LASERLAB-EUROPE

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Deliverable D33.27

"Report on high brightness pump source of up to 100 W average power"

Lead Beneficiary: CELIA

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Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

A. Abstract / Executive Summary

We report on the demonstration of various fiber laser architectures specifically designed to deliver high power (100 W) diffraction limited beams in the continuous wave regime at the particular wavelength of 976 nm. These architectures are based on Yb-doped fibers operated on the 3-level scheme.

B. Deliverable Report

1 Introduction

Rare earth Yb ions are the only elements to provide an emission line at 976 nm with the advantage of being optically pumped by laser diodes. However, this emission line corresponds to laser operation in a 3 level system with strong reabsorption. As a consequence, it is very hard to operate an Yb system at 976 nm. Pioneering works with bulk materials have demonstrated 1.4 W at 985 nm with Nd:YVO4/Yb:S-FAP crystals.

Fibre technology is probably the only promising solution for the high power operation of Yb at 976 nm. By using a double clad elliptical fiber wave guide, a diffraction limited beam of 1 W at 978 nm has been obtained. The associated brightness of 100 MW/cm²/sr is comparable to single mode laser diodes. Later on, by reducing the clad diameter a maximum power of 3,5 W at 977 nm has been demonstrated in a single mode beam (B = 370 MW/cm²/sr).

These works were limited by the small diameter of the outer cladding. Recently, we have designed at CELIA a specialty fiber with an extremely large core and cladding. It turns out that this fiber is indeed very well adapted to an efficient operation at 976 nm. We propose to demonstrate the potential of this fiber to deliver either narrow band or broadband emission around 976 nm in a diffraction-limited beam ($M^2 < 1.3$).

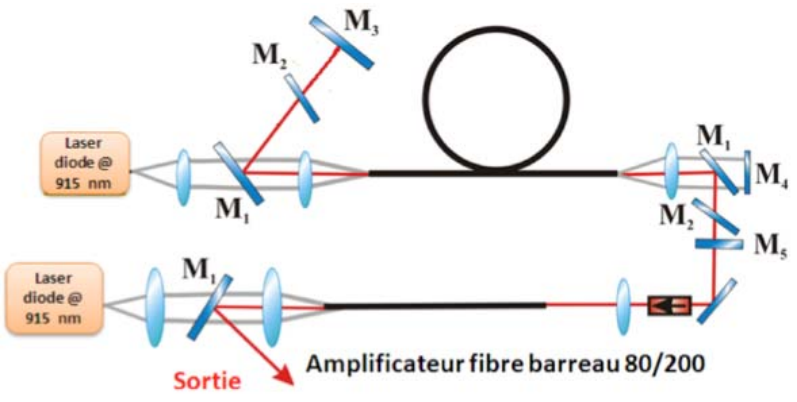
2 Objectives

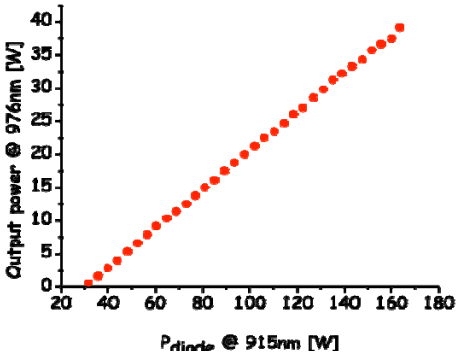
The objectives are many-fold. Not only the average power is important, but also the beam quality and stability requires particular attention. Depending on the laser material optically pumped by such source, we may use a single frequency or narrow band laser or a large bandwidth pump typically originating from amplified spontaneous emission.

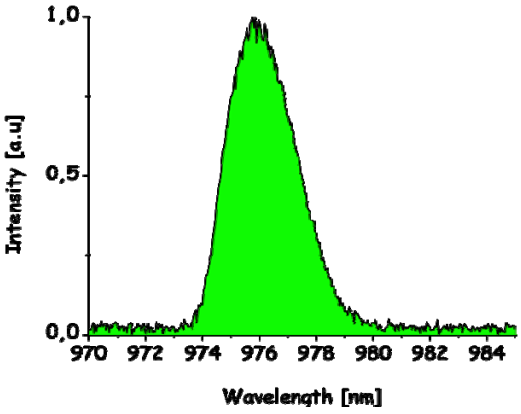
3 Work performed / results / description

Two types of architectures have been investigated. On the one hand, we have continued our studies based on the rod-type fiber in order to optimize the beam output. On the other hand, we use a commercial product from a spinoff company exploiting our technology.

Microstructured fibers: a typical architecture is given in the sketch below. A half cavity allows generating a seed consisting of amplified spontaneous emission (ASE). The seed if further amplified in a microstructured fiber (rod-type) whose geometry is optimal for operation at 976 nm. The rod-type fiber is optically pumped by a multimode diode emitting at 976 nm. Although, a 100 W of average power can be extracted in this configuration, the beam quality degrades considerably above 40 W average power. In fact, the lower wavelength emitted by the fiber propagates in a waveguide that is slightly multimode (as compared to operation at 1030 nm). Therefore this configuration is operated below 40 W for an optimal beam quality efficiently used for optical pumping of Yb-doped crystals. The efficiency curve and spectrum is given below.







