

DESIGN AND SIMULATE NANOFIBER LASER USING MICROWAVE CST

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PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN AND SIMULATE NANOFIBER LASER USING MICROWAVE CST

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APPROVAL

This report is submitted to the Faculty of Electronics and Computer Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering (Telecommunication) with Honours. The member of the supervisory committee is as follow

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ABSTRACT

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. Laser research has produced a variety of improved and specialized laser types, optimized for different performance goals, including the new wavelength bands, maximum average output power, maximum peak pulse energy, maximum peak pulse power, minimum output pulse duration, maximum power efficiency and minimum cost. Now, the usage of fiber laser is more in nano scale which is nanofiber laser. This project is design and simulate nanofiber laser using Microwave CST. Nanofiber is optical fiber with diameter in range from tens to a few hundred of nanometers. This means that the diameter is often well below the optical wavelength. The nanofiber use because it provide strong confinement and low propagation losses. However the wavelength of the fiber laser is at L band region, typically 1565nm to 1625nm. The refractive index of the numerical aperture is very high gain and the effective mode area is very small. For constant nanofiber diameter is in range from 150nm to 5 μ m, the losses become very high when the diameter is too small. This project is intended to simulate the wavelength of the fiber laser is at L band region and investigate the refractive index for constant nanofiber diameter in range from 150nm to 500 μ m and the effect of various dopant concentrations nanofiber structures on performance of nanofiber laser theoretically to get the parameter design for output power and full width at half maximum (FWHM). The preparation is design the nanofiber laser using Microwave CST Software by analyse the characteristics of performance parameter which is dimension, refractive index and structure.

ABSTRAK

Laser ialah sebuah alat yang mengeluarkan cahaya melalui satu proses penguatan optik berdasarkan pancaran dirangsang sinaran elektromagnet. Penyelidikan laser telah menghasilkan pelbagai jenis laser lebih baik dan khusus iaitu, mengoptimumkan untuk matlamat prestasi berbeza, termasuk kumpulan-kumpulan panjang gelombang yang baru, keluaran purata maksimum mendayai, tenaga denyut puncak maksimum, denyut puncak maksimum mendayai, tempoh denyut keluaran yang minimum, kecekapan kuasa maksimumnya dan kos minimum. Pada masa kini, penggunaan laser gentian ialah lebih banyak di skala nano yang merupakan laser nanofiber. Projek ini mereka dan mensimulasi laser nanofiber menggunakan Microwave CST. Nanofiber ialah gentian optik dengan garis pusat dalam merangkumi berpuluh bagi beberapa ratus daripada nanometer. Ini bermaksud yang garis pusat selalunya di bawah panjang gelombang optik. Penggunaan nanofiber kerana ia menyediakan pengurangan kuat dan kehilangan perambatan yang rendah. Bagaimanapun, panjang gelombang laser gentian berada di rantau jalur L, lazimnya 1565nm hingga 1625nm. Indeks biasan apertur berangka ialah keuntungan sangat tinggi dan kawasan mod yang berkesan sangat kecil. Untuk garis pusat nanofiber malar ialah dalam rangkuan 150nm hingga 5 μ m, kerugian menjadi sangat tinggi apabila garis pusat terlalu kecil. Projek ini dimaksudkan mensimulasikan panjang gelombang laser gentian berada di rantau jalur L dan menyiasat indeks biasan untuk garis pusat nanofiber malar dalam merangkumi 150nm hingga 500 μ m dan kesan penumpuan bahan dop yang pelbagai struktur-struktur nanofiber di prestasi laser nanofiber dari segi teori untuk mendapatkan parameter mereka untuk kuasa keluaran dan kelebaran penuh di separuh maksimum. Persediaan ialah reka bentuk laser nanofiber menggunakan Microwave CST Software dengan menganalisis sifat parameter prestasi yang merupakan dimensi, indeks biasan dan struktur.

