# Sub-Nanosecond Passively Q-Switched Multi-kHz MOPA Laser System

**A. Agnesi, P. Dallocchio, C. Di Marco, F. Pirzio, G. Reali**

*Dipartimento di Elettronica dell'Università di Pavia, IT- 27100 Pavia, Italy*

Many industrial and scientific applications require extremely short (< 1 ns) high peak power (> 100 kW) laser pulses. A sub-ns passively Q-switched composite Yb:YAG/$Cr^{4+}$:YAG microchip laser was reported recently, operating at up to 3.5 kHz with 175 μJ pulse energy [1]. Owing to extremely high intracavity power density and reliability issues, a different approach relying on a moderate-energy high-frequency oscillator and a single amplifier stage looks more flexible and power-scalable.

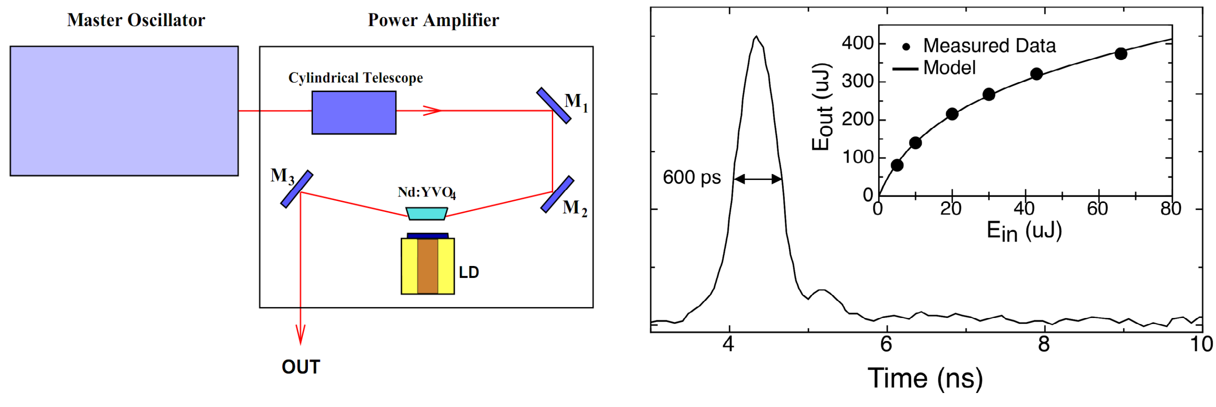
In this work we present a sub-nanosecond passively Q-switched multi-kHz laser system in a Master Oscillator Power Amplifier (MOPA) configuration. The system setup is shown in Fig. 1(a).

The master oscillator was a $Cr^{4+}$:YAG passively Q-switched Nd:YAG laser, longitudinally pumped by a pulse-driven 40-W diode laser array. By a proper choice of $Cr^{4+}$:YAG unsaturated transmission and output coupling we obtained in a 10-mm long, plane-concave resonator up to 66-μJ, 600-ps long pulses (see Fig. 1(b)). Diffraction-limited and single-longitudinal mode operation was observed up to the maximum repetition frequency of 10 kHz.

Owing to the good overlap between Nd:YAG and Nd:$YVO_4$ gain bandwidths, we can exploit both materials' favourable characteristics taking advantage of Nd:YAG physical properties for an efficient passively Q-switched oscillator and design a simple compact, grazing-incidence Nd:$YVO_4$ amplification stage [2–4].

The amplification medium was a 4 × 2 × 15 $mm^3$, 1% doped, 6° wedged slab with input and output beam faces antireflection-coated at 1064 nm and the pumped side AR-coated at 808 nm. The slab was pumped by a 40-W cw diode laser array, tuned at 808 nm and collimated by a microlens, yielding a vertical gain sheet of about 300 μm. The 4 × 15 $mm^2$ faces of the slab were placed in contact, by thin indium foils, with a water-cooled heat exchanger. In order to optimize the energy extraction both the incidence angle and the seed beam waist inside the amplifier medium must be properly controlled. The optimization of the energy extraction efficiency and the control of the thermal aberrations was achieved by carefully matching the mode size of the injected seed to the amplifier gain sheet dimensions. For that reason the transverse seed spot needed a different focusing along the vertical and horizontal axes using a cylindrical telescope. The grazing angle has been chosen to be as small as possible in order to maximize the gain while avoiding clipping effects.

As shown in Fig. 1(b) (inset) at a maximum energy injection of 66 μJ, we obtain up to 375 μJ pulse energy corresponding to an average power as high as 3.75 W at 10 kHz repetition rate. No distortions in the pulse shape and in the beam quality has been observed. Single-pass small-signal gain was ≈ 26 at 10 kHz.




(a) (b)

**Fig. 1** **(a)** Laser system setup: M1, M2, M3: turning mirror; LD: laser diode. **(b)** Oscilloscope trace of the laser pulse at 10 kHz and output pulse energy versus input pulse energy of the power amplifier stage (inset).

## References

[1] J. Dong, K. Ueda, A. Shirakawa, H. Yagi, T. Yanagitani, and A. Kaminskii, "Composite Yb:YAG/$Cr^{4+}$:YAG ceramics picosecond microchip lasers," Opt. Express **15**, 14516 (2007).
[2] J. E. Bernard and A. J. Alcock, "High-efficiency diode-pumped Nd:$YVO_4$ slab laser," Opt. Lett. **18**, 968 (1993).
[3] T. Omatsu, K. Nawata, D. Sauder, A. Minassian, and M. J. Damzen, "Over 40-watt diffrcation-limited Q-switched output from neodymium-doped YAG ceramic bounce amplifiers," Opt. Express **14**, 8198 (2006).
[4] A. Agnesi, L. Carrà, F. Pirzio, G. Reali, A. Tomaselli, D. Scarpa, and C. Vacchi, "Amplification of a low-power picosecond Nd:$YVO_4$ laser by a diode-laser side-pumped grazing-incidence slab amplifier," IEEE J. of Quantum Electron. **42**, 772 (2006).

978-1-4244-4080-1/09/$25.00 