Philanthropy Grant Proposal:

Advanced LASER Mining Array (ALMA)

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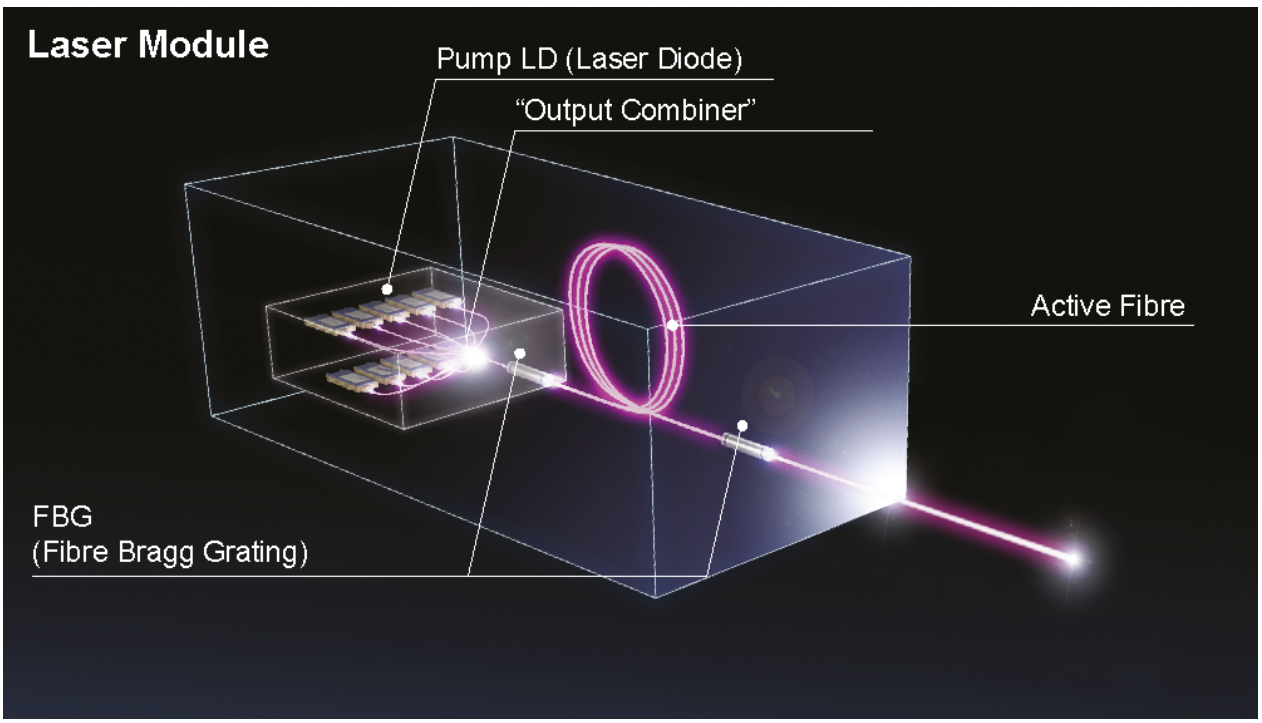

1 Abstract

The overall achievement and mission for **ALMA** is to prove that you can use a Fiber Laser (FBL) for mining water ice, we'll just call this ice for now, in the vacuum of space. This includes ice on the moon, NEO's, and asteroids in the asteroid and Kuiper belt (which mainly consist of C-types and comets) [2]. The reasoning behind using a FBL and not a nd:YAG or CO_2 gas LASER is due to the efficiency and accessibility the FBL has. The FBL uses less electricity and therefore more cost efficient [4], has a higher amplification coefficient meaning more power, uses a simpler design than both and is more compact [4], and are very reliable essentially maintenance free [1]. Most high powered FBL's have a recorded 30% - 50% power efficiency, much greater than any other option [3].

