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Hybrid master oscillator power amplifier single-frequency, nanosecond, multi-mJ, 5 kHz at 1030 nm

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Abstract: We demonstrate that the combination of doped fiber and bulk crystals, in a Master Oscillator Power Amplifier configuration (MOPA) allows obtaining a narrow spectrum with high energies, short pulses with high repetition rate. © 2020 The Author(s)

Introduction

The detection of greenhouse gases in the atmosphere requires the use of high-energy laser pulses ($> \text{mJ}$), wavelengths in the medium infrared, and narrow-linewidth. Optical parametric oscillators (OPOs) are frequently used in this type of application. Nevertheless, the energy from these oscillators is often too low for long-distance propagation. To overcome this constraint, optical parametric amplification stages (OPA) are essential. However, these amplifiers require specific pumping sources, especially very high energies. For this purpose, hybrid amplifiers combine the advantages of doped fiber and bulk crystal amplifiers (Fig. 1). Ytterbium-doped fiber amplifiers are particularly interesting for their compactness, but limited in peak power due to stimulated Brillouin scattering (SBS) in a narrow line width regime ($< 100 \text{ MHz}$) [1, 2]. Bulk crystal amplifiers make it possible to bypass this limitation, and considerably increase the energy per pulse. In this paper, we study the amplification of the DFB laser diode with a high repetition rate, a nanosecond and a narrow linewidth.

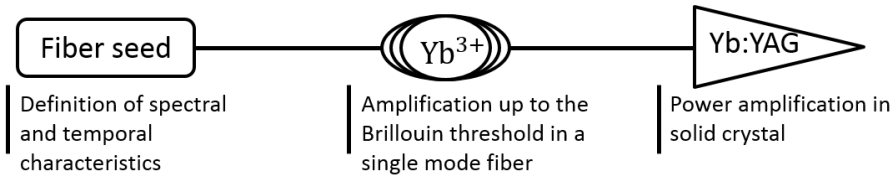


Fig. 1. Overall representation of the hybrid amplification chain

1. Ytterbium fiber doped amplifier

The first amplification stage is composed of an optical circulator, an amplifying fibre, an acousto-optic modulator (AOM) and a retroreflector (Fig2).

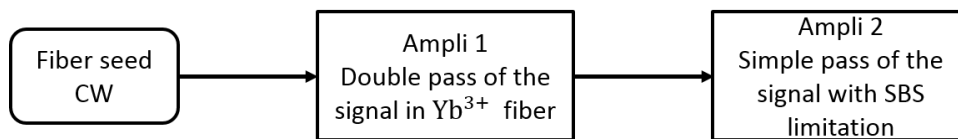


Fig. 2. Overall representation of the Ytterbium fiber amplification chain

The goal for the fiber stage is to generate energetic pulses, a few μJ , at 5 kHz. The idea is to be able to generate energy pulses, a few μJ , from a continuous signal of average power $250 \mu\text{W}$ in continuous wave. For this reason, the circulator/retroreflector torque allows the signal to pass twice through the doped fiber, which significantly increases the gain in pulse mode. The injection signal is amplified in a 1.3 m long doped fibre and pumped by a DFB butterfly diode at 976 nm, delivering 700 mW. In single pass, we obtain a gain of $G_1 = 32 \text{ dB}$. The gain in the amplifier fiber is fixed by the first signal passage through it. If the amplified signal is directly re-injected into the fiber during the second pass, the amplification saturates. This does not allow the maximum use of the potential performance of the amplification. The fact of placing, directly at the output of the amplifying fiber, an acousto-optique modulator (AOM) is reflected for this. First, it allows to create pulses with durations and repetition rate desired, and to re-inject into the fiber lowered average powers. Indeed, the gain established during the first pass is reused when the signal is returned. This means that the energy of the pulses at the input of the second passage increases by the factor G_1 . Thus, the output energy of the first stage approaches 40 nJ, with pulses of 15 ns and a repetition rate of 5 kHz.

Following this, a second AOM is used at the amplifier output, to eliminate as much as possible the amplified spontaneous emission (ASE). A second amplification stage is placed in series. Composed of a 0.9 m long fibre, we achieve pulse energy of $1.6 \mu\text{J}$, with a signal/ASE ratio of 95%, as the intended objective.

2. Yb:YAG cristal bulk amplifier

To overcome the SBS limitations of fiber amplifier, it is possible to amplify the signal resulting from the amplification of the section 1 in Yb:YAG crystals. The final amplification is performed by the crystal-based amplifier of Yb:YAG [3], shown in Fig.3 (left). The seed is the one presented in the section 1 limited to an energy of 300 nJ. A first stage is optimized to maximize the gain of the double pass signal. Thanks to a continuous pump of 80, it makes it possible to obtain gains of 435 in double flow, or energies of $70 \mu\text{J}$.

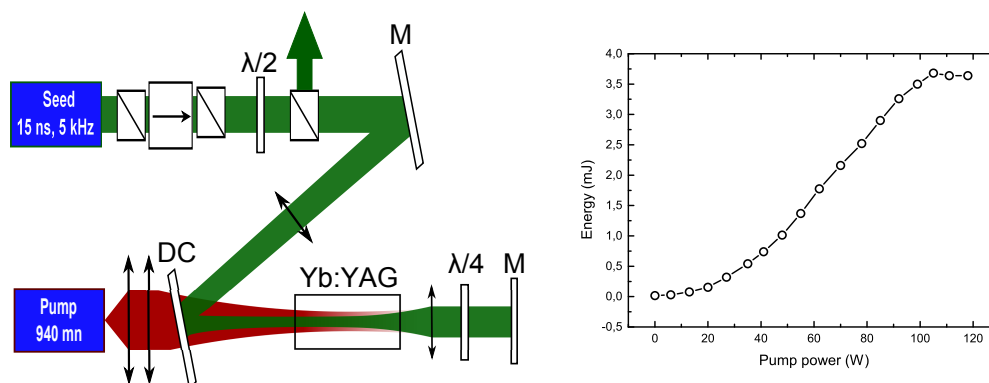


Fig. 3. Representation of the amplification chain based on Yb:YAG crystal (left). The signal beam path is shown in green, and the pump path in red. DC : Dichroic Mirror. Pulse energy of the signal at the double-pass amplification output, depending on the pump power for an injection of $70 \mu\text{J}$ (right).

A second stage, pumped by a 120 W continuous wave diode, is then placed at the exit of the first stage. Thanks to this last amplification stage, we obtain energies of 3.5 mJ with $70 \mu\text{J}$ as input (Fig.3 (right)).

Conclusion and perspectives

We have demonstrated the interest of MOPA hybrid for energy pulse generation, narrow linewidth at 1030 nm. Pulse optimizations will be presented to reach 10 mJ. The use of this source to pump an OPA stage will be presented at this conference.

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