Study of Mechanisms Limiting Short-Wavelength Generation in a CW Fiber OPO

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Parametric four wave mixing (FWM) is an attractive process for nonlinear frequency conversion in optical fibers. Fiber optical parametric oscillators (FOPOs), utilizing the FWM principles, offer an opportunity to efficiently generate tunable laser radiation in new spectral ranges, where conventional fiber lasers are not efficient or absent, in particular, in short-wavelength region, <1 μm. This region is highly attractive for biological nonlinear microscopy - optical coherence tomography and coherent Raman scattering microscopy. In both cases, the large tuning range is required. In order to obtain FOPO generation below 1 μm, a photonic crystal fiber (PCF) pumped by an Yb-doped fiber laser is usually used. Recently, we have demonstrated CW FOPO in such configuration with wavelength tuning from 923 to 1005 nm [1]. The next step of the study is an extension of this range to shorter wavelengths to produce light source suitable for bioimaging applications.

Implementation of a light source with higher pump power in the developed FOPO configuration allowed us to extend the FOPO tuning range down to 920 nm (CW mode) and 900 nm (intensity modulation mode). At that, slope efficiency amounted to 25% and 35% for the CW and modulated radiation, respectively. In order to increase the generation stability, an all-polarization maintaining (PM) configuration of the CW FOPO is realized for the first time to our knowledge. However in both all-PM and standard configurations the laser threshold power was significantly increased with increasing the parametric frequency shifts limiting the shorter wavelengths generation. Influence of pump linewidth and fiber longitudinal dispersion inhomogeneity may be responsible for the integral parametric gain decrease inside the FOPO cavity.

Several approaches to investigate influence of the dispersion fluctuations on the gain of fiber parametric amplifiers have been reported earlier [2], [3], but the oscillators were not investigated. In the present work, a numerical simulation model of the oscillator according to FOPO theory described in [4] has been developed to account the impact of fiber inhomogeneity on the FOPO threshold at different generating wavelengths. Simulations show that the effect of longitudinal dispersion fluctuations significantly increases the oscillator threshold at shorter wavelengths. A good agreement between the simulation and experimental data is obtained.

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