Microarticle

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Long-wavelength spectral filtering in anisotropic tapered fiber

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A B S T R A C T

We report on special tapered large mode area (LMA) polarization-maintaining fibers demonstrating inherit long-wavelength spectral filtering. The attenuation more than 25 dB of long-wavelength spectral range arising after amplified spontaneous emission (ASE) of a preamplifier, and also preservation of polarization state (extinction ratio more than 20 dB) and mode composition is presented in these fibers. Integration of this approach into the amplifier gain medium is promising for solving the problem of effective spectral filtration and polarized light generation.

Introduction

Generation of ultrashort high peak power pulses with high beam quality is necessary for majority of laser radiation applications at the wavelengths longer than ≈ 1.4 μm («eye-safe» region) [1,2]. The need to use several amplifying cascade is associated with a method of chirped pulse amplification (CPA) that assumes reduction of the peak power of amplified pulses and, therefore, increasing of the threshold for parasitic nonlinear effects [3,4]. One of the main disadvantages of multi-cascades amplifiers is the ASE emerging in each of the cascades as unavoidable amplifier noise effect. Approaches of effective spectral filtration between cascades still remain open problem. The absence of the necessary ASE filtering between the cascades leads to the fact that the gain of the signal decreases. Standard ASE filtering methods assume the use of additional undistributed filters that overload the optical amplifier scheme and cooling system. An ASE reduction filter in EDFA based on optical fiber grating coupler demonstrated efficiency of about 70% [5]. In [6] a liquid crystal infiltrated photonic bandgap fiber was used as a tunable filter. Despite the benefit of ASE standard filtering, the insertion loss is relatively high. Previously, the advantages of Yb-doped LMA tapered fibers for amplifying optical signal at a wavelength of about 1 μm were shown: preservation of single-mode radiation at the output of the optical fiber, high amplification of weak and high power optical signals, high threshold of nonlinear effects (including mode instability) [7]. In paper [8], slight decrease of ASE intensity was observed in a tapered fiber. Also, preservation of the polarization state of light is one of the most important issues for MOPA based on LMA fibers, but it still remains a poorly studied question. In this way, the study of LMA tapered fibers is of a particular interest for research and development of single-cascade MOPA systems operating on their basis at a wavelength of 1.55 μm [9,10]. In this study we propose a novel approach to spectral filtration - distributed total filtration of ASE inside the anisotropic tapered fibers using the effect of enlarged bending losses. Investigated approach could be effective employed in high power single-cascade amplifiers based on active anisotropic tapered fibers, whose longitudinal profile allows to replace multi-cascade schemes.

Experimental results and discussions

The present study mainly concerns spectral filtration. This effect is more convenient to study in passive fibers without any active dopants to separate the influence of passive losses and absorption at active centers. For this purpose, a series of LMA anisotropic passive tapered fibers (LMA-APTF) were produced and experimentally studied. Fiber samples were sorted in geometric parameters of the longitudinal and transverse structure. Typical parameters of the experimental LMA-APTF samples were: length of about 11 m, core diameter of narrow/wide part of about 7 /75 μm, ratio of outer cladding diameter to core diameter 15.6, minor / major axis of internal elliptical cladding 15-17 μm / 32-36 μm, core NA 0.11.Core diameter increases smoothly adiabatically from strictly single-mode diameter about 7 μm to a size up to 75 μm. LMA-APTF refractive index profile was W-structured with depressive inner elliptical cladding with difference of 1*10^-3 relative to pure silica outer cladding. Refractive index difference between core and outer cladding was about 4*10^-3. Anisotropy in LMA-APTF was formed by residual thermoelastic stresses arising due to elliptical inner cladding, while core and external silica cladding remain nominally circular (Fig. 1a). Earlier, it has been demonstrated theoretically and experimentally that no excitation of the higher transverse fiber modes is observed in LMA-APTF when the radiation propagates in direction from narrow to wide end [9].

Preliminarily macro-bending losses were calculated for a similar step-index profile in dependence on the profile diameter using a numerical model [11]. Material properties and material losses were not taken into account in calculation. The calculated graph is shown in Fig. 1a. The ratio of the calculated profile diameter to the initial profile diameter is plotted along the abscissa axis. Typical narrow part length of LMA-APTF was more than 1 m where the core diameter increases from the original core diameter of 7 μm to 8 μm. Simulation results showed that bending losses at the wavelength up to 1700 nm were much higher than at 1550 nm in this region (Fig. 1a)..MFD enlargement with an increase of the radiation wavelength leads to increase of the bending losses demonstrating acceptable values at the wavelength at 1550 nm, but crucial at 1700 nm. It allows concluding that almost all long-wavelength spectral part is filtered out during the light propagation along the narrow part of sample.