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To cite this version:

HAL Id: hal-00691664
https://hal-iaos.archives-ouvertes.fr/hal-00691664
Submitted on 26 Apr 2012

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High-efficiency multipass Ti:sapphire amplifiers for a continuous-wave single-mode laser

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Received May 1, 1990; accepted October 19, 1990

We present the amplification of a continuous-wave single-mode ring dye laser in Ti:sapphire. A peak gain of \(2 \times 10^6\) has been obtained in a passive multipass amplifier, which yielded 20-nsec pulses of 0.7-mJ energy at 780 nm. We discuss the advantages of this passive multipass amplifier in comparison with a regenerative amplifier that we have also developed. By second-harmonic generation we used the region where the absorption is maximum, i.e., 0.48 cm\(^{-1}\) at 532 nm (corresponding to an effective absorption of 70%). The propagation of the pulses illustrates the principle of an unstable cavity. At each pass, the beam is moving away from the optical axis of the cavity. The number of passes (six in our experiment) can be adjusted by translating a plane mirror along the X axis as shown in Fig. 1. The crystal is pumped by the second harmonic of a Q-switched Nd:YAG laser (B.M. Industries, Evry, France) to produce 6-nsec (FWHM) pulses at a 50-Hz repetition rate. The spatial profile of the frequency-doubled beam is Gaussian, while the temporal profile corresponds to that of a noninjected Q-switched Nd:YAG laser. The beam is focused by a 1-m focal-length lens into the Ti:sapphire. Owing to the Brewster incidence in the Ti:sapphire, the beams are elliptical inside the crystal. The minimum and maximum pump-beam diameters are 1 and 1.7 mm, respectively, while the amplified beam diameters are 300 and 510 μm (determined with a homemade beam profiler) and remain constant over all the passes.

Because of the relatively small angle of the amplified beams in the crystal, the spatial overlap is quite good along the 2.5-cm length of Ti:sapphire. Such a multipass amplifier could be designed with only two concave mirrors. However, the alignment of this amplifier is easier with four mirrors. Furthermore with the two-mirror configuration we observed a laser effect between the two facing mirrors, while this effect has been avoided with the four-mirror amplifier. The average input power of the continuous-wave beam is...
MHz, which corresponds to the inverse of the pulse.

Even if the amplified beam diameter is larger than the pump-beam diameter in comparison with the amplified beam fluence of 0.6 J/cm$^2$ in the crystal, which is close to the saturation fluence of Ti:sapphire. This explains the gain saturation in the crystal and the short amplified pulse duration.

The amplifier does not affect the spatial beam profile of the dye laser, and the amplified beam remains a perfect Gaussian beam. This can be explained by the larger pump-beam diameter in comparison with the amplified beam diameter. No significant amplified spontaneous emission has been observed. In fact, we did not observe any signal on a fast photodiode when we blocked the input beam. Consequently, we did not observe any feedback light from the amplifier, and the dye laser remained locked on a single mode.

Owing to the absence of amplified spontaneous emission and considering that the multipass amplifier does not present a longitudinal mode, the amplified pulses are expected to remain single mode. Even if the linewidth of the pulses has not been measured directly, it can be estimated to be of the order of 20 MHz, which corresponds to the inverse of the pulse duration.

The amplified pulses are tunable from 700 to 800 nm. This range is limited by the injection dye laser, but the gain is wavelength dependent.
high gain in a Ti:sapphire crystal of single-mode near-infrared emission. A passive multipass amplifier has also been studied. The results are similar, but the single-mode dye-laser operation is easier with the multipass amplifier, whereas the pump efficiency is higher with the regenerative amplifier.

We think that this kind of amplifier configuration can be upgraded to produce higher energy and will replace the dye amplifiers in the near infrared. By using laser diodes instead of dye lasers, these all-solid-state systems could be an alternative to dye systems. Furthermore these amplifiers can be used to amplify picosecond or femtosecond pulses,\(^\text{10}\) which shows their great versatility.

The authors thank Gilles Brassart (B.M. Industries, Evry, France) for stimulating discussions, encouragements, and the loan of part of the equipment for the experiments. The research of Frederick Estable is supported by a fellowship from B.M. Industries and the Association Nationale de la Recherche Technique. At the time of these experiments Patrick Georges was also with the Ecole Polytechnique Feminine, Sceaux, France.

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