

# Lasers Technology



*Single crystal fibers growth*

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# Lasers Technology

## Introduction

The Lasers Technology Program of IPEN is committed to the development of new lasers based on the research of optical materials and new technologies, as well to laser applications in several areas: Nuclear, Medicine, Dentistry, Industry, Environment and Advanced Research. Additional goals of the Program are human resource development and innovation, in association with Brazilian Universities and commercial partners. The Program is basically divided into two main areas.

“Material and Laser Development”, includes crystal growth of optical materials (laser crystals); characterization, modeling and optical spectroscopy of solids, plasmas and biological materials; development of compact diode pumped-solid state lasers and the development of a high power (TW) laser system, one of the main projects of the Center for Lasers and Applications. High power ultrashort pulses lasers based on Chirped Pulse Amplification technologies and Ti:Sapphire gain media, allowed the generation of TW peak power on top of conventional optical tables and the realization of relativistic intensities ( $10^{18}$  W/cm<sup>2</sup>) at modest costs.

The main area, “Laser Applications”, is concerned with technological laser uses such as laser processing, laser remote sensing, development of new diagnostic and therapeutic methods such as optical coherence tomography (OCT), laser Doppler flowmetry, photosensitization, prevention of dental caries, plus other advanced applications of high intensity lasers.

Recent activities are highlighted bellow:

- Development of single crystal fibers for compact laser systems;
- Growth of a solid solution  $\text{LiGd}_{0.232}\text{Lu}_{0.75}\text{Nd}_{0.018}\text{F}_4$ :Nd crystal suitable to obtain a laser medium for mode-locking purposes;
- Characterization, modeling and optical spectroscopy of rare-earth doped crystals and glasses for the development of solid laser medium;
- First single crystal Nd:YLF fiber laser;
- Evaluation of the performance of fs laser-induced Breakdown Spectroscopy (fs-LIBS) for the determination of elements in animal tissues.
- New method for the evaluation of microvascular functionality using low-frequency fluctuations in the laser Doppler flow signal;
- Construction of an automatized workstation with ultrashort laser pulses (femtoseconds) for the study of thermal and non-thermal processes in dielectrics, semiconductors and metals;
- Study of a therapeutic method combining Nd:YAG laser and topical fluoride treatment for effective reduction of caries incidence in patient.
- Development of studies showing that photodynamic antimicrobial therapy is able to reduce 99% of multi-resistant bacteria in burn wounds.
- Analysis of Optical Coherent Tomography applied to dermatology (research work winner of the Natura Campus 2010 Premium for Technological Innovation),
- New LIDAR system for Industrial Emission and Detection installed in Cubatão/SP (collaboration in The National Institutes of Science and Technology Program /INCT).
- Studies for isotope enrichment by ultrashort laser pulses.

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## Lasers Development

### Crystal growth

Crystal growth involves the process of forming a single crystal from a melt or solution. The process is highly sensitive to temperature and impurities. Key parameters include growth rate, crystal size, and defect density. Common materials used in laser crystals include Nd:YAG, Ti:sapphire, and Yb:YAG. The growth process typically involves a seed crystal and a growth solution, with the crystal growing from the seed as the solution is slowly cooled or evaporated.

### Bulk single crystals growth

Bulk single crystal growth is a process used to produce large, high-quality single crystals. This is often done using the Czochralski method, where a seed crystal is dipped into a melt and slowly pulled out, allowing a single crystal to grow. Other methods include the Bridgman-Stockpfer method and the Verneer method. The resulting crystals are used in various applications, including laser gain media and optical components. The growth process is highly controlled to ensure the crystal's purity and structural integrity.

### Single crystal fibers growth

Single crystal fibers are grown using a process similar to bulk single crystal growth, but the crystal is pulled out in the form of a thin fiber. This process is used to create fibers for various applications, including fiber lasers and optical communication. The growth process involves a seed crystal and a growth solution, with the crystal growing from the seed as the solution is slowly cooled or evaporated. The resulting fibers are highly uniform and have excellent optical properties.



Figure 1: Single crystal fiber growth process.

### Development of compact diode-pumped solid-state laser sources

The development of compact diode-pumped solid-state laser sources has been a major focus in laser technology. These lasers are small, efficient, and easy to use, making them ideal for a wide range of applications. They typically use a diode laser as the pump source and a solid-state gain medium. The development of these lasers has led to significant advances in various fields, including medicine, industry, and defense. Key challenges in the development of these lasers include improving the pump efficiency and the thermal management of the gain medium.

# Lasers Technology

## Lasers Development

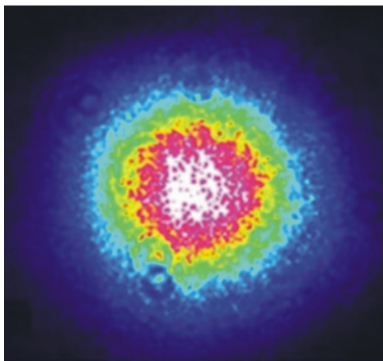


Figure 1: Laser beam profile showing a central spot and surrounding ring structure.

Production and optical characterization of active laser media based on nanopowders and metamaterials. The image shows a laser beam profile with a central spot and a surrounding ring structure, likely representing a Gaussian beam or a similar optical mode.

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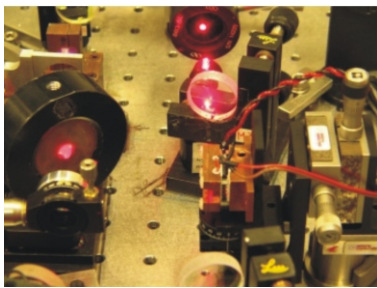


Figure 2: Laboratory setup for laser production and optical characterization.

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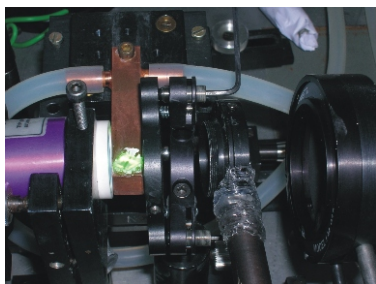


Figure 3: Close-up view of a laser component during production or characterization.

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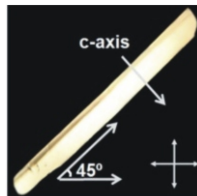


Figure 4: Diagram of a laser rod with a 45-degree angle cut and c-axis label.

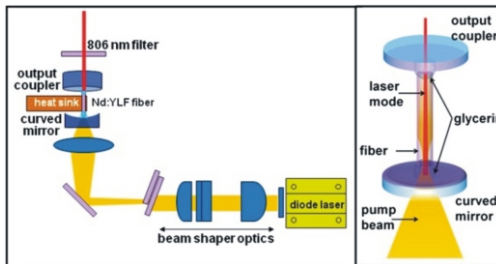


Figure 5: Schematic diagram of a laser system with various components labeled.

### Production and optical characterization of active laser media based on nanopowders and metamaterials

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### Characterization, modelling and optical spectroscopy of rare-earth doped solid laser media

Characterization, modelling and optical spectroscopy of rare-earth doped solid laser media. The image shows a laser beam profile with a central spot and a surrounding ring structure, likely representing a Gaussian beam or a similar optical mode.























