Modeling of Rare Earth Doped Microspheres

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Two computer codes for the design of active microspheres coupled with tapered fibers have been developed. The former code models the amplification of the Whispering-Gallery Modes (WGMs) propagating into rare earth doped microspheres. The latter code solves the rate equations and the power propagation equations in frequency domain (FD).

Introduction

High Q quality factor dielectric microspheres are very attractive for many applications: nonlinear optics, evanescent-wave sensing, amplification. In particular, active microspheres allow to design novel devices, e.g. in active biosensing area. In this work, two different versatile models are ad hoc developed/optimized for the design of rare earth doped dielectric microspheres. The design of an Er^{3+} doped silica microsphere, surrounded by air and coupled to a tapered silica fibre permits to show the code effectiveness. The tapered fibre can couple the light at both pump and signal wavelengths into low order WGMs closely confined to the sphere surface and equator. In the former home made computer code, the cavity resonances and the amplification due to rare earth have been modelled by means of an advanced FDTD (Finite Difference Time Domain) algorithm. The latter home made computer code takes into account the FD (Frequency Domain) analytical WGM solution, the coupling between microsphere and the tapered fiber, the rate equations, pertaining to ion population of the Er^{3+} energy levels and the power propagation equations, in the frequency domain. The simulated results are compared and their agreement validates each other both the codes.

Results

The investigated amplifying system consists of an erbium doped silica microsphere having radius R_s=15 μm. A tapered fibre having waist radius R_f=0.45 μm excites and extracts both the pump and the signal and it is far 300 nm from the microsphere. In this way the phase matching between the microsphere WGM at the signal wavelength and the fibre fundamental mode occurs. The fibre fundamental modes are considered for both signal and pump. The pump wavelength is 980 nm, the signal wavelength envelopes a sinusoidal carrier at 1.53 um. The pump power is 0.8 mW, because this value allows the complete ion population inversion. By means FDTD approach the transient response of the amplifying system to the CW input signal is simulated. In order to simplify the amplifying system model, a two-dimensional (2-D) approach can be used to study the WGMs along the sphere equator. The electromagnetic field profile of the microsphere WGMs are analytically calculated for both pump and signal. In regime-state, the 2D FDTD method is less rigorous than 3D FD. Thus, the WGM electromagnetic field profiles and the propagation constants show a slight displacement. Nonetheless, by means of 2D FDTD approach it is possible to investigate other different structures.

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References L. Mescia, F. Prudenzano, M. De Sario, T. Palmisano, M. Ferrari, G.C. Righini, “Design of Rare Earth Doped Microspheres”, accepted on Optics & Laser, Technology.