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CHAPTER I

INTRODUCTION

1.0 Introduction

The basic overview of this project is explained in this chapter. In addition, the objective, problem of statement, scope of work and methodology are included. The basic principle of this project where design the fiber laser in nano-scale which is nanofiber laser.

1.1 Overview project

Laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym Light Amplification by Stimulated Emission of Radiation. Laser is different from other light sources because they emit coherent light. In 1917,

Albert Einstein's first theory of the process which makes lasers possible called "Stimulated Emission". It is based on the concept of probability coefficients (Einstein coefficients) for the absorption, spontaneous emission, and stimulated the production of electromagnetic radiation.

Laser today and all applications are the result of these efforts is not an individual, but the work of several prestigious scientists and engineers who are leaders in optics and photonics throughout history. Early laser initial use powerful energy source to excite the atoms in synthetic ruby to a higher energy level. At a certain level, some atoms emitted light particles that called photons.

These newly created photons hit other atoms, rapidly stimulate the release of more similar and amplify photons of light intensity. Maiman was continue the process of stimulated emission and amplification by placing a silver mirror fully reflect on one end of the model and partly reflecting silver mirror on the other. This way the photons bounce back and forth between the mirrors until they get enough intensity to break through the end of the partially silvered as powerful, coherent and beam of light.

Before the laser is a Maser. A maser (Microwave Amplification by Stimulated Emission of Radiation), a device that amplified microwaves as compared to the light and soon found use in microwave communication system. In 1953, Charles Hard Townes and graduate students James P. Gordon and Herbert J. Zeiger produced the first microwave amplifier, a device operating on similar principles to the laser, but amplify microwave radiation from the infrared or visible radiation. Townes's maser is incapable of continuous output.

Soon after the Maser, Arthur Schawlow and Charles Townes began to think of ways to make the infrared or visible light masers. In 1957 Schawlow and Townes

built an optical cavity by placing two highly reflective mirrors parallel to each other, and put a moderate increase in between. In 1958, they published a seminal paper in *Physical Review* their findings and submitted a patent application for the so-called Optical Maser. At the conference in 1959, Gordon Gould published the term 'LASER' in the paper 'The LASER', is Light Amplification by Stimulated Emission of Radiation. Gould's linguistic intention was using the word "-Aser" particle as a suffix to indicate accurately the spectrum of light emitted by the 'LASER' device, although "Raser" was briefly popular for marking frequency radio transmitter device.

Maiman's functional laser used a solid-state flash lamp-pumped synthetic ruby crystal to produce red laser light, at 694 nanometres wavelength. However, the device only was capable of pulsed operation, because of its three-level pumping design scheme. Then in 1960, the Iranian physicist Ali Javan, and William R. Bennett, and Donald Herriott, constructed the first gas laser helium and neon that is capable of operating continuously in the infrared. In 1962, Robert N. Hall shows the first laser diode device, made of gallium arsenide and emitted at 850 nm near infrared spectral band.

After that, in 1962, Nick Holonyak, Jr. shows the first semiconductor laser with a visible emission. This first semiconductor laser could only be used in pulsed-beam operation, and when cooled to liquid nitrogen temperature. In 1970, Zhores Alferov, in the USSR, and IZUO Hayashi and Morton Panish Bell Telephone Laboratories also independently developed room-temperature, continuous-operation diode lasers, used the hetero-junction structure.

Since early-period laser history and keep going until today, laser research had produced various improved and more specific laser types, optimise for different performance target, including the new wavelength band, maximum average output power, maximum peak pulse energy, maximum peak pulse power, output pulse duration that is minimum, the maximum power efficiency and minimum cost.

