Modulating light

BY JOHN KOSHEL AND

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Light intensity modulation is one of the oldest means of communication—the semaphore contains may of the same basic elements as a modern optical communications system: a light source (the sun), a modulator (the flags) and a detector and demodulator (the observer). Today, optical fibers carry much greater amounts of information with significantly lower loss than comparably sized copper wires.

To demonstrate the remarkable ability of light beams to transmit information, we've created a setup that uses an amplitude-modulated laser driven by an audio signal source, and a remote photodetector. During the Forum on Education at the OSA Annual Meeting in Portland, we distributed a design for an easily constructed and relatively inexpensive example of such a device: a diode laser-based audio link.[1]

System setup

The system is based on a 780 or 670 nm diode laser whose intensity is modulated in proportion to the voltage from a CD player [2] (see Fig. 1). The optical signal can then be detected and played through an amplified speaker. We have found that a photovoltaic cell that has a suitably large area (> 10 mm^2) works well (see parts list, page 60).

To reproduce the signal with reasonable fidelity, the laser diode must be biased so that it is above threshold even when the minimum signal voltage (in this case the "line out" port of the CD player) is applied. For a typical low-power laser diode this requires an current of about 65 mA at a voltage of 2.0 V. The current is supplied by a pair of 9 V batteries connected in parallel by means of an emitter-follower circuit.

The base of the transistor is driven by the output of an operational amplifier, since the op-amp cannot provide sufficient output current to drive the LD directly. The bias voltage is set by a resistive divider connected to the non-inverting input of the op-amp. The CD player is also hooked to this input, but via a high-pass filter, to prevent the bias voltage from damaging it. The output resistance of a typical "line out" port is about 1 kW. Because this is a single channel device, you will need to combine both channels of the stereo signal at the input jack. This is achieved using a spliced cable. With the component values indicated, the circuit of Figure 1 provides a DC bias of around 60 mA to the laser diode (the current threshold is around 45 mA) with a modulation range of 0 to 2 mA.

Detecting the signal

We use a large-area photoconductive silicon photodiode connected directly to an amplifier and speaker. Because the signal level from this detector is about the same as that of a microphone, a reasonable degree of amplification is necessary—more than is provided by an amplified speaker system for the CD player, for example. We use either the microphone input on a home stereo system, or a microphone-level amplified speaker.

The next step is to incorporate an optical fiber into the system. You can use the fiber from the OSA Optics Discovery Kit for this purpose, but a short length of commercial multimode communications fiber with a brightly colored jacket performs a lot better. The broad emission angle of the laser diode (~10° × 40° is typical) does not lead to particularly good coupling even in this case, but the detected signal is acceptable.

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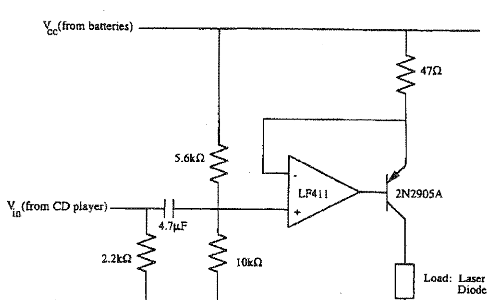

Figure 1. Circuit diagram for the laser diode modulator.

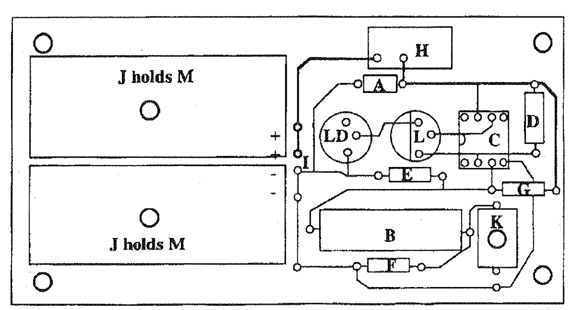

Figure 2. Layout of the laser diode modulator circuit board (2" × 3 7/8").

Education

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All that is left is for the students to classify the problem as pertaining to the above equation, plug in the numbers, and use their calculator! In four steps we have, "thrown out the baby with the bathwater." We have turned a question that requires a combination of skills relevant for solving the type of problems scientists face into one that requires hardly any skills at all. The original analytical challenges are now contained in the equation and in the statement of the problem. All opportunities to develop logical reasoning, to build confidence are lost.

The general idea illustrated by this example is this: Most textbook problems test mathematical, instead of analytical, thinking skills. Is this what we want to accomplish? In my opinion the numerical or algebraic answer to a problem and the mathematical manipulations that lead up to it are perhaps the least interesting aspect of problem solving—they should certainly not be ignored, but they shouldn't be the exclusive focus either. Even though we manage to produce first-rate scientists with the conventional way of teaching introductory science courses, those who currently succeed in the sciences may well do so in spite of the current educational system, not because of it. Standard textbook problems perpetuate the students' impression that science is a complicated web of facts, equations, and algorithms. We shouldn't be satisfied when a student just knows how to plug numbers into an equation in familiar situations, how to solve a differential equation, or how to recite a law of physics. We must insist on more meaningful problems that will better prepare our students for the demands of their future careers.

Eric Mazur is Gordon McKay Professor of Applied Physics and professor of physics at Harvard University. The above article is adapted from his forthcoming book entitled Peer Instruction: A User's Manual, *which will be published by Prentice-Hall this summer. Visit Mazur's web site at http://www.harvard.edu.*

Light Touch

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It is possible to fit this entire setup, including the batteries into a small aluminum box (see Fig. 2). Each part is labeled and listed with approximate price and source. Note that you will have to alter both the bias and collector resistors if you choose a laser diode with significantly different operating characteristics. Also, some laser diodes have grounded cases, and some do not, so care is necessary when mounting. We estimate that the total cost for the device is about $25.

PARTS LIST
(For further information, contact John Koshel at 716/275-8007 or koshel@optics.rochester.edu):

	Description	Radio Shack No.	Price/ #in Pkg
A.	0.1 μF disc Capacitor	272-135	$0.69/2
B.	4.7 μF Non-Pol Capacitor	272-998	$0.99/1
C.	741 Op Amp (or LF411)	276-007	$0.79/1
D.	47 Ω Resistor: 1/2 W	271-1105	$0.49/5
E.	10k Ω Resistor: 1/4 W	271-1335	$0.49/5
F.	2.2k Ω Resistor: 1/4 W	271-1325	$0.49/5
G.	5.6k Ω Resistor: 1/2 W	271-1125	$0.49/5
H.	Submini Slide Switch	275-406	$0.99/2
I.	9-V Battery Clips	270-325	$1.39/5
J.	9-V Battery Clamp/holder	270-326	$0.99/2
K.	3-conductor 1/8" phone jack	274-249	$1.99/2
L.	2N2905A Transistor: TO-39	N/A	--
M.	9-V Battery (2)	not priced at Radio Shack	

Finally, the usual warning applies: even though these are low-power lasers be careful of both direct and reflections of the beam—school children just seem to love looking into the diode directly.

Happy optical communicating.

References

1. I.A. Walmsley and R.J. Koshel, "Optics roadshow: Simple demonstrations for engaging neophyte scientists," presented at OSA Annual Meeting, Portland, Ore., paper WM3 (1995).
2. These laser diodes can be purchased for $10–15 from Timeline Inc. (310/784-5488).

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