

“Acoustic Laser” Kit Instructions

Introduction

We at the Penn State Graduate Program in Acoustics hope that you enjoy assembling the Acoustic Laser and that you will learn about thermoacoustics through its operation. We have included a one-page description of our program and a list of faculty, research areas, and facilities with this kit.

Enclosed with the parts listed on the following page is a reprint of an article entitled “The Power of Sound.” That article appeared originally in the November/December 2000 issue *American Scientist Magazine*, Vol. 88, No. 6, pages 516-525. The article includes a good-quality, color, close-up photograph of the fully-assembled demonstration device on the left-hand-side of Figure 3, on page 519. The right-hand-side of that same figure shows the acoustic laser being powered by concentrated sunlight.

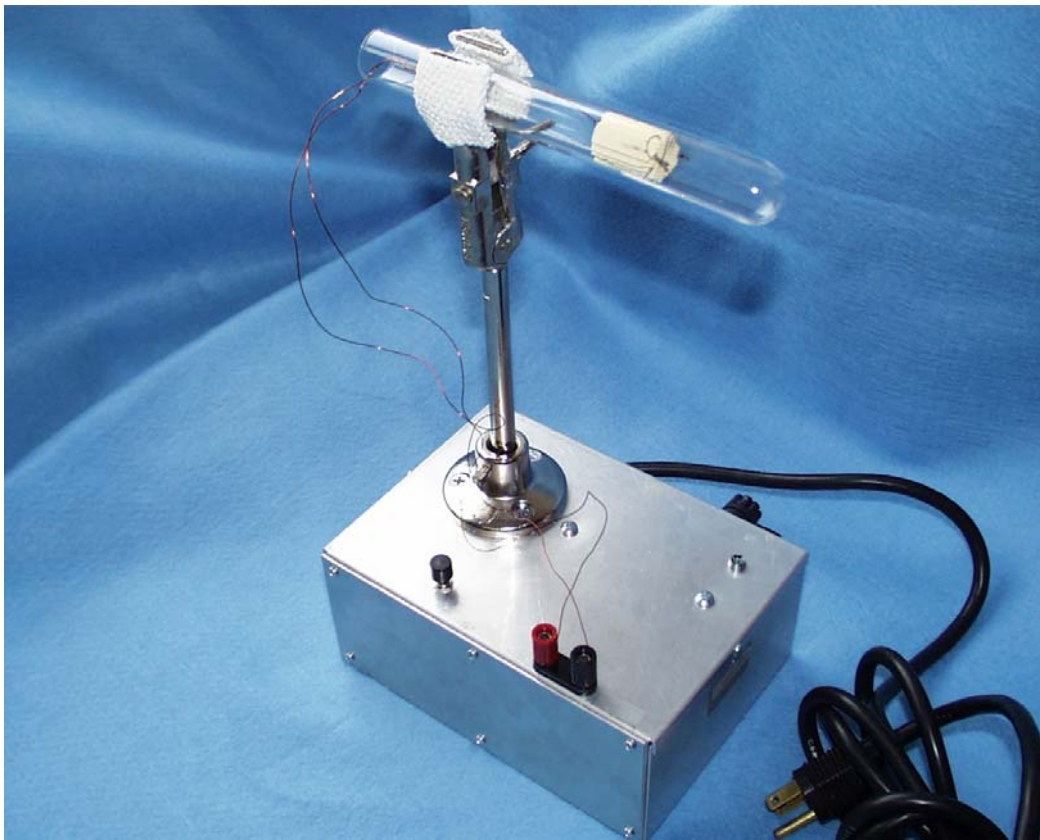


Figure 1. Photo of laser demo mounted on the box that contains a filament transformer, binding posts, switch, power cord and fuse.

Safety First!

Burn/Fire Danger: Since the acoustic laser requires heat for operation, be careful not to touch the closed end of the test tube during operation or shortly thereafter as it becomes **VERY HOT**. Also, be careful not to place the acoustic laser on any flammable material (*e.g.*, paper, foam insulation, etc.) when it is hot.

Broken Glass Danger: If the test tube becomes broken or chipped, discard it immediately. Broken or chipped glass is **VERY SHARP** and can cause painful skin cuts.

