

## I. IDENTIFIKAČNÍ ÚDAJE

<b>Název práce:</b>	<b>Ultrasensitive nanoscopy with phase detection</b>
<b>Jméno autora:</b>	<b>Bc. Kateřina Jiříková</b>
<b>Typ práce:</b>	diplomová práce
<b>Fakulta:</b>	Fakulta jaderná a fyzikálně inženýrská (FJFI)
<b>Katedra:</b>	Katedra fyzikální elektroniky
<b>Oponent práce:</b>	Ing. Barbora Špačková, Ph.D.
<b>Pracoviště oponenta práce:</b>	Fyzikální ústav Akademie věd České republiky

## II. HODNOCENÍ JEDNOTLIVÝCH KRITÉRIÍ

<b>Zadání</b>	<b>náročnější</b>
<i>Hodnocení náročnosti zadání závěrečné práce.</i>	
<p>The diploma thesis presents a comprehensive investigation into the field of ultrasensitive phase imaging, with a special focus on interferometric scattering microscopy (iSCAT) and its applications in characterization of nanoparticles. The thesis tackles a highly specialized and complex topic in the field of photonics, specifically focusing on enhancing the capabilities of iSCAT for phase detection in the nanoscale. The subject requires a deep understanding of optical physics, microscopy techniques, and data analysis, indicating a high level of difficulty.</p>	

<b>Splnění zadání</b>	<b>splněno</b>
<i>Posuďte, zda předložená závěrečná práce splňuje zadání. V komentáři případně uveďte body zadání, které nebyly zcela splněny, nebo zda je práce oproti zadání rozšířena. Nebylo-li zadání zcela splněno, pokuste se posoudit závažnost, dopady a případně i příčiny jednotlivých nedostatků.</i>	
<p>The thesis meets the set objectives comprehensively. It reviews relevant literature on interferometric scattering microscopy, mass photometry, and wavefront shaping. It also develops a new generation of photothermal spatial light modulators and demonstrates its application in detecting the characteristics of scattered light by nanoparticles. In particular, it meticulously analyzes the influence of a substrate's surface roughness on the detected properties of the scattered light. The detailed theoretical background, the review of existing technology, and the experimental part suggest a thorough approach to fulfilling the task.</p> <p>The thesis does not address the task regarding the design and implementation of alternative quantitative phase detection approaches that do not require time scanning with an active spatial modulator. However, this task was not a mandatory requirement and was defined in a more tentative way. Therefore, its omission does not represent a significant shortfall.</p>	

<b>Zvolený postup řešení</b>	<b>vhodný</b>
<i>Posuďte, zda student zvolil správný postup nebo metody řešení.</i>	
<p>The student has selected suitable methods for the research topic, blending theoretical analysis with practical experiments, demonstrating a robust methodological approach. Employing iSCAT, known for its sensitivity to phase changes, together with the photothermal spatial light modulators (PT-SLM) based on PDMS matrix doped with gold nanoparticles (GNP), aligns well with the goal of ultrasensitive phase detection.</p> <p>Nonetheless, the work could benefit from a more explicit and pedagogical explanation in certain parts. Specifically, the objectives behind the spatial resolution characterization of the PT-SLM is not clear. Moreover, the thesis lacks adequately describing the data processing, particularly in defining the position of GNP from the images.</p>	

**Odborná úroveň**

**výborná**

*Posuďte úroveň odbornosti závěrečné práce, využití znalostí získaných studiem a z odborné literatury, využití podkladů a dat získaných z praxe.*

The thesis demonstrates a high level of expertise. The review part showcases an extensive understanding of the field, and the experimental section indicates practical competence. The student has successfully utilized knowledge gained from studies and professional literature, evident from the detailed discussions and critical analyses throughout the thesis.

