Opponent's review of a doctoral thesis

Title in Czech: Metody hodnocení moderních optických materiálů

Title in English: Quality Evaluation Methods for Advanced Optical Materials

Author: Ing. Jan Bednář

Study programe: (P2612) Elektrotechnika a informatika/Electrical Engineering and Information Technology

Study specialization: (2601V010) Radioelektronika/Radioelectronics

University: Czech Technical University in Prague, Faculty of Electrical Engineering

Introduction

The following opponent's review of a doctoral thesis was proceeded in accordance with all facts presented in the doctoral thesis, the self-report, the journals and conference proceedings papers and all aspects below.

The doctoral thesis is well and clearly presented in English, the thesis is logically divided into six chapters within 71 pages. Chapter 1 introduces of the thesis content within the field of optical design, optical materials and quality evaluation. Chapter 2 introduces advanced optical materials used in modern optics. It is focused on Calomel optical material. Chapter 3 describes multiple methods which can be used to determinate the quality of the tested materials. Chapter 4 describes measuring setup based on optical Fourier transformation and provides its detailed description. Chapter 5 compares two selected methods, i.e. conoscopy and light scattering and compares them with the index of Calomel quality measurement based on optical Fourier transformation. The last chapter 6 summarizes the results and relates them to the doctoral thesis objectives.

a) Topicality of the selected task

The topics presented within the doctoral thesis titled "Quality Evaluation Methods for Advanced Optical Materials" can be considered as current and currently being developed mainly in connection with describing and developing methods for defining the quality of optical material, called Calomel, with advanced properties and prospective use in the long wave infrared region of optics to build polarizers or an acousto-optical tunable filters. The thesis is focused on selecting methods to test the quality of the material for use methods in the production of the material. A new method for quality evaluation based on optical Fourier transformation is presented. The monitored research is currently at the forefront of interest and research by different research groups within the advanced optical materials around the Europe and world. The chosen subject of work is clearly up to date.

b) Doctoral thesis aims and their fulfillment

Within the doctoral thesis there have been determined three relevant aims (page 1 and 2) and these ones were fulfilled by the following way.

Selection and description of multiple methods for testing the quality of optical materials concerning Calomel, as a promising modern material, and ability to use methods in the material production process. There were selected optical methods as light scattering and conoscopy (chapter 3).

Proposal of a new method and quality evaluation metric based on described methods. There was proposed the new method based on the optical Fourier transformation and the new quality evaluation metric called index of Calomel quality (ICQ) (chapter 4).

Comparison of the selected methods to the proposed method. Author of this doctoral thesis performed the comparison of the optical methods as light scattering and conoscopy with the new proposed one called optical Fourier transformation (chapter 5).

c) Selected methods within the doctoral thesis

The doctoral thesis contents the obvious methods used within the doctoral research. There is well processed state of the art. Based on this state of the art there were formulated three aims of the doctoral thesis. Theoretical research was then very important for the application of the PSF (MTF) theory and computation. The method proposed in this thesis is based on optical Fourier transformation with spatial high pass filtration and with high dynamic range processing. There were used three optical measurement methods (setups) with control SW, i.e. light scattering, conoscopy and optical Fourier transformation. All experimental results obtained from the above mentioned methods were compared and evaluated. The author has thus demonstrated that he is able to use these methods appropriately and effectively within the relevant research.

d) The outcomes of the doctoral thesis

Novel method for quality evaluation of optical crystals based on optical Fourier transformation providing multiple different outputs in accordance with ANSI IT7.215 standard: the spatial Fourier spectrum, HP filtered image and value of index of Calomel quality (ICQ).

Optical setup DEMON realizing the optical Fourier transformation method (Chapter 4) with software control designed in Python. This automated setup is used in the BBT Materials processing company for the quality evaluation of produced Calomel crystals.

Method for analyzing of the spatial Fourier spectral images from the optical Fourier transformation setup (Chapter 4.5).

Comparison of different quality evaluation methods (light scattering, conoscopy and optical Fourier transformation, chapter 5).

There was developed special measurement setup with control SW and methodology based on the optical Fourier transformation with figure of merit called index of Calomel quality (ICQ). The system was developed at the Department of Radioelectronics, Faculty of Electrical Engineering, Czech Technical University in Prague, with the participation of the author of this thesis and with co-operation of experts (BBT Materials processing company) from the field of advanced optical materials.

e) Importance for practice or for further development of science

This doctoral thesis presents novel method and figure of merit for quality evaluation of optical crystals based on optical Fourier transformation. There was developed special measurement setup with control SW and methodology based on the optical Fourier transformation with figure of merit called index of Calomel quality (ICQ). The system was developed in co-operation with experts (BBT Materials processing company) from the field of advanced optical materials and will be used for deeper understanding of the influence of the inner crystal structure to measured parameters. This doctoral thesis will help to focus the future research activities on improving the crystal production process

(crystal growth, crystal processing) according to the analysis of tested samples, their quality properties and the dependence on their process of production. Based on the results of this doctoral thesis there will be possible to prepare Calomel for usage within the long wave infrared region of optics to build polarizers or an acousto-optical tunable filters.