Flexible fiber: thanks to a close collaboration with the spinoff company Azur Light System, we also use a commercial "custom" pump source emitting a narrow bandwidth at 976 nm. The system is very compact as it is based on a flexible fiber with comparable opto-geometrical parameters as the rod-type fiber. Since the core is much smaller, the fiber is intrinsically single mode and delivers a beam with a M^2 of 1.1. However, the clad diameter is also small limiting the injection of high power pump diodes. The output average power is therefore limited to 15 W.

Combining: actual specific fibers developed so far have shown limitations in average power due to either a small clad (limiting pump power) or a too large core (leading to mode beatings). The road to the 100 W level will therefore imply coherent combining of two channels based on either fiber. Combining has been demonstrated with such fibers at 1030 nm. Work is ongoing to demonstrate the combining at 976 nm and the achievement of more than 100 W with a transform-limited beam within the next 12 months.

4 Conclusions

We have demonstrated different architectures based on Yb-doped fiber laser operated at 976 nm. More than the actual average power, the brightness is the parameter of interest for efficient optical pumping. We have demonstrated so far a brightness of 2300 $MW.cm^{-2}.sr^{-1}$ with a microstructured rod-type fiber (40 W) and 1300 $MW.cm^{-2}.sr^{-1}$ with a flexible fiber (15 W). Increased power/brightness up to 100 W will require beam combining. It is planned for the next 12 months.

5 References/Publications

Peer reviewed publications

(1) **"High-gain amplification in Yb:CaF2 crystals pumped by a high-brightness Yb-doped 976 nm fiber laser"**
G. Machinet, G. Andriukaitis, P Sévillano, J. Lhermite, D. Descamps, A. Pugžlys, A. Baltuška and E. Cormier
Appl. Physics B **111**, 495 (2013)
DOI 10.1007/s00340-013-5363-z - no open access

(2) **"High-brightness fiber laser pumped 68 fs-2.3 W Kerr-lens mode-locked Yb:CaF_2 oscillator"**
G. Machinet, P. Sevillano, F. Guichard, R. Dubrasquet, P. Camy, J.-L. Doualan, R. Moncorgé, P. Georges, F. Druon, D. Descamps and E. Cormier
Optics letters **38**, 4008 (2013)
http://dx.doi.org/10.1364/OL.38.004008 - no open access

Communications in international conferences

(1) "High power, linearly polarized, continuously tunable ytterbium-doped rod-type photonic crystal fiber laser"
R. Royon, J. Lhermite, L. Sarger, E. Cormier
Specialty Optical Fibers (SOF 2012), [**SW2F.2**] 17-20 June 2012, Colorado Springs, CO (USA)

(2) "Single frequency, ultra-low noise, CW, 4W 488nm fiber laser"
R. Dubrasquet, J. Boullet, S. Lugan, G. Mery, N. Traynor, E. Cormier,
Photonics West, [**8601-37**], 2-7 February 2013, San Francisco CA (USA)

(3) "Sub-70 fs Kerr-lens mode-locked Yb:CaF2 laser os- cillator delivering up to 2.3 W"
P. Sévillano, G. Machinet, F. Guichard, R. Dubrasquet, P. Camy, J.L. Doualan, R. Moncorgé, P. Georges, F. Druon, D. Descamps, and E. Cormier
Conference on Lasers and Electro-Optics Europe (CLEO-EQEC)[**CA-6.4 TUE**], 12-16 May, 2013, Munich (Germany)

(4) "fs mode-locked fiber laser continuously tunable from 976 nm to 1070 nm"
R. Royon, J. Lhermite, L. Sarger, and E. Cormier
Conference on Lasers and Electro-Optics Europe (CLEO-EQEC) [**CJ-6.1 WED**], 12-16 May, 2013, Munich (Germany)

(5) "Kerr-lens mode-locked Yb:CaF2 laser oscillator delivering sub-70 fs pulses with 2.3 W average power"
P. Sévillano, G. Machinet, F. Guichard, R. Dubrasquet, P. Camy, J.L. Doualan, R. Moncorgé, P. Georges, F. Druon, D. Descamps, and E. Cormier
Int'l Conference on Coherent and Nonlinear Optics (ICONO'LAT 2013) [**53806**], 18-22 June 2013, Moscow (Russie)

(6) "Frequency-doubled Yb-doped fiber laser to produce picosecond pulses with 20 W average-power at 489 nm "
J. Lhermite, R. Royon and E. Cormier
Int'l Conference on Coherent and Nonlinear Optics (ICONO'LAT 2013) [**53832**], 18-22 June 2013, Moscow (Russie)