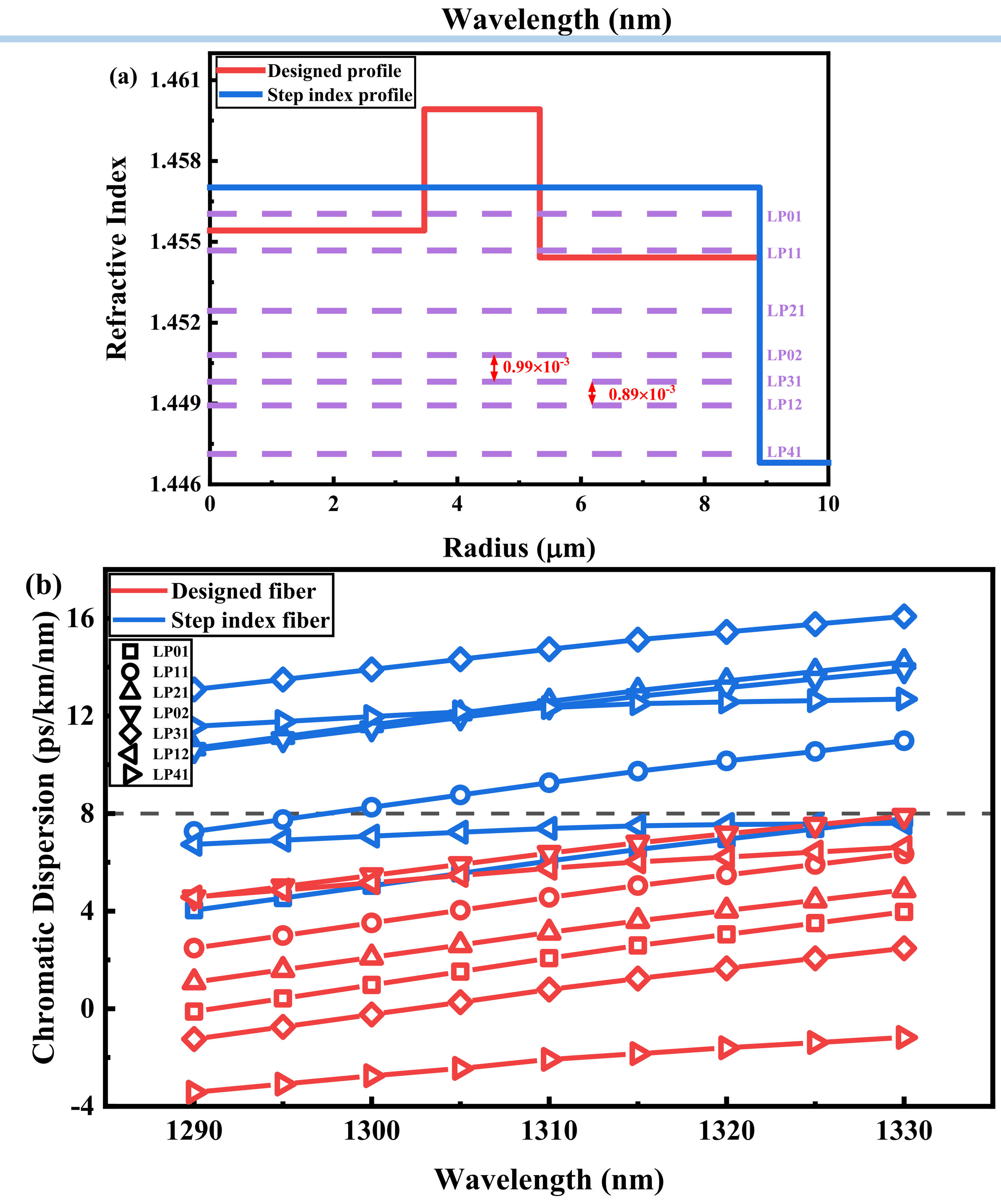
(a) Refractive index profile of designed and step-index 4-mode FMF, and n_{eff} of 4 supporting LP modes;
(b) Chromatic dispersion curves of 4 supporting LP modes in designed and step-index FMF.



- The min$|\Delta n_{\mathrm{eff}}|$ is improved from 0.50×10^{-3} to 1.05×10^{-3}
- All modes have $|D| < 8$ ps/km/nm over the wavelength range from 1290 nm to 1330 nm

7-mode FMF

(a) Refractive index profile of designed and step-index 7-mode FMF, and n_{eff} of 7 supporting LP modes;
(b) Chromatic dispersion curves of 7 supporting LP modes in designed and step-index FMF.



- The min$|\Delta n_{\mathrm{eff}}|$ is improved from 0.56×10^{-3} to 0.89×10^{-3}
- All modes have $|D| < 8$ ps/km/nm over the wavelength range from 1290 nm to 1330 nm

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