

A Practical Laser Interlock

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June 12, 2002

1 Introduction

This project was a collaboration between myself, Ben Edwards, and Thomas Park. Thomas undertook this as an independent study project in the Engineering Department. Ben, on behalf of the Radiation Safety office, oversaw and funded the project. As the most senior graduate student in the lab, I participated in the design and installation.

The lab uses a Coherent 899 Ti:Sapphire laser as the primary laser light source. This laser can emit as much as 1 W at approximately 800 nm. The 899 is pumped by a 10 W (max) Argon Ion laser (Coherent Innova-310) that has no other role, and whose beam is completely enclosed until it enters the 899 (and therefore poses little danger directly). Small diode lasers are occasionally used, but because they are not currently in use and much less dangerous, they were not considered for this project. Nonetheless, the design presented here can be extended trivially for multiple lasers.

The desired functionality consisted of switches mounted on the (two) entrances to the room, which would disable the laser until it was turned on again. Additionally, warning lights were to be placed outside each door. The lights would be on when the laser was on. The lights both serve as a warning of danger, and tell those familiar with the interlock that opening the door will inconvenience those inside.

2 Design Philosophy

This interlock was designed to balance safety and convenience. This may seem like a silly thing to say when, as we all know, “safety always comes first,” but one reality of laboratory research is that if a safety mechanism is too inconvenient, it will be overridden. The goal, therefore, was to design something that was as safe as possible, yet convenient enough that it would be used every day.

Most large lasers have an electronic input designed specifically for interlock control. The Innova-310 is no exception. However, disabling the laser in this way results in a complete power-down. On subsequent restart, the laser takes 10-30 minutes to warm up and stabilize, and additional time may be required to return it to its previous state. Using the built-in mechanism was therefore deemed unacceptable, and a shutter placed after the Ti:Sapphire laser was used instead. After the shutter closes, the experiment is disabled for only as long as it takes to re-open it.

Another safety/convenience trade-off occurred at the internal door connecting two laboratories. Because equipment is shared between the labs, it is often necessary to pass through this door. It was therefore desirable to have an “override” switch that allows the internal door to be opened (and remain open) without closing the shutter. Additionally, the students in that adjacent lab occasionally need to turn off the lights in the room because the lights interfere with some optical measurements. Therefore, it was necessary to also include an override switch that allowed those students to disable the warning light in their lab, without closing the shutter.

3 Design

The electronic design (Fig. 1) is based on a self-energizing relay. This allows the shutter circuit to remain closed until interrupted (by an open door), and then remain open until manually reset using the *reset button*. The *main power switch* controls the power for the entire circuit, and the *light-on switch* forces the warning lights to turn on even if the shutter is closed.