The design of a FBL utilizes a very simple design: coupled diodes, a combiner from diode to cable, a Yb doped fiber cable, Bragg gratings (one of higher polarization on the input and another of low polarization on the output), and a lens to protect the inside of the cable (*Fig. 1*). There is also means of cooling so that the LASER performs at its highest efficiency. Due to the fact this project is researching means of mining in space, where the resting temperature is app. 2.7K, there would be no use for cooling. More likely a means to find ways to shield the FBL from the vacuum of space, radiation, and the chilling temperatures. The temperature is not consistent once on the surface of the moon and other bodies in space. Because of this, there will be a need to upgrade the FBL based on its environment it's obtaining the water from. Is it going to the moon, a nearby asteroid with little to no atmosphere, or a planet with temperatures of up to 300K?

To be able to do any of what was discussed above, there needs to be means of safety for experimentation. The bulk of this project will be theoretical and consist of simulations to prove if the design of the FBL will be sufficient enough to mine ice in space. Though there will be a downsized model, as discussed above, and for this a system of precaution will be put in place including PPE, a safe and isolated environment for testing, and documentation with information disclosing in depth safety measures. This will be further discussed in the **Safety** section of the proposal, along with the theory and more information disclosing the design of the system in the **Background** section.

2 Background

The physics of LASER's, stimulated emission, was discovered by Albert Einstein in year 1917 and not engineered until 1960! The first FBL was demonstrated in 1963 by Elias Snitzer and are still being advanced today [5]. They have many applications from communications to slicing a multitude of materials. From rising technology, these LASER's have improved exponentially and are able to work very efficiently in all aspects of these fields. The newest area for the FBL is mining, which is one of the most discussed topics between scientists and businessmen.

What exactly is a FBL and how does it work? A FBL uses a diode coupled to a doped fiber optic cable, using amplification by stimulation. Some dopants for the amplification process are the elements Yb, Er, and Tm [6]. This process is called population inversion, defined as the redistribution of energy levels by collisional excitation of the electrons in the atom [7]. When electrons collide with a photon, from the diode input, it becomes energized and jumps to a higher atomic level (*Fig. 3*). This process can be mathematically described by the elementary equation: $E_2 - E_1 = \Delta E = hf$, where h is Plank's Constant and f is the frequency of light. Once the electron re-emits the photon, it gets reflected from the Bragg grating inside the fiber cable, thus exciting more electrons and emitting more photons. From this quantum phenomena, a single photon can start a domino effect and amplify the input significantly.

The cladding of the fiber cable, surrounding the doped core, allows the light to have total internal reflection (*Fig. 2*) allowing minimal energy loss and scattering. This effect comes from Snell's law: $\sin(\theta_c) = \frac{n_{clad}}{n_{core}}$, where n is the refractive index. For this to work and there to be total internal reflection: $n_{clad} < n_{core}$. There can be some scattering loss due to bending of the cable, which can be calculated. This can mostly be ignored and the cable can move freely through the system.

The Bragg gratings on each end of the fiber filter the photons so that it can be reflected and energized to the correct wavelength. The input grating has a larger n so no light can re-enter the diode, where the output grating is manufactured to pass a certain wavelength. Once the photon has reached the max wavelength, it is transmitted as the beam.

3 Safety Precautions

The EPPL in room 123.2 of the COAS is a very secure environment to preform experiments. I will store ALL of my equipment, including PPE and experimental tools, inside the lab. This space has a locked door which I will utilize while preforming experiments and storing the equipment. There is also a test cage which I will preform all of my experiments and will be storing all of the equipment in. The test cage will also have polarization tint on the outside so that if anyone comes in during experimentation they will NOT be harmed. I will be wearing polarized goggles at all times while conducting experiments and handling equipment. In the test cage, there will be designated spot for NO crossing, where the beam would be active. Money will also be allocated to buying a downsized test cell with polarization features, in case the lab's test cage cannot be tinted.

