A universal all-in-fiber coherent light source at wavelength 1550 nm and output power 5 W

Paweł R. Kaczmarek,* Grzegorz Soboń, Adam Wąż, Grzegorz Dudzik, Arkadiusz J. Antończak, Krzysztof M. Abramski

Laser and Fiber Electronics Group, Wroclaw University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland,

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Abstract—In this paper we present a fiber-based coherent light source operating at 1550nm wavelength and 5W of the output power. It utilizes the Master Oscillator Power Amplifier scheme of operation. This allowed to get a universal design which can work in a couple of different operation regimes: CW, pulsed and wideband ASE generation. The all-in-fiber construction makes it compact and environmental conditions resistant.

Fiber sources of coherent radiation become an attractive alternative to traditional, solid state lasers which have been used up to now. Over the recent years, a significant increase in available output power levels could be observed and use of medium to high power fiber lasers is getting more and more common in a variety of industries [1]. Medium to high power fiber sources can be produced in two main ways. The first approach (classical) consists in building a high power fiber laser. This design is a natural development of the concept of solid state lasers and works well in the case of CW sources. Pulse lasers usually require the use of bulk optical elements, which makes it hard to build fully fiber devices. High energy densities in the fiber can lead to unfavourable non-linear effects which are hard to eliminate [2]. Simultaneous control of multiple parameters of generated radiation is also very difficult. This can be overcome by another property of active fibers - the high gain. Fiber optics technology makes it possible to build a high power source using a low-power signal laser, with radiation amplified in a cascade of fiber amplifiers. This is the MOPA (Master Oscillator Power Amplifier) configuration. The control of almost all high power radiation parameters is implemented through the control of a low power signal laser which is far easier than direct control of the parameters of a high power laser. Many low power, tuneable, narrow bandwidth lasers are available, both for continuous operation and for pulse operation with gain switching or mode locking, which are perfectly suitable as radiation sources for MOPA configuration. Additionally, such a cascade of amplifiers can be successfully implemented in traditional applications of fiber lasers, wherever an appropriately high output power is required - (standard WDM systems [3], passive optical networks PON [4], deep space optical communications [5] or CATV amplifiers [6]).

The proposed device was intended to be flexible and to operate both in the CW and pulse regime, which is relatively easy in the MOPA approach. The required output power in CW mode was 5W, which imposes the need to build a two stage cascade of amplifiers [7]. The block diagram of the device is shown in Fig. 1.

A telecommunication standard DFB laser with an output power of 10mW and wavelength 1550nm was used as the seed for the MOPA configuration.

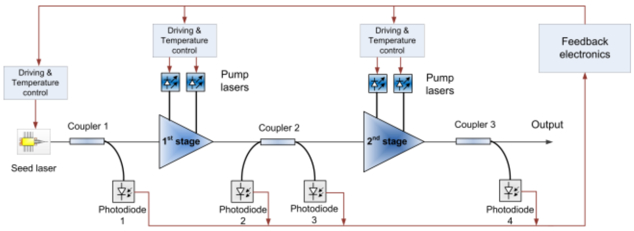

Fig. 1. Block diagram of the device.

The first stage of our system is a standard fiber amplifier based on erbium doped fiber pumped bidirectionally by two 980nm laser diodes in the configuration shown in Fig. 2. The output power of this stage is about 150mW, which is sufficient to drive the next stage of the MOPA – booster amplifier. Additionally, in the case of operation, as the broadband ASE source, the first amplifier operates without a seeding signal and acts as a seed itself, generating wideband optical noise with power of tens of mW.

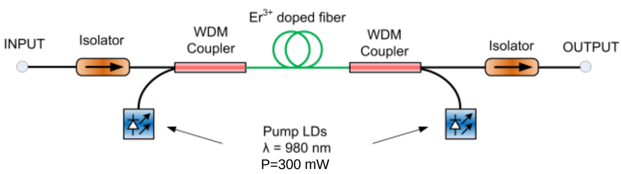

Fig. 2. The first amplification stage.

* E-mail: pawel.kaczmarek@pwr.wroc.pl

The second amplifying stage is the booster stage shown in Fig. 3. It is based on a singlemode double clad optical fiber codoped with erbium and ytterbium. Active fiber is pumped with two 10W multimode fiber pigtailed diodes through a power combiner. The configuration of this stage is shown in Fig. 3. The pumping wavelength is chosen to be 975nm, which is the maximum absorption of ytterbium ions. It allows to use short active fiber in order to minimise nonlinearities in the setup. Unabsorbed in active fiber, the pumping power is dissipated in a mode-striper placed directly on the splice of active fiber with input fiber.

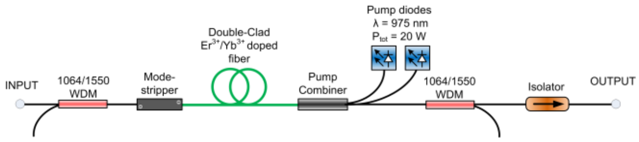

Fig. 3. The second amplification stage – booster.

WDM couplers play an important role in the setup. They are used to extract and dump ytterbium ASE noise from highly pumped erbium/ytterbium doped active fiber. This noise can lead to a heavy thermal load of the output isolator or the spurious lasing at 1060nm as well [9]. This could easily lead to the damage of the device.