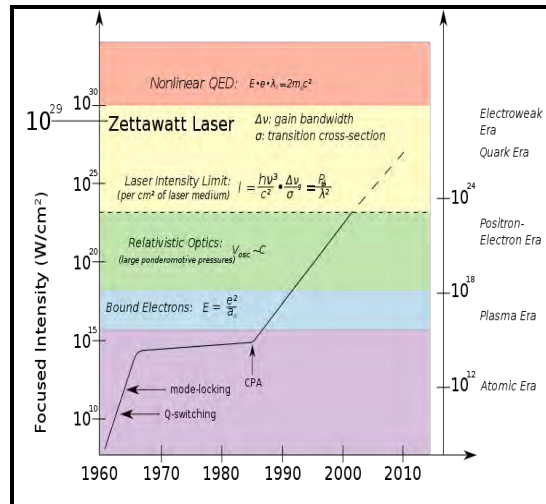


Figure 1.1: The history of maximum laser pulse intensity throughout the past 40 years.

Nowdays, the usage of fiber laser is enhanced to be used in nano scale which knows as nanofiber laser. As a result when reduce the scale it provide strong confinement and low propagation losses. Many commercial available software can be use to design the nanofiber laser such as CST Microwave Studio, Matlab, GainMaster, Laser Application Design (LAD) and others.

1.2 Objectives of Project

To ensure that the main purpose of the project can be achieved successfully in accordance with the scope of the project, scope of work mentioned, some of the objectives of this project.

The objective of this project is to design the nanofiber laser using Microwave CST and simulate its specific performance parameter. This project is intended to:

1. To simulate the wavelength of the nanofiber laser at L band region.
2. To analyse the effect of various dopant concentrations nanofiber structures on performance of fiber laser theoretically to get the parameter design for output power and full width half maximum (FWHM).

1.3 Scope of works

The scope of this research is to analyse the laser construction which is the pump source, laser medium and the optical resonator. The pump source is the action energy transfer from one external source into the gain medium of a laser. The energy is absorbed in the medium and produce excited states in its the atoms. Laser medium is optical source of gain in a laser. The gain results from the stimulated emission of electronic transitions or molecule to one lower state of energy from one higher energy state previously populated by pump source. An optical resonator is an arrangement of reflect that form a standing wave cavity resonator for light wave. They are also used in oscillator parametric optic and a few interferometers. Light confined in cavity reflect repeatedly produce standing wave for certain resonant frequency.

This research is using simulation method. The software use is CST Microwave. CST Microwave is enable the accurate and quick analysis of high frequency (HF) tools such as antennas, filter, couplers, structures planar and multiply and SI and EMC effects. Besides is a user-friendly, MWS CST also quickly giving an insight into EM behaviour of high frequency design. Performance of parameter to investigate is fiber length and fiber laser wavelength accurately at L band region (1565nm to 1625nm).

The result is supported by the simulations of performance parameters in CST Microwave is refractive index, dimension of the fiber and the fiber structure. In the optical, the refractive index or index of refractive n of a material is a number of dimensionless which describes how light, or any other radiation and expand through the medium. By the simulation, we will get the design parameter such as output power, pump injected, full width height maximum (FWHM) and Q factor.

1.4 Problems Statement

Nanofiber is optical fiber with diameter in range from tens to a few hundred of nanometers. This means that the diameter is often well below the optical

wavelength. The nanofiber use because it provide strong confinement and low propagation losses. However the wavelength of the fiber laser is at L band region, 1565nm to 1625nm. The refractive index of the numerical aperture is very high gain and the effective mode area is very small. For constant nanofiber laser , the losses become very low when the diameter is too small. The effect of design the various dopant concentrations nanofiber structure on performance of fiber laser will get the parameter design for output power and full width half maximum (FWHM).

1.5 Project Summary

Nanowires are intriguing materials for fundamental studies of light-matter interactions at the nanoscale, as well as for design and simulation of nanophotonic components and structure. Photonic nanowires exhibit low optical loss such as semiconductor nanowires, glass nanofibers, and silicon-on-insulator (SOI) waveguides but optical confinement in these structures is limited by the diffraction limit (on the order of λ/n , with refractive index n typically less than 5).

Micro and nano-photonic devices requires component-based small scale photonic glass. In this context, silica nanofibers have great potential as a low-loss waveguides for nano-optics and microphotronics applications. The tensile strength of the fiber allows the development of micro and nanomechanical springs and levers. Nanofibers can also be used as reinforcement for the fabrication of dental composites. Various techniques have been proposed for the design of nanofibers, such as high-temperature tapered-painting and electrospinning.

