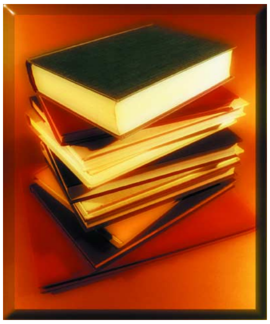

# Teaching the Physics Of a Diode-Pumped Laser

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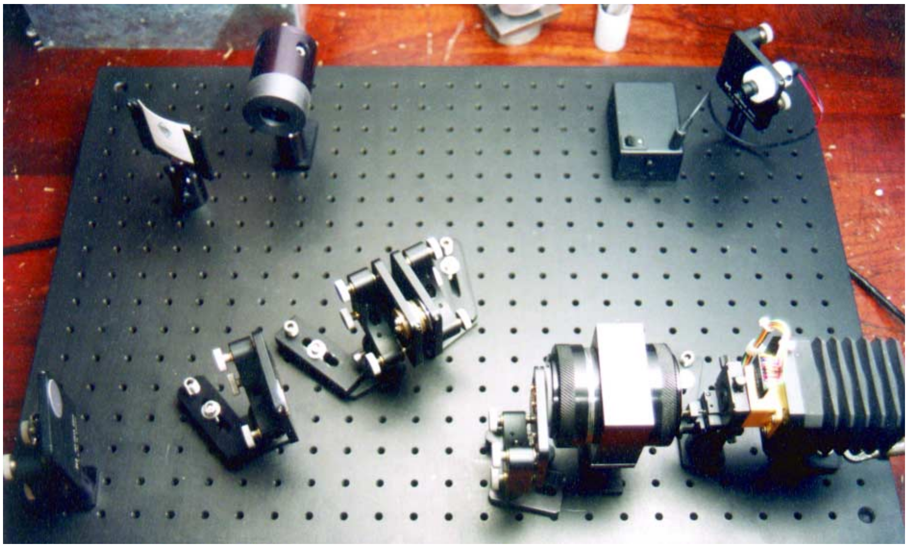

**Figure 1**. Components in a V-folded cavity are arranged across a 650 x 450-mm black anodized aluminum bench plate.

Solid-state laser systems enjoy great popularity in today's labs because of their high efficiency, ruggedness, and relatively small size. To teach the basic physics of laser radiation, with support from the government of Argentina we designed a modular kit featuring all the solid-state components necessary to assemble a Nd:YAG laser. The kit can be used in undergraduate optics or optoelectronics laboratory courses for science and engineering students, or in a course for science teachers.

The solid-state laser is an end-pumped Nd:YAG or Nd:$YVO_4$ crystal with a 2W-laser-diode pumping source. Both these components, as well as the focusing optics, are designed as independent building blocks. This allows students to learn about how the introduction of each one modifies the radiant energy, as well as to get acquainted with its purpose in the overall system.

The kit offers ideas for seven different laboratory experiments once laser oscillation has been obtained. The experiments are written as broad guidelines, featuring a number of questions and hints, to encourage students to discover the answers on their own. The first questions deal with the characterization of coherent and incoherent light. Then the focus shifts to the fundamental concepts of the physics of laser radiation. The final questions cover nonlinear effects such as second-harmonic generation.

Below is a description of the material covered in each of the seven experiments.

## The experiments

*Experiment 1: Comparison of a light-emitting diode (LED) and a laser diode.*
The first experiment allows the students to become familiar with the instruments used in the entire series. It demonstrates the characteristics of incoherent and coherent sources by focusing on spectral and spatial sources. The concept of laser threshold is introduced.

*Experiment 2: The laser cavity.*
The next experiment teaches students to identify the laser medium, optical pumping, and the laser cavity. All the components are set-up and aligned to obtain laser oscillation. The efficiency curve and the energy threshold are measured.

*Experiment 3: Stability condition for the laser cavity.*
Different cavity configurations are considered, along with the concept of cavity losses. The lab work consists primarily of parametrizing each cavity configuration.

*Experiment 4: Transverse oscillation modes.*
The laser is started in cw mode and adjustable losses are introduced to inhibit lower order transverse modes of oscillation. Higher transverse modes of oscillation are observed and characterized.

*Experiment 5: Optimal coupling.*
For each cavity, the optimal output coupling mirror is determined. The efficiency curve for different mirrors is determined for a linear and a V-folded cavity.

*Experiment 6: Q-switch emission.*
By incorporating a saturable absorber into the cavity, modulated laser emission is obtained in the form of large, Q-switched pulses. Once again, different cavity configurations are parametrized.

*Experiment 7: Second-harmonic generation.*
In this experiment, nonlinear optics phenomena are considered. The second harmonic of the main neodymium laser line is obtained by the intracavity insertion of a KTP crystal. The green (532 nm) radiation is extracted from the V-folded cavity through a dichroic mirror. Phase matching and the efficiency of energy conversion are studied.

## Initial experiences

The kit is now being used with excellent results in an advanced laboratory course for undergraduates at the Facultad de Ciencias Exactas y Naturales of the Universidad de Buenos Aires in Argentina. It lasts a semester and has been part of the curriculum of the Physics Department since 2000. Thirty students have taken the course so far, after having participated in an undergraduate course in optics. In the


**Figure 2**. Laser-diode driving source.

optics course, they have used lasers as tools but have not studied their operation. Students who pass the advanced laboratory course may begin doing experimental work for their Masters dissertation, majoring if they choose in the field of photophysics. Some of the students who participated in the laser lab have gone on to join the authors' research team at the CITEFA Laser Lab, a federally funded laboratory located in close proximity to the university.

In the future we are planning to enhance the kit with the addition of an experiment that covers Kerr lens mode-locking by insertion of nonlinear glass in the cavity. To give students experience in working with fiber optics, we are also developing a new experiment that will feature optical fiber.

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