Compact Fibre-Laser-Pumped Ho:YLF Oscillator-Amplifier System

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Ho:YLF is an attractive laser material for 2 µm high energy sources since it has a much longer upper laser level lifetime (~14 ms) and higher emission cross section than Ho:YAG. In addition, the very weak thermal lens on the σ-polarisation helps to deliver diffraction limited beams even under intense end-pumping. However, Ho:YLF has a somewhat stronger quasi-three-level nature, which implies that in order to reach transparency at the 2065 nm line, 22% of the Ho ions need to be pumped into the upper laser level (at room temperature), but it already reaches transparency at the 1940 nm pump wavelength with only 56% of the Ho ions in the upper laser level. In addition, the pump absorption cross section at 1940 nm is relatively low and strongly polarised. Therefore, the laser design requires a trade-off between efficient pump absorption and low laser threshold.

Efficient fibre-laser-pumped Ho:YLF oscillators have previously been demonstrated [1], but to scale the output energy further, an oscillator-amplifier system can be employed. The traditional approach when pumping an oscillator-amplifier system with one fibre laser pump source is to split the unpolarised pump beam into two polarised beams in order to pump the oscillator and amplifier crystals separately [2]. In our novel approach, we used the full unpolarised pump beam from our 82 W Tm-fibre laser to pump a relatively short oscillator crystal (30 mm long, 0.5% doped), which absorbs roughly half the pump power under lasing conditions, mainly on its π-polarisation . The transmitted pump power is subsequently used to pump the amplifier crystal (50 mm long, also 0.5% doped), as illustrated in Figure 1. We orientated the c-axis of the two crystals perpendicular to each other, in order to optimally utilise the unpolarised pump light and to facilitate lasing on the σ-polarisation (with the weak thermal lens) in the oscillator, while amplifying on the stronger π-polarisation. The distances between the pump fibre collimator and the crystals were kept short to minimise atmospheric water absorption at 1940 nm. This enabled us to work without any enclosure or dry-air flushing.

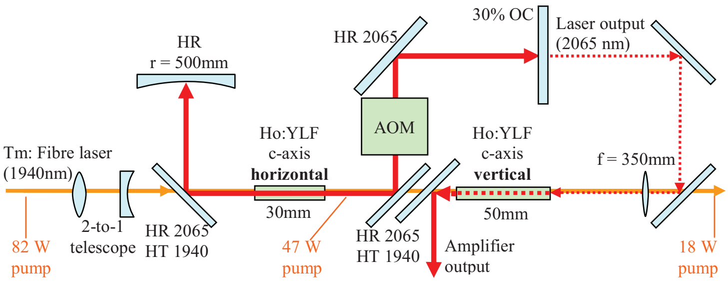

Fig. 1 A schematic diagram of the compact fibre-laser-pumped Ho:YLF oscillator-amplifier system.

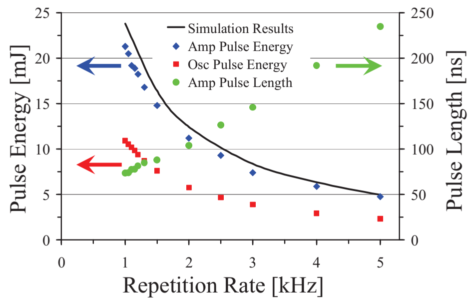

Fig. 2 Output energy of the Ho:YLF oscillator, and of the oscillator-amplifier system.

The 370 mm long oscillator, initially operated CW, had a threshold of 31 W (17 W absorbed) of pump power, an overall slope efficiency of 25% (47% vs. absorbed power), and a maximum average output power of 12.4 W at a centre wavelength of 2065 nm. The oscillator was subsequently Q-switched with an acousto-optic modulator at repetition rates of 5 kHz down to 1 kHz, which resulted in a maximum pulse energy of 10.9 mJ, as indicated in Figure 2. Lower repetition rates were not attempted in order to keep the intra-cavity energy density below the damage threshold of the two 45° dichroic pump mirrors.

After passing the laser output through the amplifier crystal, the slope efficiency of the system increased to 47%. The maximum pulse energy at 1 kHz was 23.7 mJ in a FWHM pulse length of 74 ns. This gain factor of 2.2 was not much less than the measured maximum small-signal gain of 3.3. The beam quality of the amplified beam had an M^2 of better than 1.1. The amplified energies agreed well with the predicted values from a two dimensional rotational symmetric amplifier model that we have developed (solid line in Figure 2). The model considers upconversion losses and ground-state depletion, as well as the spatial distribution of the pump beam.

In conclusion, we demonstrated a Ho:YLF oscillator-amplifier system in a compact setup which efficiently utilises the unpolarised power from a fibre laser. The system produced more than 23 mJ energy per pulse at 1 kHz, while maintaining an M^2 of better than 1.1. These results agreed well with our amplifier model.

References

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