Optics for the Fish—Part II

BY R. JOHN KOSHEL

Last month I introduced a series of experiments that use water-filled fishtanks to show refraction, reflection, and scattering. This month, I discuss some water-based optical systems that can be demonstrated using your fishtank. The first, "the luminous fountain," is an optical fiber made out of water; the second is an optical communication system that I call an "optical waterguide." The same equipment and supplies described last month are used for the first experiment; for the second, you'll need to procure a modulatable laser,[1] a photodetector,[2] and an audio amplifier with a speaker.[3]

The luminous fountain

For this demonstration you'll need two containers. The first one should be an acrylic fishtank so that a hole can be drilled in its side (up to 3-cm diameter); the second can be any standard tank or container that can hold water. It is, however, beneficial to have a clear catch basin (this will be explained below).

Set up the system as shown in Figure 1. Center an HeNe laser beam on the hole in the acrylic tank. Tape or cork the hole and fill the tank with water. Then, as in the scattering experiment described last month, add a trace amount of milk or yellow dye to make the beam visible. Once everything is set up, the laser turned on, and the lights turned off, unplug the hole and allow a stream of water to flow into a catch basin placed on the floor. Ask your audience to explain what they see.

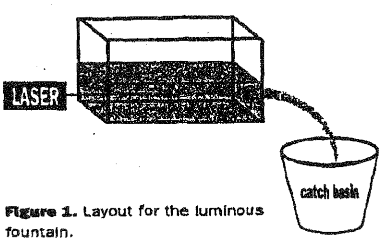

Figure 1. Layout for the luminous fountain.

The laser beam will be confined to the stream of water by total internal refraction. The stream of water is not typically smooth, so it is often difficult to see the beam after a couple of internal reflections. It gets easier to see multiple reflections as the pressure drops and the stream curves more sharply. This little experiment usually gets many "oohs" and "ahhs," since everyone can easily see that the stream of water is glowing. Explain to the audience the analogy between this luminous fountain and optical fibers.

If your catch basin is clear, then you can show nice scattering effects. The water in the catch basin will glow red, especially when the water level in the source tank is low and the stream curves sharply. The light that does make it to the catch basin is scattered due to the water turbulence, air bubbles, and suspended milk particles, making for a visually spectacular demonstration!

Optical waterguide

This experiment uses a modulated HeNe laser, a speaker with a photodetector connected to it, and an audio source such as a microphone, CD player, radio, or tape deck (see Fig. 2). Connect the "line out" signal of the audio device to the modulation input of the HeNe laser. You may have to buy the appropriate connector cables or adapters from a store such as Radio Shack. It is useful to explain the concepts of modulated signals to your audience. Simply said, you are varying the power of the laser in proportion to the amplitude of the audio signal.

Show the audience that you can transmit an audio signal via the laser beam. (You may wish to hold the photodetector next to a fluorescent lamp to demonstrate the fluctuating intensity. You'll hear a 120-Hz buzzing sound corresponding to twice the line frequency.

Position the laser so that the beam strikes the photodetector. Show that you can make sounds from the speaker just by chopping the beam

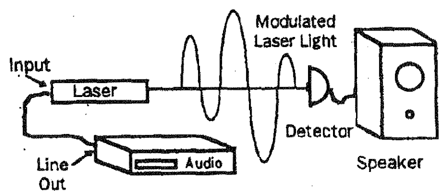

Figure 2. Layout for generating an amplitude-modulated laser beam from an audio signal.

with a comb or your hand, or by blowing chalk dust into the beam. Next, connect the audio source to the modulated laser and get ready for gasps of surprise from your audience. Block and unblock the beam to prove that you're not cheating.

You're now ready to demonstrate an optical waterguide using the same setup described in last month's total internal refraction experiment, this time using a modulated laser (see Fig. 3). The photodetector should be *Continued on page 65*

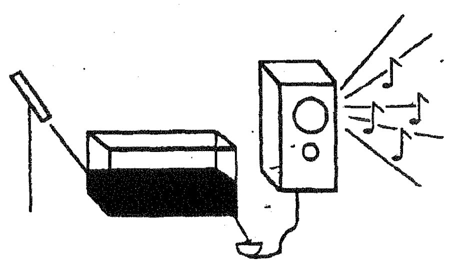

Figure 3. Optical fishtank showing total internal reflection. Place the photodetector on the output end of the tank and connect to an amplified speaker.

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located so that it intercepts the beam exiting the tank. Start playing the music when the water surface is calm and serene, transmitting the audio as before.

Stir the water in the tank lightly. What happens? The quality of the signal is destroyed; in fact, it's lost. Let your students observe what is happening by showing them how the beam is wandering around. Turn off the music and let the water calm. Now rap on the table lightly with your fingers. What do you hear? Your fingers cause vibrations that are carried into the water and set up a wave pattern on its surface. "Play" some tunes by drumming your fingers—this tends to be more amazing to students than playing music through the system.

One final demo uses the modulated laser and the speaker. Rest the speaker against the tank of water, and set the amplifier to maximum volume. Turn on the music and listen to the annoying sound that is generated. What does it sound like? Feedback! You are setting up a wave pattern on the surface of the water that is due to the sound from the speaker. I was amazed the first time I heard this.

Many additional experiments can be performed with a fishtank. Try explaining interference and diffraction by setting the fishtank on an overhead projector and using it as a wave tank. Explore gradient-index optics by dissolving sugar in the water. Or, explain the color of white light (*i.e.*, dispersion) and preferential scattering with the sunset effect.

I plan to continue developing experiments that use the optical fishtank. I'd like to hear about any new ones you discover.

References

1. Edmund Scientific (609/573-6250) sells modulateable HeNe and diode lasers. The HeNe lasers are made by Metrologic at 0.8 mW (D61,310; $550), or 1.5 mW (D61,311; $600). The low-divergence diode lasers are rated at 0.95 mW (D53,162; $345) and 4.2 mW (D53,163; $275). In my opinion, the HeNe lasers are better.
2. Radio Shack sells a 5-pack of Cadmium Sulfide Photocells for $2.29 (Part #276-1657). There are numerous other options from such places as Edmund Scientific and Thorlabs.
3. The best amplified speakers that I have found are at Radio Shack (Part #40-1361 or 40-1403) for $40 and up. Speakers from other companies are typically not amplified enough.

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