The Construction of a High Power Fiber Laser

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***Abstract*— The paper presents work in progress for research on high power fiber lasers (HPFL). A fiber laser is a laser in which the active gain medium or the laser medium is an optical fiber usually doped with rare-earth elements such as erbium, ytterbium, and neodymium. The functionality of a basic laser, enabling high output power and the difficulties in achieving them are covered in the paper. Concepts such as stimulated emission and coherent light are briefly discussed and the aims of the research are also defined. In the past, fiber lasers have been unable to meet high output power requirements for industrial and military applications, but due to the growth in technology through the years, a number of methodologies have been developed to achieve output powers of 1kW and more. It is possible to achieve an output power of 1kW or more with a fiber laser by changing some of the fiber laser components and determining the correct methodology to be used.**

Index terms - High power fiber laser

I. Introduction

Laser is an acronym for light amplification by the stimulated emission of radiation [1]. A basic theory of how a laser works is necessary to understand how a fiber laser works. A laser is a device, which emits light through a process called stimulated emission. Figure 1 illustrates the process of stimulated emission. The incident photon is pumped at a certain wavelength and with a certain amount of energy into the laser medium via the energy source. The incident photon moves towards the excited atom and stimulates the atom to release energy in the form of a photon. The photon is identical in wavelength, direction, polarization, and phase to the stimulus photon [2].

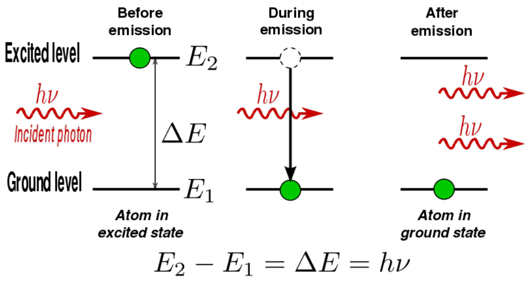

Fig. 1. The process called stimulated emission

II. Laser Operation

A basic laser is illustrated in figure 2. Light from the energy source is pumped into the amplifying medium, the electrons undergo stimulated emission and emit light, the light is reflected backwards and forwards by the reflectors. From figure 2 it is seen that one reflector is partially reflective and the light moving through the partial reflector creates the laser output beam.

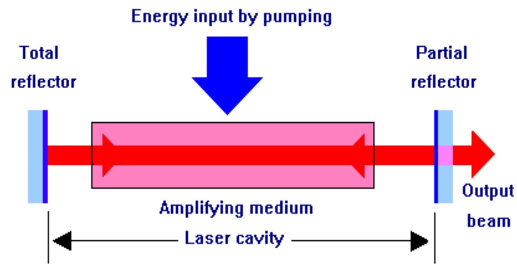

Fig. 2. An illustration of a basic laser

Some lasers emit light with a broader wavelength spectrum, while others emit light at multiple distinct wavelengths simultaneously. Other light sources emit incoherent light where as lasers emit coherent light. Coherent light is when all the photons have the similar wavelength and the similar phase [3]. The ability of lasers to emit coherent light increase the intensity of the output beams.

III. High Power Fiber Laser

Many laser applications require watts of optical power rather than milliwatts [4]. The increase in technology through the years has lead to an increase in the output power capabilities of fiber lasers.

A. Enabling High Output Power

The following can be done to increase the output power of fiber lasers:

1) Changing the pump source or combining pump sources: Using diode stacks or combining beams from the required number of independently running pump lasers can provide extremely high output powers of hundreds or thousands of watts [5];
2) Amplifing Pump Signal: Amplify the pump signal by using either an Erbium Doped Fiber Amplifier (EDFA) or a Master Oscillator Power Amplifier (MOPA). EDFAs increase the input signal regardless of the number of wavelengths [6] ; and

3) Using double clad or Photonic crystal fibers: Photonic crystal fibers provide better control through large single-mode core sizes and short fiber lengths and are expected to reach power levels of around a factor of ten or higher [7].

B. Difficulties Achieving High Output Power

Some challenges to achieve high output power are:

1) Eliminate nonlinear effects such as stimulated Brillouin scattering (SBS), stimulated Raman scattering, and the optical Kerr effect by selecting other dopants in the core and cladding [8];
2) Maintaining polarization by using polarization maintaining fiber, which preserve and transmit the polarization state of the light, even when subjected to environmental perturbations [9];
3) Heat is generated inside an active optical device and by using or designing heat-sinks, the performance can be improved in the devices [10];
4) One method to realize high pump power is to combine a number of high power semiconductor pump lasers. The semiconductor pump lasers can be combined by either wavelength or polarization multiplexing which will obtain a sufficient high output power [11]; and
5) Damage occurs to the input of the optic fiber which forces the use of a large diameter fiber and consequent loss of flexibility. To prevent input damage, a tapered optical fiber can be used, which has a large input diameter and allows a smaller diameter pigtail for convenience [12].

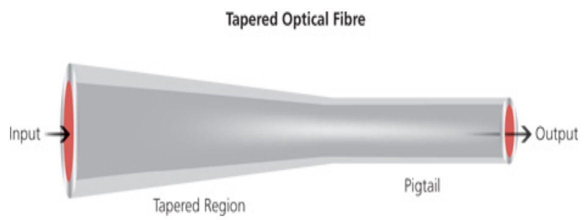

Fig. 3. An illustration of a tapered fiber

IV. Research Aims

Some goals to be achieved during the project are a better understanding on how fiber optics work; How fiber lasers work; What are the non-linearities that influence the performance of a fiber laser; And how is it possible to achieve a high output power. The questions will be answered within the literature study and others will be answered through practical applications. Some of the aims of the project are the following:

1) Determine appropriate software, which will be able to simmulate fiber lasers;
2) Use the software to simmulate a basic erbium doped fiber laser;
3) Build the erbium doped fiber laser, measure the output power and compare the results to the simmulated version;
4) Use the appropriate software to deterime which changes in components can lead to a high output power of a few hundred watts;
5) Design the layout for a high power fiber laser using the simmulations from the software;
6) Build the high power fiber laser using the designed layout;
7) Measure the output power of the built high power fiber laser; and
8) Compare the results from the built version to the simulated version and determine if the output power requirements have been met.

V. Conlusion

Fiber lasers are becoming more useful because a fiber laser is more compact, has a lower running cost, is light weight and has a higher efficiency as their bulk counter parts. The combination of high power and ease of use can benefit applications in a wide variety of fields such as medical surgery, material processing, laser spectroscopy, remote sensing and imaging, and scientific instrumentation. The opportunity exists to build a high power fiber laser locally, which will help to decrease costs involved to buy a high power fiber laser overseas and also increase the useage of high power fiber lasers in local industrial and military applications.

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Josias Johannes Le Roux was born in Brits, South Africa in 1985. Received his B.Eng electronic and electrical engineering at the University of Johannesburg in 2009. Since March 2009 he has been working on his research M.Eng at the University of Johannesburg in Optical Fibers with the research on High Power Fiber lasers.