3.1 Storage's SOP

Money for the FBL equipment will be allocated for secure, pelican crates for the equipment. It will be stored in the test cage, behind the locked door, and will only be available to the project lead once stored. Only 3 research interns and the supervisor have access to this door inside the lab once locked. The PPE will also be stored in pelican crates inside the test cage along with the equipment. The PPE includes polarized goggles, a headset, grounding cables, and protective gloves. Along with this, there will be NO jewelry of any kind inside the test cage when handling/experimenting with equipment.

3.2 Experiment's SOP

The experiments will always be conducted inside the test cage, behind the locked door, inside the lab. There will be warning lights when the FBL is active and will be warning signs on the locked lab door and test cage at all times. Inside the test cage, there will be warning tape, at all times, where the beam would cross while active. The FBL will also have a switch to turn power on/off and a shutter on the output lens to block any light coming out of the FBL, on or off. Stated above, the test cage will have polarization tint so that if the beam gets reflected towards the cage, it will not be transmitted through the cage.

4 Methodology

While this project will be centered around simulating the high powered FBL in space to study the effects rather than building it. We will be starting with a down-scaled version of the LASER (about 1 Watt of power) before moving into the theoretical aspects of the research. The reason being is so we can have a proof of design for the project, not just the theory. With the smaller version, we will be able to experimentally derive the necessary processes that the simulations will be sourced from. If we did not do this, there would be a lot of educated guessing and assumptions to be made. The FBL will also be used for demonstrations of how the physics work, so that we are able to have theoretical, equations, graphs, simulations, etc., and physical data.

There will most likely need to be multiple versions of the down-scaled FBL so that we can test multiple wavelengths. One reason for this, is due to there not being an exact value for the absorption coefficient of ice. The basic definition of the absorption coefficient: *If equal to 0 the light is completely reflected; if equal to 1, then the light is completely absorbed.* This comes from: $\alpha = \frac{4\pi k}{\lambda}$, where α is the absorption coefficient, k is the extinction coefficient, and λ is wavelength. The extinction coefficient is defined: *How efficiently light is absorbed or reflected from a material* and comes from: $k = \frac{A}{cl}$, where A is the absorbance, c is molar concentration, and l is path length or depth of the material. Because of this, we will need to experimentally derive the Absorbance to solve for k and α. Without this coefficient, we would essentially be guessing what wavelength ice absorbs most efficiently for the simulation.

This is one example of why we need to have multiple versions of the FBL, even though the project is heavily theoretical. There are plenty of other examples, including power consumption, power regulation and efficiency, beam quality, implementing equations of motion for the beam, mining techniques, single vs multi-mode diodes, etc. Completing any of these experimentally will help the theoretical process go by smoother and also make it more accurate for our purposes. Most online information for constants and general information applying to FBL's are strictly for manufacturing and communication purposes, not so much for experimental. Side note, it will be extremely interesting for everyone working on this project and for peer's in the future learning about our research if we do most of our derivations.

4.1 Times Table

	TASKS	START DATE	COMPLETION DATE
1	Determine sim software to use	10/2022	10/2022
2	Find/Derive equations for sims	10/2022	12/2022
3	Start sims	11/2022	05/2023
4	Receive grant money	01/2023	01/2024
5	Order components for FBL and apparatus	01/2023	When delivered
6	Make apparatus to mount FBL	01/2023	02/2023
7	Start testing FBL	02/2023	04/2023
8	Collect data for sims	03/2023	05/2023
9	Finalize sims with data	03/2023	05/2023
10	Continue expanding/improving sims	05/2023	10/2023
11	Finish and publish work	11/2023	01/2024

5 Significance

Space mining is one of the ”Big Talks” in fields of science and business alike. Once pioneered and efficient, mining in space will rid the need for ripping earth of its materials. If we continue to mine earth, we will eventually run out of resources within the millennia. This project introduces the concept of using a FBL to mine in space. From this project, the aerospace industry will have a new, optimized process of extracting resources in space.

6 References

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7 Appendix

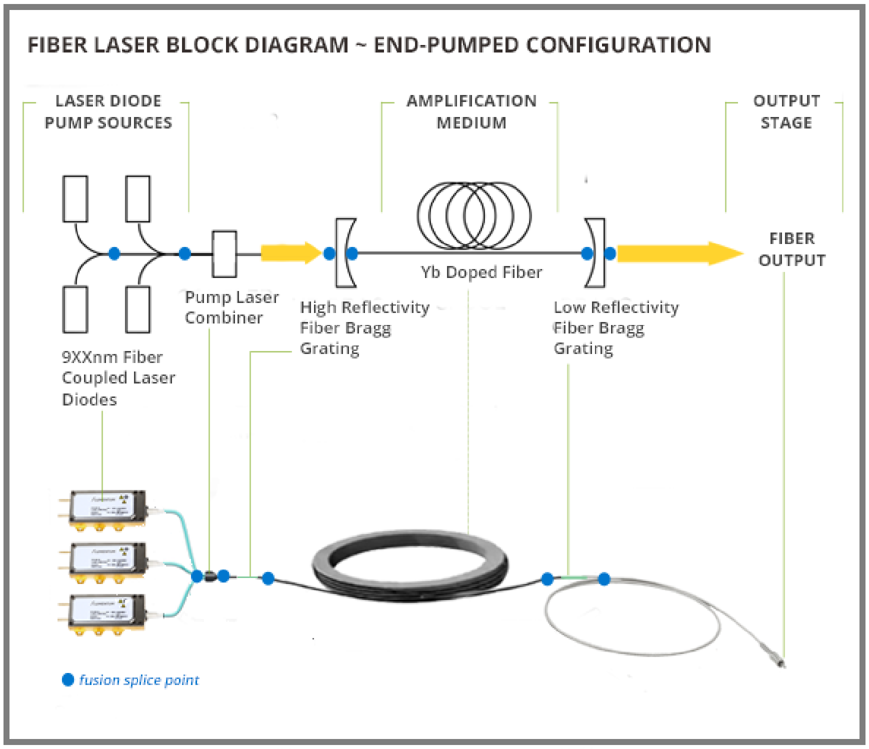

Figure 1: FBL design setup for amplification [7]

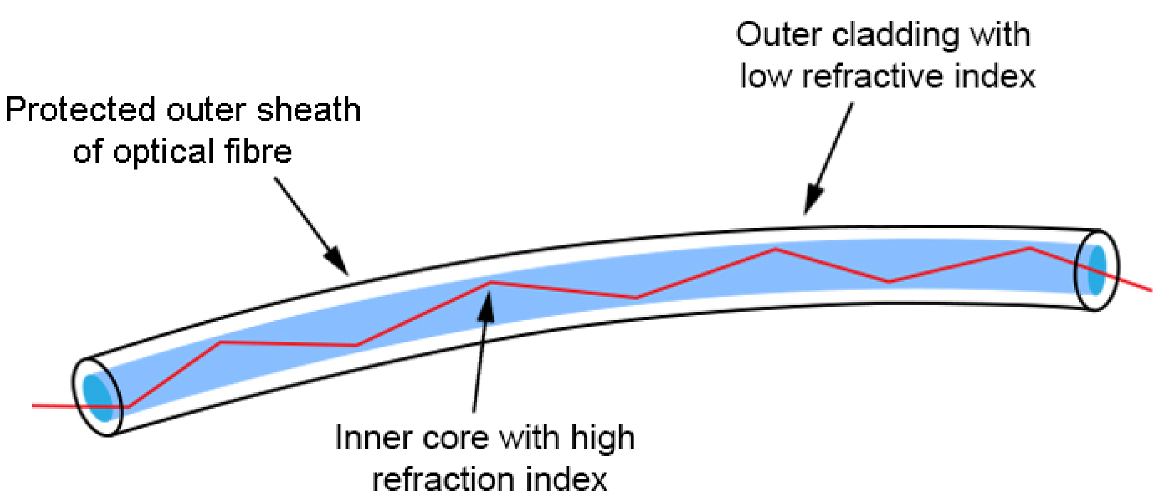

Figure 2: Example of total internal reflection in cable [8]

