Numerical Comparison of Pulse Amplification in Ytterbium-Doped Media

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We present a new amplification code that allows the realistic simulation of ytterbium-based regenerative or multipass amplifiers with a very broad range of input parameters. A regenerative amplifier is fully simulated with 3D modeling of the pump, population inversion, gain, thermal load and spectrum. These results were successfully benchmarked against our experimental data for several ytterbium-doped media.

In recent years there has been a growing research in and use of diode-pumped ytterbium-doped materials in laser amplifiers, due to their excellent properties for high repetition rate and high energy pulse generation. This has led to the development of several simulation codes, with the purpose of studying their behavior for different host media, amplifier configurations or pump parameters (see e.g. ref. [1]). In particular, a realistic simulation of thermal effects in the gain medium is a major issue, since they ultimately limit the achievable repetition rate.

We present here the results of a simulation code that has a number of novel and interesting features: it allows the simulation of both regenerative and multipass amplifiers, and allows the realistic monitoring of the relevant physical parameters during the amplification process, such as the spectral dependence of the small signal gain per pass, pulse temporal and spectral evolution, and optimal output energy. This is achieved by taking into account a large number of real input parameters for each of the amplifier variables: gain media (% doping, length, fluorescence time, spectral dependence of absorption and emission cross sections), pump pulse (power and power density, pulsewidth, wavelength), seed pulse (wavelength and spectral bandwidth, energy and energy density, pulsewidth), and amplifier configuration (cavity type, roundtrip loss). The calculation of the pulse parameters is undertaken at each pass through the gain media, simultaneously updating the inverted population profile. Thermal effects such as thermal lensing are fully taken into account, allowing the determination of the maximum practical repetition rate.

As an example, Figure 1 shows the calculated gain per pass for different Yb-doped hosts (Yb:CaF_2, Yb:YAG, Yb:glass, Yb:KYW) as a function of doping. These results were benchmarked against our experimental data for the same media, in the frame of a 100 mJ-level regenerative and multipass amplifier. This has shown the accuracy and validity of the code for this range, allowing us to perform an estimate of the behavior of Joule and kJ-level ytterbium-based amplification.

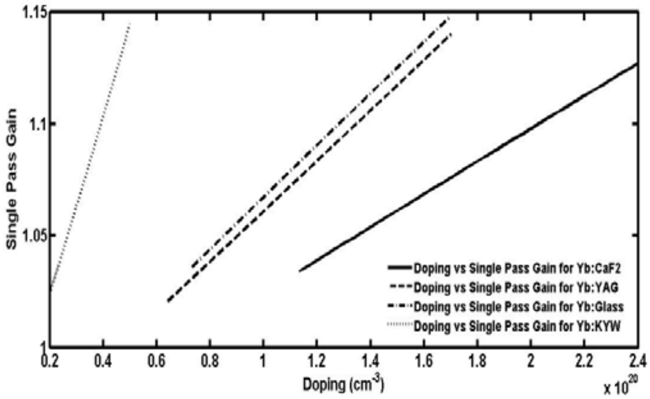

Fig. 1. Evolution of the gain per pass as a function of doping (cm^{-3}) for several Yb-doped hosts.

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[1] Raybaut P., IEEE J. Quantum Elec., **41**(3), 415-425 (2005)

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