Spatial and Spectral Effects in Optically Coupled Multicore Fiber Laser Cavities with Fiber Bragg Gratings

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Multicore fibers (MCFs) are treated now as a perspective laser medium which may overcome limitations imposed in singlemode fibers by nonlinear effects [1], from one hand, and offer new opportunities in laser cavity design by forming reflectors such as fiber Bragg gratings (FBGs) in different cores, from the other hand. The technology of point-by-point refractive index modification by femtosecond laser is able to form FBGs at arbitrary position in the fiber core (both in longitudinal and transverse direction) [2]. The FBG cavities formed in individual cores may be optically coupled that leads to new effects at lasing in active MCFs, as well as at Raman conversion in passive fibers. Here we review our experiments where new spatial and spectral effects in optically coupled 2, 4 and 7-core fiber laser cavities with FBGs have been observed.

Femtosecond (fs) point-by-point inscription of FBGs in optically coupled cores of a passive 2-core fiber with shifted longitudinal positions of FBGs leads to the formation of a Michelson-type interferometer, leading to the modulation of generation spectra near threshold. This technique offers new possibilities for spectral filtering to single narrow line ($<$0.02 nm) or multi-line generation [3]. A highly-reflective FBG array has been fs-inscribed in peripherical cores at both ends of a 7-core passive fiber with coupled cores, thus forming in them a high-Q cavity, whereas central core remains fully open. When pumped into the central core at one end, the Raman lasing is observed from the central core at the other end. At the same time, both the pump and Stokes power is equally distributed between all the cores inside the Raman laser cavity formed by the two highly-reflective FBG arrays. Thus, the pump radiation is efficiently converted into the Stokes radiation generated in all 7 cores while the output beam is spatially localized in central core having narrow linewidth (corresponding to the 7 times larger effective mode area inside the cavity). The laser linewidth is additionally narrowed (to $<$0.02 nm) when random longitudinal shift of $\sim$0.5 cm is formed between the individual FBGs in the array [2].

A similar highly-reflective FBG array has been fs-inscribed in the double-clad 4-core [4] and 7-core Yb-doped fibers of two types (with 28-um-spaced uncoupled cores and 17-um-spaced coupled cores) fabricated from the same preform [5]. With 4 times difference in active fiber length providing nearly the same absorption of 976-nm laser diode (LD) pump radiation, the 7-core fibers generate nearly the same output power at 1064 nm: up to 33 W at 50 W multimode LD pumping. Herewith, the generated spectrum is quite different in spite of that the mode field diameter is nearly the same. For uncoupled cores, each core generates at the resonant wavelength of individual FBG inscribed in this core and the total linewidth of output beam from all the cores varies from $\sim$1.6 to $\sim$2.2 nm with power. For coupled cores the multiline spectrum collapses into a single line defined by a geometric mean of individual FBG spectra: its linewidth linearly grows from 0.05 to 1.2 nm with power growth. The theory has been developed showing that the hybridized supermodes are generated in the last case.

Mechanisms of spatio-spectral control in multicore fiber lasers with FBG arrays and their potential for narrowband generation with high beam quality and power scalability will be discussed.

Acknowledgements: The authors acknowledge financial support by the Russian Science Foundation (21-72-30024).

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