**Formální a jazyková úroveň**

**průměrná**

*Posuďte správnost používání formálních zápisů obsažených v práci. Posuďte typografickou a jazykovou stránku.*

While the thesis maintains a generally high standard in its formal notations and language, certain areas could benefit from refinement. The English grammar occasionally falters, particularly with inconsistent tense usage, and some phrases do not always adhere to conventional English structures. Moreover, some figures are presented without adequate axis descriptions or scale bars (Figure 26, 28, 32). However, these are isolated issues rather than systematic flaws and do not significantly impact the thesis's overall quality.

**Výběr zdrojů, korektnost citací**

**výborné**

*Vyjádřete se k aktivitě studenta při získávání a využívání studijních materiálů k řešení závěrečné práce. Charakterizujte výběr pramenů. Posuďte, zda student využil všechny relevantní zdroje. Ověřte, zda jsou všechny převzaté prvky řádně odlišeny od vlastních výsledků a úvah, zda nedošlo k porušení citační etiky a zda jsou bibliografické citace úplné a v souladu s citačními zvyklostmi a normami.*

The student has shown proactive engagement in sourcing relevant materials for the thesis. The extensive reference list and the critical review of existing literature reflect a thorough research process. The proper distinction between adopted elements and original results or considerations indicates adherence to citation ethics.

**Další komentáře a hodnocení**

*Vyjádřete se k úrovni dosažených hlavních výsledků závěrečné práce, např. k úrovni teoretických výsledků, nebo k úrovni a funkčnosti technického nebo programového vytvořeného řešení, publikačním výstupům, experimentální zručnosti apod.*

The main results notably contribute to advancing the field of ultrasensitive quantitative imaging. Particularly findings regarding the impact of sub-nanometer surface roughness on precision of quantitative interferometric imaging offer valuable insights to the field. It is apparent, however, that the developed PT-SLM requires further optimization to fully realize its potential. With these improvements, it is anticipated that this work will pave the way for publication and wider recognition in the scientific community.

### III. CELKOVÉ HODNOCENÍ, OTÁZKY K OBHAJOBĚ, NÁVRH KLASIFIKACE

*Shrňte aspekty závěrečné práce, které nejvíce ovlivnily Vaše celkové hodnocení. Uveďte případné otázky, které by měl student zodpovědět při obhajobě závěrečné práce před komisí.*

In conclusion, the diploma thesis by Bc. Kateřina Jiříková is a well-structured, meticulously researched, and methodically sound piece of work. It successfully addresses a complex and specialized topic in the field of photonics, demonstrating a high level of expertise and a notable contribution to the field of ultrasensitive phase imaging.

For the thesis defence, the student should be prepared to address the following questions:

(1) Can you elaborate more on the measured distribution of iSCAT contrast, amplitude, and phase of GNPs (Figure 34)? It is generally assumed that the properties of GNPs, and consequently the iSCAT contrast, follow a Gaussian distribution. The measured data (Figure 34a, 34b), however, shows a significant deviation from this expectation. Moreover, Figure 34e, 34f suggest two distinct populations of GNPs characterized by positive and negative phase, respectively. Could you comment on an origin of such behaviours?

(2) Based on the contrast, amplitude, and phase measurements from iSCAT, how feasible is it to estimate the distribution of sizes or other properties of the particles? How do these estimates compare when using different substrates?

(3) Figure 33 displays stitched images of several fields of view (FOVs). Although the stitching appears effective for iSCAT contrast, significant discrepancies are observed at the borders of the FOVs in the calculated phase map. What factors contribute to these phase discrepancies?

(4) Could you detail the methodology used for distinguishing GNP signals from noise during data processing? How was the precise position of each GNP determined?

(5) Can you explain the principle behind the autofocus system used to maintain consistent focus during extensive scans? Moreover, how did you ensure long-term stability in the x-y axis throughout these scans?

(6) In the outlook of the thesis, it is suggested to improve the performance of the PT-SLM by introducing sapphire substrates instead of glass. Are there any foreseeable challenges associated with this implementation?

Předloženou závěrečnou práci hodnotím klasifikačním stupněm **A - výborně**.

Datum: 24.1.2024

Podpis:

