Review of PhD thesis:

Erbium-doped diode-pumped solid-state lasers generating in mid-infrared spectral range

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Topicality of the subject

This thesis describes an experimental research program on the topical subject of diode-pumped, erbium-doped solid-state lasers generating at wavelengths of around 3 micrometers. Lasers at these wavelengths possess features that are nowadays highly topical in several areas of applications, from medicine (thanks to high absorption in water), nonlinear devices (wavelength conversion), polymer processing to defense. Another beneficial aspect is the relaxed eye-safety measures thanks to the high absorption of the laser light at 3 μm in the vitreous body of the eye so that the risk of retina damage is significantly lowered. The dissertation builds on previous work and experience in the Laboratory of solid-state lasers at the Department of Physical Electronics of the Czech Technical University and broad worldwide collaborations on the topic, indicating the importance and impact of the work in this field.

Methods

In the doctoral thesis, Richard Švejkar provides a comprehensive state of the art as well as sufficiently detailed description of all methods and experimental setup and apparatuses used in the characterization of spectroscopic parameters of the erbium-doped crystals under study and their performance in various laser cavities. It should be pointed out that Richard Švejkar, together with his supervisors, published recently an extensive review on this subject in prestigious journal Progress in Quantum Electronics that is ranked in the first decile of journals in optics. The author has good insight into spectroscopy, crystallography, as well as laser physics and technology. He proved good programming skills in automatization of the measurements and in efficient processing of the measured data. Build-up of an autocorrelator can be mentioned as another example of the authors' experimental skill. The dissertation is well written, the ideas are expressed clearly and accurately. Figures are well-readable. It is evident that the author paid really great care to check the text so that it almost does not contain typos and terminological or stylistic errors.

Originality of the results and scientific impact

The candidate contributed to the development of novel solid-state lasers generating at a wavelength at around 3 µm suitable for various applications, e.g., in medicine, material processing. His results are important also for development of novel laser crystals. For example, he presented the determination of temperature-dependent spectroscopic parameters of several types of crystals, including Er:YAP and Er:GGAG. He demonstrated a significant improvement of the tunability range of more than 120 nm, spanning from 2690 nm to 2813 nm in Er:SrF_2 crystal. He participated in the design, development and characterization of novel laser gain material Er:GGAG. Development of miniaturized microchip lasers is an example of applied research and collaboration with industry. As stated above, his comprehensive study of different laser crystals for 3 µm lasers that was published in a review in the journal Progress in Quantum Electronics will surely receive broad interest within the community of researchers and demonstrate the scientific impact of the investigations done.

Richard Švejkar successfully published the research results in scientific journals (5 papers have been already published) and he presented his results in number of conferences. Apart from this, he participated in several other research works that lead to valuable publications and applied results usable in the photonics industry.

Questions

In connection with the subjects treated in the thesis, I would like to ask the author to answer several questions that follows.

1. On page 26, the results of Q-switched regimes are discussed. While the generation of 29 ns pulses are surely giant pulses, some other lasers generated almost 5-µs-long pulses that might resemble the spiking of more-less sustained train of relaxation oscillations. Could the author comment on his observations of pulsed regimes? For example, he can show comparison of pulse width, pulse energy, and stability of the pulse train of his lasers, at least the two lasers with 29-ns and 5-µs-long pulses.

2. On page 46, the influence of water vapor on pulse width is shortly mentioned. Could the author explain how water vapor can prevent to set the short-pulse (picosecond or even femtosecond) regime of operation? It was only the dry atmosphere that allowed to generate ps-pulses or other measures were applied?

3. The method of fluorescence lifetime determination is based on a single exponential fitting of the measured fluorescence decay curve. Did the author observe also fluorescence decay curves with fast decay components that would require multi-exponential fitting? In Fig 4 in

the paper in Laser Physics Letters 16, 075802 (2019), the fluorescence decay tail bows under the fitting curve. Could the author explain this effect, or it was just because of the calibration of the zero level of fluorescence?

4. The work is focused on erbium lasers at 3 μm but such laser crystals can operate also at 3.5 μm as mentioned in state of the art in Fig. 1(a). In erbium doped fluoride fiber, for example, dual pumping at 0.98 μm by laser diodes and at ~1.95 μm by thulium fiber laser may lead to efficient generation at 3.5 μm. Did the author try to build a similar scheme using erbium doped crystal or does he think about to try it in the future?

Conclusions

The author of this thesis has proven to have the ability to perform research and to achieve scientific results. He fulfilled all three defined goals, i.e., comprehensive investigation of available erbium-doped crystals for lasers at around 3 μm, generation of pulse regimes in lasers with selected erbium-doped crystals, and research of erbium microchip lasers. I do recommend the thesis for presentation with the aim of receiving the Degree of Ph.D.

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