Nonlinear combining of chirped and phase-modulated Gaussian pulses in multi-core fibers

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Multi-core optical fibers (MCF) are utilized for a great variety of applications in various areas of photonics, they have attracted a lot of attention in the fields of high capacity optical communications and fiber lasers. Recently we have demonstrated that nonlinear effects in MCFs, which are generally undesirable in many applications, can be utilized for nonlinear pulse combining and compression [1]. Such approach can be more robust and insensitive to phase fluctuations as compared with linear beams combining. In our paper [2] we have considered ring, hexagonal and square MCFs and found the best combination efficiency and maximum pulse compression, which can be obtained by each type of MCF. Fibers with square and hexagonal core configurations offered the best combination efficiency, so it is possible to combine 91.6% of total energy using 7-core hexagonal fiber, for example.

The disadvantage of nonlinear combining is the scheme operates only for specific combining beam parameters. In the present paper we demonstrate that combination of linear pre-focusing and pulse chirping makes nonlinear combining more flexible and efficient, so the influence of the initial pulse chirping and modulation in radial direction on nonlinear pulse combination efficiency was investigated. We considered 7, 19 and 37-core MCFs with hexagonal lattice (see Fig. 1a). Here the results of pulse combining optimization based on numerical solution of the discrete-continuous nonlinear Schrödinger equation (NLSE) are presented. Hexagonal structure of cores originally demonstrates improvements in combining performance as compared with a ring structure. On the other hand, the required length of the hexagonal MCF for obtaining combined pulse is much shorter [2]. So hexagonal MCFs were chosen as the purpose of further research.

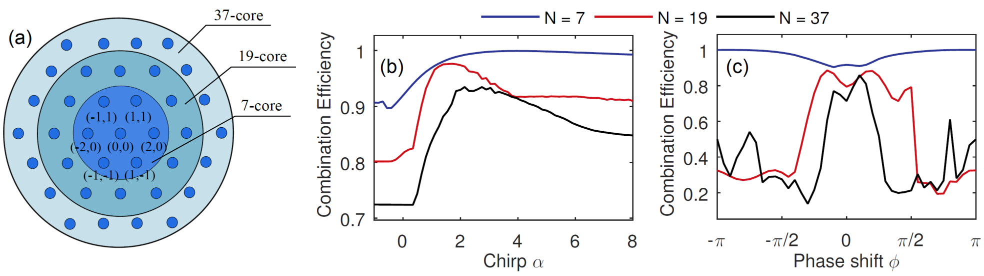

Fig. 1 Scheme of considered 7, 19 and 37-core hexagonal multi-core fibers and core numbering (a). The dependence of the combining efficiency on chirp α (b) and phase modulation ϕ (c) for different number of cores N.

We simulated the dynamic of Gaussian pulses $U_{n,m}(z=0,t) = \sqrt{P}\exp\left[-(1+i\alpha)t^2/(2\tau^2)\right]\exp\left(-i\phi R_{n,m}\right)$, where α is the chirp coefficient, ϕ is the phase modulation, $R_{n,m} = \left(n^2+3m^2\right)/4$ is the normalization constant, which is proportional to the square of the distance to the core (n,m). We performed numerical simulations to determine the conditions of most efficient coherent combination by varying the amplitudes P and the widths τ for every certain value of chirp α and phase modulation ϕ. Figure 1b shows the best obtained values of combination efficiency in dependence on the chirp parameter α. The maximal value for 37-core fiber is about 93.45%, for 19-core fiber is 97.58%, and for 7-core fiber this values equals 99.6%. Calculations showed the pulse combining efficiency increases with the modulation of phase with any sign. Only in the case of a 7-core optical fiber the maximum efficiency is higher in compare with an adding a positive chirp (99.99%).

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References

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