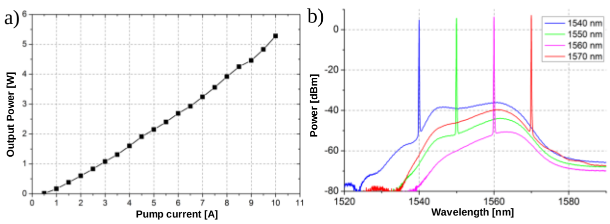

Fig. 4. The booster characteristics: a) Output power vs. pumping current, b) optical spectra for 5W of the output power.

Figure 4 shows the booster stage characteristics. The maximum output power is 5.3W and it is possible to achieve it in the wavelength range of 1540nm to 1570nm. At the output of the device a high power optical isolator is used. It makes the device insensitive to any reflected power from the systems connected to the output of the device. At the output a standard SMF 28 singlemode fiber pigtail without any connector was left. It can spliced to the rest of the setup or ended by a fiber collimator if one wants to have a free space beam at the output.

To provide the required modes of operation and full self-diagnostics, each stage of the MOPA is independently controlled and monitored by a microprocessor control unit. Optical power levels at several points in the system and temperatures of critical components are measured. It allows to fully control output radiation parameters and ensures proper device operation. If the safe working conditions are exceeded the control unit sets off the alarm, turns off the device and signals an error message.

The device can be controlled with a PC connected through an USB interface by the software developed in the LabVIEW enviroment. Figure 5 presents the appearance of the user interface.

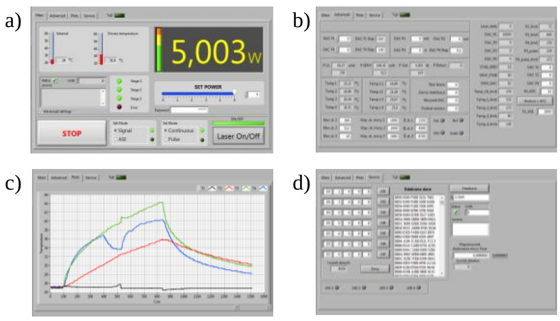

Fig. 5. PC software interface: a) main tab, b) advanced settings tab, c) temperatures graph tab, d) advanced diagnostics tab.

The main window allows one to determine the mode of operation, output power and also displays basic diagnostic messages like status of each stage, temperatures and error messages. The advanced settings window allows to fully control the parameters of each stage such as temperatures of the laser diodes (changing temperature of the seed laser allows to tune its wavelength slightly), constants for calibrating laser drivers, etc. The rest tabs are for diagnostics purposes – temperatures and device to PC transmission monitoring.

The control software allows one to select one of the three modes: CW operation, generation of broadband optical noise and pulsed operation. For CW operation the maximum output power is limited to 5 W, the signal noise ratio better than 45dB. Output power stability is better than 0.5%. The wavelength of generated radiation depends on a seeding laser wavelength and in the present case is 1550nm. It can be fine-tuned by changing the temperature of a seed laser as shown in Fig. 6a - in a range of ±1nm. If one wants to have a different wavelength it can be changed to one in the 1540 nm to 1570 nm range by seed laser replacing.

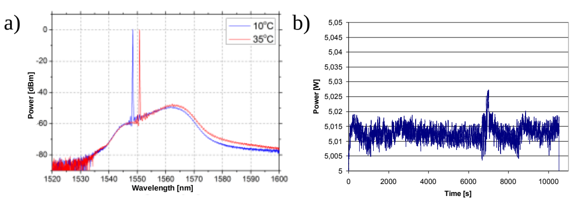

Fig. 6. 5 Watt of the output power CW operation characteristics: a) spectrum of the output signal, b) output power stability graph.

The second mode of operation is the generation of broadband noise. Figure 7 shows the spectrum of the output signals. The source of the signal in this case is the first amplifier stage. The spectrum shape of the generation (flatness etc.) can be slightly tuned by adjusting pumping powers of both amplifiers. Due to the lower level of the input signal to the booster, the device output power in this mode is limited to 3W.

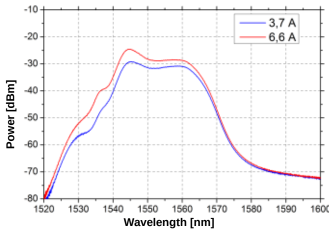

Fig. 7. Spectrum of the output signal in ASE noise mode of operation.

The last mode of operation is pulses generation. They are of 10ns duration with energy >6 µJ and are triggered by an external signal with repetition frequencies from 100kHz up to 1MHz. Time duration can be settled in the 10ns to 50ns range if required. Pulses are shaped in order to avoid distortion and achieve reasonably flat top of output in the cascade of amplifiers [8] so the change of pulse duration must be done by adjusting pulse forming circuits.

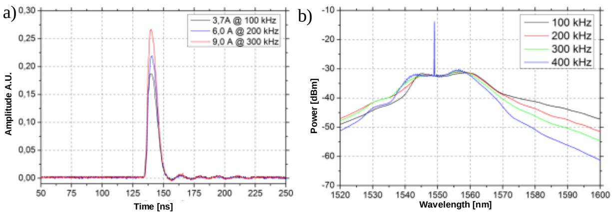

Fig. 8. Pulsed mode of operation: a) pulse shape, b) pulses optical spectrum.

The presented source is of universal design, not optimized for specific applications. However, it can be configured in an easy way and adopted to certain applications. It has a wide range of operating modes and output parameters possible to obtain. Its reliability was proven over a year of utilization in laboratory practice.

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