This thesis is an integral part of the doctoral study program "Electrical Engineering and Information Technology", with its results the field develops, it brings new knowledge verified by experiments that can be used in the future. The positive aspect of the thesis is also the fact that the achieved results can be applied within the following research and within the optical material engineering domain.

f) General overall description

References

The whole number of references, i.e. 42, was cited within the doctoral thesis. Wide shot of publications years 1934 – 2019, especially then 2000 – 2019 (the majority of used references), sufficient number, and representative references were used. Relevant books, journals, proceedings and others categories were used as well.

Relevant scientific projects

There could be appreciated that the dissertation has contributed to the several scientific projects also.

This thesis was partially supported by Grant no. SGS18/141/OHK3/2T/13 „Analysis and advanced algorithms for ultra-wide imaging systems“, SGS16/165/OHK3/2T/13 „Algorithms for Advanced Modeling and Analysis of Optical Systems with Variable Impulse Response“ and SGS13/212/OHK3/3T/13 „Advanced Algorithms for Processing and Analysis of Scientific Image Data" of the Student Grant Agency of the Czech Technical University in Prague and by Grant No. GA14-25251S „Nonlinear imaging systems with spatially variant point spread function“, and GA17-05840S „Multicriteria Optimization of Shift-Variant Imaging Systems“ of The Grant Agency of the Czech Republic.

Author’s publications

The outcomes of the doctoral thesis were presented in at least 15 papers. Three papers were published in journals with IF. Four papers were published in reviewed journals. Eight papers were published in conference proceedings. There were used very good and relevant journals as Applied Sciences, Optics Express, Astronomische Nachrichten, Jemná mechanika a optika, Slaboproudý obzor, Acta Polytechnica, Elektrorevue and conference proceedings as SPIE or IEEE.

There shoud be appreciated that the extent of the following journal paper was 17 pages.

Páta, P.; Klíma, M.; **Bednář, J.**; Janout, P.; Barta, C.; Hasal, R.; Maresi, L.; Grabarnik, S. *OFT Sectorization Approach to Analysis of Optical Scattering in Mercurous Chloride Single Crystals*, In: Optics Express, 2015, 23(16), 21509-21526. ISSN 1094-4087 – 17 pages.

Within the WoS and SCOPUS, there can be found majority of the author’s publications and a few citations of the selected author´s papers as well.

Formal layout of the dissertation thesis is well elaborated the linguistic level is good and all issues are

well understandable. Formal and graphical style of this doctoral thesis is on a very good level. All figures are very well readable and have very good quality.

Formal shortcomings

A lot of references have incomplete record as regards publisher, relevant pages, ISO 690-2 items and so on.

Reference [3] - incomplete citation.

Reference [4] - incomplete citation.

Reference [6] - incomplete citation (see ISO 690-2).

Reference [12] - incomplete citation (see ISO 690-2).

Reference [21] - incomplete citation.

Reference [23] - incomplete citation.

Reference [28] - incomplete citation, it seems to be U.S. Military standards available on the web (see ISO 690-2).

Reference [34] - incomplete citation.

Reference [35] - incomplete citation (see ISO 690-2).

Reference [36] - incomplete citation (see ISO 690-2).

Reference [37] - incomplete citation.

Reference [38] - incomplete citation.

Reference [41] - incomplete citation.

It should be noted that these shortcomings are minor and they have no effect on the quality of doctoral thesis.

Possible questions:

1. By what way did you test the ability of the optical Fourier transformation method (experimental setup) to measure appropriate (true) values of the Calomel samples? Did you use some special „Calomel phantom“ with determined internal structure?

2. Why you didn´t use the standard uncertainty of measurement as a result of repeatability?

3. What do you know about the temperature dependence of a Calomel properties?

4. Explain the term „schlieren photos“ (see Figure 4.15).

5. Try to define sensitivity and spatial resolution of the proposed methods, resp. index of Calomel quality with respect to the structural changes within the Calomel crystal samples. In another words, how the smallest inhomogeneities could be evaluated by the new proposed method?

g) Conclusion

The presented doctoral thesis represents a complex processing of the selected problem. All parts required for doctoral thesis are included. The PhD student demonstrated the ability to work independently and orientation within the given topic.

The dissertation fulfills the conditions of a separate creative scientific work and contains the original and by the author of the dissertation published results of the scientific work in accordance with § 47, paragraph 4 of Act No. 111/1998 Coll., Article 28, paragraph 1 of the Study and Examination Rules for CTU students in Prague and Methodical Guideline No. 1/2009 "On the observance of ethical principles in the preparation of university graduate theses" issued by CTU Rector.

I recommend the dissertation for the defense.

doc. Ing. Jiří Hozman, Ph.D.
doctoral thesis opponent

doc. Ing. Jiří Hozman, Ph.D.
ČVUT v Praze/CTU in Prague
Fakulta biomedicínského inženýrství/Faculty of Biomedical Engineering
Katedra biomedicínské techniky/Department of Biomedical Technology
Nám. Sítná 3105
272 01 Kladno
Česká republika/Czech Republic
+420 728 335 738
hozman@fbmi.cvut.cz