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Oponent´s Review of Ph.D. Thesis

Fangxin Yue: Development of a cryogenic 2 μm multi-pass amplifer in nanosecond regime

It is very interesting to follow the permanent progress in laser technology during the last fifty years. A variety of laser materials and laser types have been investigated and successfully used. The activity has been motivated by application requirements of particular output parameters. The development was always limited by technological possibilities at a given time. Interesting progress can be witnessed in solid state lasers based on ions doped in various dielectric matrixes. Here, not only the improvement of high quality laser crystal growth but also a remarkable progress in semiconductor diode pump sources at hand resulted recently in the revival of well-known laser materials of the first decade of laser existence.

The topic of the thesis of Fangxin Yue contributes to this laser story: it concentrates on thulium ion, whose lasing was reported in the 1960s. However, recently it re-appeared in the focus of scientific and laser activity as a material which has the application-required wavelentgth of 2 μm and is suitable for optical pumping by GaAsAl based semiconductor diode. The aim of the thesis was an investigation of the physical properties of thulium doped yttrium oxide ceramics, and the realization of pulsed Tm:Y_2O_3 laser operating at cryogenic temperatures. The topic of the thesis thus corresponds to current trends of laser development. The thesis draws on the work done by Fangxin Yue during her Ph.D. study performed jointly at Czech Technical University in Prague, and at University Rovira I Virgili, Tarragona, in Spain. The principal part of the experimental work directly connected with laser was done at HILASE Centrum of Institute of Physics, Academy of Sciences of the Czech Republic.

The thesis has approximately 90 pages. It is completed with great care and at very high graphical quality. As far as I can judge, its English is very good. The text is divided into 7 chapters. Chapter 1 contains a rather short but nicely written introduction. The rest of the thesis consists of two parts. The first part (chapters 2-3) is devoted to material and optical spectroscopy characterization of Tm:Y_2O_3. In the second part (chapters 4-6), the realization and characterization of cryogenic Tm:Y_2O_3 laser and amplifier are described in detail. The thesis is concluded by chapter 7 summarizing the main results of the thesis.

In the first part, the author obtained original results concerning the properties of Tm:Y_2O_3 by material characterization techniques, such as X-ray scattering and SEM, and optical methods of Raman, absorption and photoluminescence spectroscopy. I understand that the results were used as an input for laser construction. However, in view of the originality and amount of data obtained, I think more effort should have been devoted to the presentation and interpretation of the results. For example, extensive investigation of values of absorption and emission cross sections was done and their spectral and temperature dependence investigated. However, I have found no error bars or a proper discussion of the precision of the results, as expected in measurement of values of any physical quantity. In chapter 3, I found it very difficult or impossible to follow the record of ion concentration (sections 3.2.2-3.2.5) of the samples.

In chapters 4, 5 and 6, the author describes in detail experimental work and parameters of cryogenic cw Tm:Y_2O_3 laser, pulsed Tm:Y_2O_3 laser, and multi-pass Tm:Y_2O_3 amplifier. I particularly enjoyed reading the parts of the text describing successive steps in a systematic work, which the author performed no doubt with great care and time deployment. Not surprisingly, the part about the cryogenic multi-pass laser amplifier seemed the most interesting one to me. The experimental laser work described is largely based on empirical approach. The setting-up of the optical cavities could also have been supported by theoretical analysis.

I have several remarks and comments, some of which can be answered by the author during the defence:

1. What information can one get from the SEM photographs shown in Figure 2-4? What is the connection between regions of different grey scale and the structure of the ceramics?
2. In section 4.3.4 the spectra of laser output are shown in Fig. 4.13. The spectra differ in shape – is there any interpretation of that?
3. The temperature dependence of the spectral widths of absorption cross-sections is given in Fig. 3.10. I understand that values of FWHM obtained in the way described in the thesis may be used as basic information in laser application of the material. But as is clear from the shape of the spectra of the relevant cross-sections, the approximation by a single Lorentzian is not correct.
4. I really like the photographs showing the experimental set-ups used. There are also interesting photographs in chapter 3 devoted to optical characterization, namely Figs. 3.2 to 3.5. Were these set-ups built by the author herself?
5. The laser cavity is open to the ambient atmosphere. Did this affect the laser performance?
6. Could the author discuss expected progress in cryogenic thulium laser systems?

In conclusion, the submitted thesis of Fangxin Yue is no doubt successful and brings a number of important original results which are significant for further progress in laser technology and applications. The author demonstrated clearly her ability of scientific work and her thesis fulfils the expected requirements. That is why it is my pleasure to suggest, after successful defence, awarding her the Ph.D. title.

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