The nanofibers are grown perpendicular to the substrate surface of the molten material in laser-drilled microvias where they intertwine and bundles on the surface. The fiber is few tens of nanometers in thickness and up to several millimeters in length. Fiber laser has the practical advantage of better stability, higher efficiency, lower sensitivity to alignment, and a more compact design of solid-state laser. However, the use of short-pulse fiber laser has been limited by the lower pulse energy available from the laser fiber.

In order to design the nanofiber laser, there have the laser construction to analyse, which is the type of the pump source, laser medium and the optical resonator. The result is supported by the simulations of performance parameters is refractive index, dimension of the fiber and the fiber structure. However, from the performance parameters it will get the parameter design such as output, pump injected, full width height maximum (FWHM), gain and Q factor

1.6 The importance of the project sustainable development

This project is using a nanofiber laser because the fiber laser in a nanoscale can emit a more complex light and the result produce is more accurate. The wavelength is accurately at L band region because it is very efficient and robust. Nanofiber is a relatively new area of research, but it is not impossible for a low peak power, as light propagates in a very concentrated. In addition, the nanofiber can form a very small ring resonator (micro cavities, interferometers microloop), which can act as a notch filter. It is also conceivable that a laser with very low threshold pump power can be built by combining a number of dope-active laser resonator ia a small nanofiber.

1.7 The impact for commercialization of the project

From a commercial perspective "nano" term describes the diameter of fibrous shape on anything below one micron or 1,000 nanometers. However, the properties of the most coveted of these materials tend to manifest themselves at below 500 nanometers depending on the material and property. As one begins to operate at the molecular level there is a significant shift in governing physics. The ability to manipulate the physics and the properties and characteristics of the essential material has been proven over time to be very valuable.

The main interests in nanofibers revolve around increased surface area and mechanical properties of novel materials in the nanoscale. If the diameter of the fiber

reduces the integrity of the mechanical properties of that material increases by an order of magnitude. Similarly, the surface area of nanofibers is substantially larger than the fiber at the one micron level and higher. These factors have profound implications in many applications.

The use of nanofibers can be expected in many new products. That is the strength, reactivity, electrical and optical quality, permeability layer, which means that they have great potential for applications such as energy conversion and storage, liquid and air filtration, food and packaging, health care and environmental protection.

1.8 Thesis Outline

This project report consists of five chapters are which is chapter I until chapter V. Chapter I is an introduction the project as a whole. The early and basic explanations are mentioned in this chapter. Introduction is discussed about background of the project, problem statement and the purpose of developing this project. It also mentions the important of this project. For the chapter II, is explain the literature review which consists about the background study and research before developing this project. The content of the background studies such as theory of fiber optic, laser and nanofiber.

Another chapter is chapter III. This chapter explain methodology described about the methods or approaches use in solving projects. Among the main content of this chapter are initial planning, planning, requirements, analysis, implementation, testing, evaluation and deployment. Chapter IV is concentrates on the result and discussion of this project. Lastly, Chapter V is the conclusion consist the summary of the project. After the project is done, recommendations are made for the betterment of this project or any expansions or upgrades that might be done in the future.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

Chapter II focus on the literature review of the project and other relevant information related to the project such as the fundamentals of optical fiber and Laser. The fundamental of project on efficiency optical fiber for nanofiber laser application configuration is explained.

This chapter consist of two parts which are theory and previous study on the optical fiber and naofiber laser. Generally, in the theory part will discuss on a few theory which study on the optical fiber and laser. Then, in the previous study part, it will be a part that discussing on the method using nanofiber laser compared to a journal that focus the other different application.

In this project, to design the nanofiber it use the fiber laser as the device to light emits. The advantage of fiber laser over the other type of laser is the light is already coupled into a flexible fiber and the output power is high. Besides, fiber laser