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Master's Thesis

Numerical Study of an Acousto-Optic Interaction

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ABSTRACT

This thesis is a study focused on the acousto-optic interaction, which involves the interaction between sound and light waves in a specific medium called an acousto-optic material. This work begins with a theoretical study of this phenomenon and focuses on the relationship between the position of diffracted orders and the modulating signal. To ensure the accuracy of the numerical model, a series of experiments are conducted. The thesis is structured into three chapters; the first chapter covers physical principles, including different types of diffraction, most importantly the grating diffraction. The second chapter provides an overview of the physical principles underlying acousto-optic interaction, while the third chapter discusses a MATLAB simulation that analyzes the effects of various parameters on the interaction, leading to a deeper understanding of the phenomenon's behavior.

Résumé:

Cette thèse est une étude axé sur l'interaction acousto-optique, qui implique l'interaction entre les ondes sonores et lumineuses dans un milieu spécifique appelé matériau acousto-optique. Ce travaille commence par une étude théorique de ce phénomène et se concentre sur la relation entre la position des ordres diffractés et le signal modulateur. Pour assurer l'exactitude du modèle numérique, une série d'expériences sont menées. La thèse est structurée en trois chapitres; le premier chapitre couvre les principes physiques, y compris les différents types de diffraction, surtout la diffraction des caillebotis. Le deuxième chapitre donne un aperçu des principes physiques qui sous-tendent l'interaction acousto-optique, tandis que le troisième chapitre traite d'une simulation MATLAB qui analyse les effets de divers paramètres sur l'interaction, menant à une compréhension plus profonde du comportement du phénomène.

ملخص :

هذه الأطروحة هي دراسة تركز على التفاعل الضوئي-الصوتي ، والذي يتضمن التفاعل بين موجات الصوت والضوء في وسط معين يسمى مادة أكوستو بصرية. يبدأ هذا العمل بدراسة نظرية لهذه الظاهرة ويركز على العلاقة بين موقع الأوامر المنحرفة والإشارة المعدلة. لضمان دقة النموذج العددي، يتم إجراء سلسلة من التجارب. وتتألف الأطروحة من ثلاثة فصول ؛ يغطي الفصل الأول المبادئ الفيزيائية، بما في ذلك أنواع مختلفة من الانحراف، والأهم من ذلك حيود البشر. يقدم الفصل الثاني لمحة عامة عن المبادئ الفيزيائية الكامنة وراء التفاعل البصري الأكوستو. في المقابل، يناقش الفصل الثالث محاكاة MATLAB التي تحلل تأثيرات المعلمات المختلفة على التفاعل، مما يؤدي إلى فهم أعمق لسلوك الظاهرة.

INTRODUCTION

Before delving into the main goal of this research and the thesis outline, it is important to highlight the historical development and significant milestones in the acousto-optic field. Scientists and researchers have studied the interaction between sound and light waves for many decades, with the acousto-optic interaction having significant implications in materials science, fiber optics, spectroscopy, interferometry, and laser technology.[1]

In 1935, Raman and Nath were able to provide a theoretical explanation for this diffraction. They demonstrated that the propagation of an ultrasonic wave in an elastic medium creates dilation and compression regions that produce periodic modulation of the refractive index via the elasto-optic effect. This produces a dynamic phase grating which diffracts incident light into one or more directions. [2-3]

This work involves a thorough theoretical study of the acousto-optic interaction, which follows the same stages as those who preceded us in this field. Starting from the fundamental principle of acousto-optic interaction, we aim to explore and establish an important relationship between the position of diffracted orders and the modulating signal.

To confirm the accuracy and validity of our numerical development, a series of numerical experiments are conducted. These experiments are designed to evaluate the performance of the numerical model and ensure that the predicted results align with the observed outcomes. We believe that this approach will contribute significantly to developing a more comprehensive understanding of the acousto-optic interaction and its practical applications.

In order to present the different stages of this research in a clear and comprehensive manner, we have opted to begin by studying the essential concept of light diffraction, which plays a crucial role in the acousto-optic interaction.

After thoroughly examining the phenomenon of light diffraction, the next important step in this study is to determine the relationship between ultrasound and the medium's refractive index to explain the diffraction phenomenon. Therefore, to ensure a logical and organized flow, this thesis has been structured into the following sections:

The first chapter of this thesis provides a detailed introduction to the phenomenon of light diffraction, which is an essential concept in acousto-optic interaction. The chapter covers physical principles that explain how light waves diffract when they interact with various materials, including different types of diffraction, most importantly the grating diffraction.

The second chapter focuses on acousto-optic interaction, which involves the interaction between sound waves and light waves in a specific type of medium known as an acousto-optic material. The chapter provides an overview of the physical principles underlying acousto-optic interaction. The chapter also covers key concepts such as acoustic frequency, sound velocity, and the interaction length.

In the third chapter, a MATLAB simulation of the acousto-optic interaction is developed based on the principles introduced in the second chapter. In this simulation, the results found in the second chapter are analyzed, and the effects of various parameters, such as acoustic frequency, on the interaction are evaluated. The simulation aims to provide insights into the underlying principles of acousto-optic interaction that can help researchers understand the behavior of this phenomenon and improve its applications in various fields.

Overall, this master's thesis contributes to the field of acousto-optics by providing a deeper understanding of the interaction between sound and light waves in acousto-optic materials. The results of this study can lead to the development of advanced technologies that rely on the acousto-optic interaction, with implications in a wide range of fields, including telecommunication, biomedical engineering, and material science.