CThJ 1500

Forum

Fibre Lasers

H. N. Rutt, *University of Southampton, Presider*

CThJ1 1500

Single frequency lasers and efficient cladding-pumped lasers using YB^{3+}-doped silica fibre

J. M. Dawes, H. M. Pask,
J. L. Archambault, J. E. Townsend,
D. C. Hanna, L. Reekie, A. C. Tropper,
Optoelectronics Research Centre, University of Southampton, Southampton SO9 5NH, U.K.

Yb^{3+}-doped germanosilicate fibre has been demonstrated to be a versatile host for laser action at wavelengths from 1 to 1.2 μm.[1] It can be pumped at wavelengths from 800–1064 nm, and the emission band extends from 970–1200 nm, including wavelengths of interest for specific applications, e.g., 1020 nm for pumping of 1.3 μm Pr^{3+}-doped fibre amplifiers, 1140 nm for pumping of Tm^{3+}-doped fluoride fibre upconversion lasers, and 1083 nm for optical pumping of ^3He.

The availability of fibre gratings has been a major element in expanding the potential of Yb^{3+}-doped fibre devices.[2] The present work is based on Yb^{3+}-doped germanosilicate fibres, fabricated by the MCVD technique. This host is photosensitive so that gratings can be written directly into the Yb^{3+}-doped fibre core.

We have previously reported efficient (up to 60% slope efficiency with respect to absorbed power) operation at 1020 nm and 1140 nm using fibre gratings and pumped respectively at 840 nm (with the output from a Ti:sapphire laser) and 1047 nm (with the output from a Nd:YLF laser). While the efficiency with respect to absorbed power was high (~60%), the overall conversion efficiency of pump light for these devices is ~30–40%, limited largely by the launch efficiency of the pump beam into the doped fibre core.

A large improvement in the overall conversion efficiency has been demonstrated through the use of a cladding-pumping scheme; it is envisaged that this fibre laser will ultimately enable very efficient pumping with a semiconductor MOPA. The fibre designed for this work consists of a single-mode doped inner core of 4.25 μm diameter and an outer core (inner cladding) of 12.75 μm diameter. The NA for the inner and outer guides are 0.16 and 0.15, respectively. Ytterbium was added by solution doping and the concentration was measured to be ~500 ppm. The pump source was a Ti: sapphire laser operating at 974 nm, launched into the fibre using a ×5 microscope objective, in order to simulate the focal spot size, which would be produced by a semiconductor MOPA focussed within the acceptance angle of this fibre. Very efficient performance (up to 80% slope efficiency with respect to incident power) at 1020, 1040, and 1140 nm was obtained.

Single-longitudinal mode operation of Yb fibre lasers has also been demonstrated, at 1083 nm. The fibre used for this work had an Yb^{3+} concentration of ~2000 ppm, NA ~ 0.28, and cutoff wavelength ~1000 nm. Stable single-frequency operation at 1083 nm was obtained using a 5.6-cm-long cavity formed by two gratings with 92% and 60% reflectivity. The grating bandwidths at full-width half maximum were 0.25 nm. Pump light at 970 nm was launched into the cleaved end of the 92% reflectivity grating pigtail (~1 cm long) and laser action at 1083.0 nm on a single longitudinal mode occurred with a threshold of ~12 mW pump light incident on the launch objective. Single-frequency operation was verified using a scanning confocal Fabry–Perot interferometer with 7.5 GHz free spectral range (FSR) and instrument-limited bandwidth of ~200 MHz. The FSR of the laser was ~1.8 GHz. The slope efficiency for these initial measurements was ~6% with respect to launched pump power, and significantly improved efficiency is anticipated in an optimised system.

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2. J. Y. Allain, J. F. Bayon, M. Monerie, P. Bernage, P. Niay, Electron. Lett. 29, 309–310 (1993).

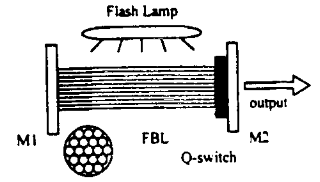
CThJ2 1515

Passively Q-switched flashlamp-pumped ND:glass fiber-bundle laser

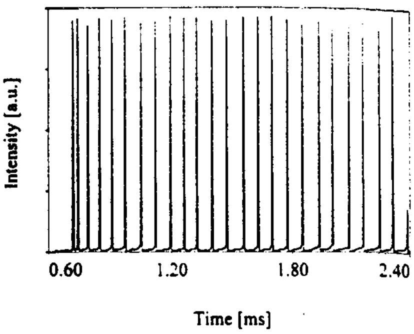
U. Griebner, R. Grunwald, R. Koch, *Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie Rudower Chaussee 6, D-12489 Berlin, Germany*

Fiber-bundle lasers (FBL) are known as a special kind of solid-state lasers with spatially separated partial gain media.[1,2] Because of the faster heat exchange in comparison to monolithic laser architectures, they allow to reach significantly higher pump levels as well as high pulse repetition frequencies (PRF). We report on advanced FBL schemes with solid-state Q-switching elements for the first time. Peak powers in the range of 100 kW have been produced.

Using a single Cr^{4+}:YAG crystal inside a Nd:glass FBL laser cavity, we demonstrated *simultaneous saturable absorber Q-switching of all fibers* in the bundle. The generation of high peak power in Q-switched fiber lasers requires the optimization of different fiber parameters like the fiber length and the dopand concentration. The best results have been obtained with short and highly doped fibers. In the most typical case, we used phosphate glass fibers doped with 9.0 wt% Nd_2O_3 in the core—what is about two orders of magnitude higher than in silica-doped fibers—and without doping in the cladding (Kigre Q-100 preforms). The drawn fibers are of multimode structure (d_{core} = 100 μm, d_{clad} = 140 μm) with a numerical aperture of 0.15. The fibers have been waterproof bunched at the ends in glass cylinders and spread out in the middle thus allowing a fast water flow for cooling. The absorption at the laser wavelength λ = 1.053 μm has been



CThJ2 **Fig. 1.** Schematic diagram of the compact passively Q-switched fiber-bundle laser (FBL).



CThJ2 **Fig. 2.** Sequence of fiber-bundle laser Q-switched pulses for a pump pulse duration of 2 ms.

determined to be ≤4 dB/m. An active length of 13 cm (total fiber length 23 cm) has been side-pumped by two flashlamps within a diffuse reflecting cavity. The experimental arrangement is shown in Fig. 1. The polished and AR-coated end faces of the FBL were in contact with the outcoupling mirror (R = 30%) at one side and the Q-switch crystal at the opposite side. The Cr^{4+}:YAG disk was 1 mm thick and had a diameter of 10 mm. The surfaces of the crystal were antireflection coated for 1.053 μm, and the initial transmission at 1.053 μm was measured to be 59%.

As we could show, rare-earth-doped fiber lasers have the capability to operate as high-gain devices. The small-signal gain coefficient g_0 has been measured to be 0.34 cm^{-1} at a pump energy of 160 J.

The flashlamp pulse duration was tunable in the range of 1–4 ms with a PRF up to 100 Hz. During the lamp pulses, the FBL exhibited repetitive Q-switching separated by 20–80 μs in dependence on the pump rate. By adjusting the pump power, periodic Q-switched operation could be established with only 5% pulse to pulse fluctuations as shown in Fig. 2.

The FBL consisting of 150 fibers generates synchronous Q-switched pulses with a duration of approximately 35 ns and pulse energies of 3 mJ (Fig. 3). For a passive Q-switched single fiber under comparable conditions, the power density has been measured to be about 7 MW/cm^2. The switching behaviour indicates that the synchronisation of the Q-switch is caused by an energetic coupling between the fibers in the bundle. The intensity of the Q-switched pulse is modulated at the round-trip frequency. The depth of the observed modulation is limited by the temporal resolution of the detection system so that the maximum power density can be significantly higher.