THERMAL EFFECTS IN ASYMMETRIC YB-DOPED 4-CORE FIBERS

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The impact of thermal effects on supermodes of Yb-doped multi-core fiber amplifiers with an asymmetric core refractive index profile has been studied through numerical simulations based on the finite element method.
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1. Introduction

Multicore fibers, which integrate multiple Yb-doped cores in a single fiber, represent a possible solution to overcome the power scaling problems of short-pulsed fiber-based lasers [1]. The dynamic thermo-optic instability, caused by the unwanted presence of higher-order modes, is one of the most detrimental physical effects preventing a further laser power scaling. Recently, the influence of thermo-optic perturbations on the guiding properties of multicore fibers with two [2] and four Yb-doped cores [3] has be analyzed, showing the impact of the total heat load q_{tot} applied to the cores on the supermode behaviour in different core coupling conditions.
In this paper, the effect of a refractive index asymmetry in Yb-doped 4-core fibers under heat load has been studied with a full-vector modal solver based on the finite element method with an embedded thermal model [2,3]. Simulation results have shown that, when the refractive index of at least one of the cores is modified, the supermode properties are significantly affected, in particular in terms of effective area A_{eff} and core overlap integral.

2. Asymmetric 4-core fibers

The Yb-doped fibers considered in the present analysis have 4 step-index cores with a 19 µm diameter and a numerical aperture of 0.038, corresponding to a V-parameter of 2.2 at the signal wavelength of 1032 nm, providing a single-mode behaviour. The distance d between the core centers changes from 20 µm to 65 µm, in order to investigate different optical coupling regimes between the cores. A refractive index difference Δn in the range between 10^{-6} and 10^{-5}, which can be due to inaccuracies in the fabrication process, has been considered in only one of the fiber cores. Fundamental supermodes, labelled from Mode 1 to Mode 4 as the effective index decreases, and the most detrimental higher-order mode, that is the one with the highest core overlap integral, have been calculated when a total heat load load q_{tot} = 20, 100, 200 W/m is applied to the fiber.
As shown in Fig. 1, for a fixed total heat load q_{tot}, the A_{eff} behaviour is significantly affected by the refractive index asymmetry, which modifies the supermode confinement in the different cores. Notice that A_{eff} of Mode 1 and Mode 4 is less affected by Δn for short core-to-core distances. In particular, the d range where this happens shrinks as Δn becomes higher. In the large core separation regime, starting from a d value strongly affected by Δn, Mode 1 and Mode 4 A_{eff} significantly decreases. Mode 4 A_{eff} reaches the minimum value, which corresponds to the effective area of the single core fiber. Finally, it is interesting to underline that the impact of the total applied heat load on the A_{eff} values is more evident when the refractive index asymmetry is low, especially for short core-to-core separations.

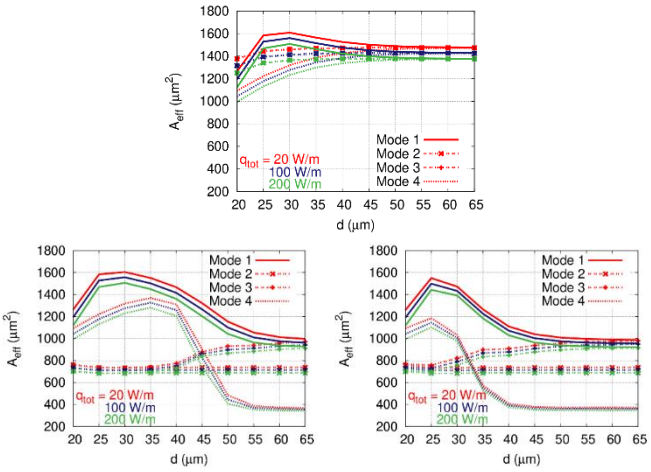

Fig. 1 Fundamental supermode A_{eff} versus core separation d for q_{tot} = 20, 100, 200 W/m when (top) Δn = 0, (left) Δn = 10^{-6}, and (right) Δn = 10^{-5}.

Results of the supermode core overlap integral behaviour, strictly related to the single-mode regime, will be discussed at presentation time.

3. Conclusion

The behaviour of the supermodes in Yb-doped 4-core fibers with a refractive index asymmetry in one of the cores is numerically analysed for different applied total heat load.

References

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