

A FUNDAMENTALLY MODE-LOCKED Yb-ER CO-DOPED FIBER LASER WITH A REPETITION RATE OF 860 MHz

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We report on the development of a passively mode-locked Yb-Er co-doped fiber laser with a repetition frequency, f_{rep} , of 860 MHz. The laser, centered at $1.54 \mu\text{m}$, exhibits a single pulse per round trip and is free of Q-switching.

Keywords: Ytterbium; Erbium; Mode-locked laser; Fiber laser.

High repetition rate mode-locked lasers are advantageous in experiments requiring large mode spacing between comb elements, such as Fourier transform spectroscopy, frequency metrology and telecommunication applications. The high repetition rate laser described here uses a gain medium of phosphosilicate fiber co-doped with Yb and Er ions and has a core-pumped geometry. This fiber's application to mode-locked lasers appears rather infrequently. In one instance the Yb-Er fiber laser contained a semiconductor saturable absorber mirror (SAM),¹ where a fundamental f_{rep} of 295 MHz was achieved. In another development the saturable absorber is formed from single-walled carbon nanotubes,² where f_{rep} = 5 GHz was produced. While this approach seems very promising, the robustness of the carbon nanotubes needs to be improved before mode-locked lasers based on the technology become reliable.³

The laser here is composed of 8 cm of Yb-Er co-doped fiber spliced to 2.5 cm of single-mode fiber (SMF). A standing wave cavity is formed between a SAM at one end and a partially reflective (95%) mirror at the input of the Yb-Er fiber, which acts as the output coupler. The light exiting the SMF is collimated, then focused by a second lens onto the SAM, where the spot size is $\sim 2.0 \mu\text{m}$ in radius. The gain fiber is driven by an optically pumped semiconductor laser with $\lambda = 977 \text{ nm}$. The optical power reaching the fiber laser cavity is $\sim 380 \text{ mW}$.

The SAM has a modulation depth of ~ 0.1 to facilitate mode-locking.

Its saturation fluence is $\sim 25 \mu\text{J}/\text{cm}^2$, relaxation time constant $\sim 2 \text{ ps}$, non-saturable loss $\sim 10\%$, and the group delay dispersion is $\sim -2000 \text{ fs}^2$ at 1540 nm . Dispersion measurements of the Yb-Er fiber give $\beta_2 = +14.0 \pm 0.2 \text{ ps}^2/\text{km}$ at 1540 nm . Combined with the dispersion of the SMF and the SAM, the net group delay dispersion of the laser is $\sim -660 \text{ fs}^2$.

Fig. 1a shows a train of pulses emitted from the Yb-Er laser. The pulses exhibit constant amplitude indicating cw mode-locked behaviour. The microwave spectrum of Fig. 1b shows the f_{rep} signal and its harmonics out to high frequency. The uniform intensity of the harmonics indicates single pulse per round trip propagation.

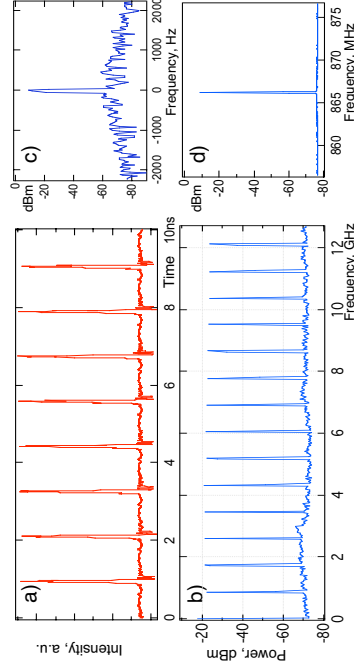


Fig. 1. a) Pulse train from the f_{rep} = 866 MHz Yb-Er fiber laser; b), c) and d) RF spectra of light from the Yb-Er laser with rbw of 3 MHz, 30 Hz and 10 kHz, respectively.

Examining f_{rep} more closely (and offset to 0 Hz) we see the narrow feature shown in Fig. 1c (res. bw = 30 Hz). Fig. 1d displays f_{rep} with a span of 20 MHz, demonstrating the absence of sidebands associated with Q-switching. At present the spectral width of the pulses is limited by the bandwidth of the gain medium and this limits the pulse width to $\sim 1.7 \text{ ps}$. Loss changes to the cavity have had little influence of the spectral output, however, attempts at gain flattening with filters may prove to be an effective means of manipulating the spectral width.

References

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