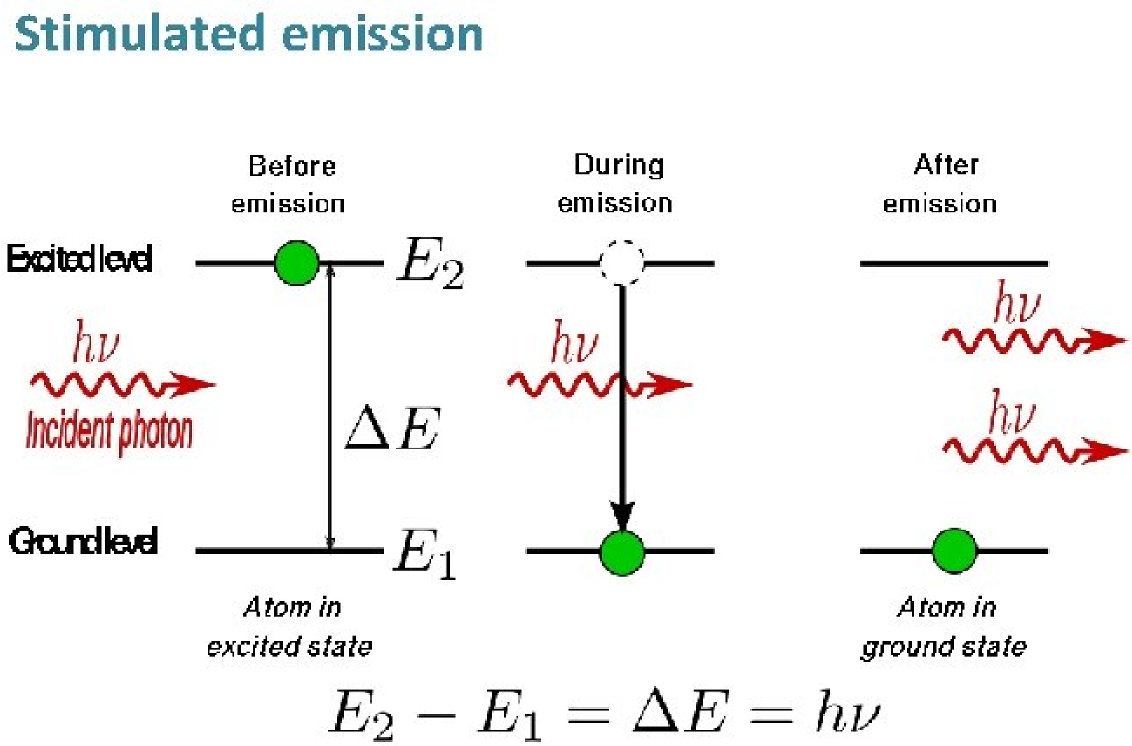

Figure 3: Population inversion cartoon example [9]

Nomenclature

$C - Type =$ Carbonaceous chondrites

$CO_2 =$ Carbon Dioxide

$EPPL =$ Engineering Physics Propulsion Lab

$Er =$ Erbium

$FBL =$ Fiber LASER

$K =$ Kelvin

$LASER =$ Light Amplification by Stimulated Emission of Radiation

$nd : YAG =$ neodymium-doped:Yttrium Aluminium Garnet

$NEO's =$ Near earth objects

$PPE =$ Personal Protective Equipment

$SOP =$ Standardized Operating Procedure

$Tm =$ Thulium

$Yb =$ Ytterbium