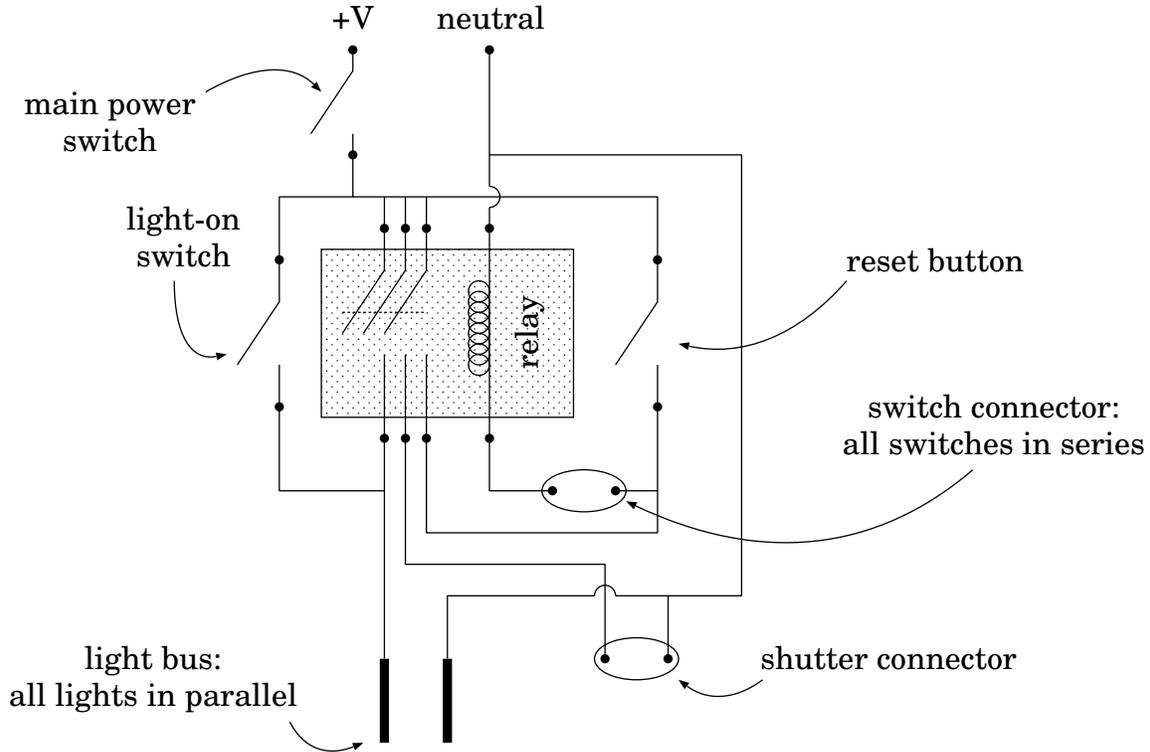


Figure 1: Circuit diagram for the interlock control box.

If a triple-pole relay is unavailable, multiple smaller relays can be combined, as shown in Fig. 2.

The shutter used is an Electro-Optical Products Corporation SH-10 laser safety shutter that takes 5 to 24 Volts DC. Shutter operation is based on a spring and an opposing electromagnet. When power is off, the spring holds the shutter in the closed position. When energized, the electromagnet overpowers the spring and the shutter is held open. The shutter does not come with any mounting apparatus (except for two screws sticking out the back) and so I needed to custom machine an aluminum mount that attaches to the shutter and standard optical mounting hardware. If the shutter is mounted so that opening moves the shutter upward, the magnet often fails to overcome the combined forces of gravity and the spring. Therefore, I needed to mount it such that the shutter arm was hanging downward. Additionally, the shutter occasionally sticks closed when closed and reopened quickly. Finally, the shutter gets *very* hot when open continuously. Ultimately, these issues do not pose a significant problem in our lab.

The door switches are Sentrol 1037 magnetic switches. They consist of two pieces with adhesive tape. One piece has three wires (they are SPDT switches) and the other piece is “free”. The switch changes state at roughly 1.6 cm separation, allowing convenient placement so that the interlock triggers when the door opens about 1 cm. This has the advantage of not triggering when the door rattles, but triggering before there is a line-of-sight through the door.

The warning lights are red LED-based lamps that require 20 V DC. Because both the lamps and the shutter require 20 V DC, the circuit is powered by a 20 V “wall brick” with a simple phono plug.

A total of four wires must be run from each door to the control box, two for the switch, and two for the light. We chose to use standard four-conductor telephone cable for this task. It is cheap, can handle the necessary current and voltage, and is convenient. We used the red and black wires to carry +20 V and neutral (respectively) to the lamps, and the other two wires (yellow and green) for the switches. Although consistent polarity is unnecessary for the switches, we chose to make yellow neutral.

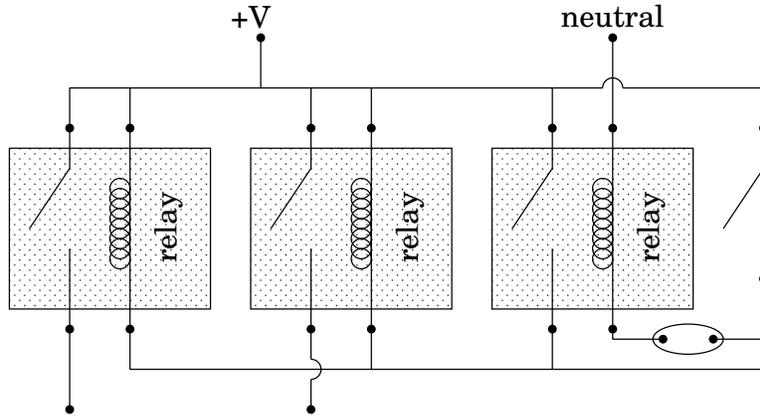


Figure 2: Diagram for combining three single-pole relays to behave as a triple-pole relay.

The overrides that were desired for the interior door were easily implemented with simple switches. A door switch override switch was placed in parallel with the door switch. This switch was physically placed inside the door (on the same side as the laser) so that the laser operator can engage and disengage the override without closing the shutter. The light override is a simple switch in series with the light. This switch was placed outside the door so that it can be operated without interrupting laser operation.