Electrocution Danger: Never operate the acoustic laser directly from an electrical power outlet. Plugging the wires of the acoustic laser into a wall electrical socket can make you **VERY DEAD**. It is designed to be operated with a 6 Volt source, such as a lantern battery or a fully-isolated step-down transformer (not an "autotransformer" also known as a Variac® or Powerstat®).

Explosion Danger: Although it is interesting to observe the change in operation of the acoustic laser that occurs when gases other than air are in the test tube, **DO NOT USE WITH, OR AROUND, EXPLOSIVE GASES**. Gases such as Hydrogen (H₂), hydrocarbons, gasoline vapors, or Methane (CH₄), also known as "natural gas," can cause an explosion. Interesting effects can be observed using inert gases (*e.g.*, Helium), or non-explosive gases such as Carbon Dioxide (CO₂) or Sulfur Hexafluoride (SF₆). The open end of the test tube **should never be capped**, as the heating of the air inside will cause a pressure increase that can also cause an explosion of the glass test tube.

Parts List

Your kit should include the following materials:

QUANTITY	UNIT	DESCRIPTION
1	each	Pyrex test tube wrapped in bubble-wrap
1	length	26 gauge nichrome (NiCr) resistance heater wire
2	lengths	24 gauge copper magnet wire with enamel insulation
1	"chunk"	Celcor ceramic catalytic converter "stack" material
1	bag	Containing two very small tubular crimp connectors
1	piece	Sand paper
1	sheet	This instruction sheet
1	sheet	Penn State Graduate Engineering - Acoustics
1	reprint	"Build an 'Acoustic Laser'" from <i>Echoes</i>
1	reprint	"The Power of Sound" from <i>American Scientist Magazine</i>

Other materials that you will need to complete the assembly, which are not provided with the kit, include a hacksaw blade, a book of matches, small pliers, a wire cutter (or scissors) and some adhesive tape. Needle-nose pliers used for electronics would be ideal, but any pliers that can be used to “crush” the tubular crimp connectors will suffice. If you have access to a soldering iron and solder, it can be used to improve the electrical contact between the copper wire and nichrome (NiCr) resistance (heater) wire, but it is not necessary. For operation, you will need a battery, or a laboratory power supply, or a step-down transformer as described in the **Operation** section of these instructions. *Safety glasses should be worn*, especially for the initial operation.

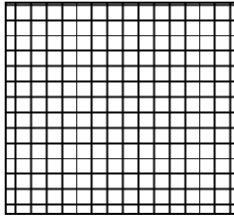
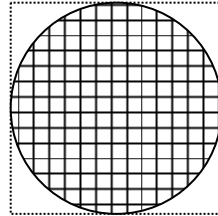
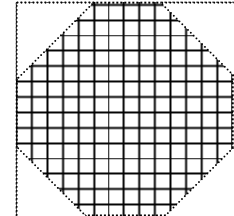
Step-by-Step Assembly Instructions

*It is best to read **all** of the assembly instructions before beginning assembly!*

- 1. A clean, well-lit place.** Before starting assembly, find a desk or table with good lighting and a comfortable seat. Since the shaping of the ceramic will generate “dust,” you may wish to cover the table with old newspaper so that it will be easy to dispose of the ceramic chips when you have completed Steps #3 and #4. ***Do not inhale the dust since it can cause respiratory distress.*** Working over a carpeted floor might *not* be a good idea if a vacuum cleaner is not readily available.
- 2. Remove insulation from ends of the copper wires.** The copper wires are used to connect the NiCr resistance heater wire to the electrical power source. There are two lengths of copper wire in the kit. Copper wire has an orange/brown color. The copper wire is insulated with enamel coating that must be removed from both ends of both wires. This is done most easily by first burning the insulation using a match held under the end of the wire. **Caution:** *The wire also conducts heat, so don't hold the wire too close to the end where you are placing the match or your fingers will get very hot!* Let the fire burn about $\frac{3}{4}$ inch (2 cm) up each end of the wire. After the wire has cooled, use the folded piece of sandpaper to scrape off the burnt insulation and expose the copper. The process of removing the insulation from the wire is known as “stripping the wire.”

If you own a soldering iron and solder, you can “tin” the ends of the copper wire by heating with the iron and applying solder to coat the uninsulated ends of the copper wire with solder. This makes it easier to connect the copper wires to the NiCr heater wire or the power source, but it is not necessary for successful operation of the laser.

- 3. Make a ceramic cylinder.** The ceramic is supplied to you in a rectangular shape. Since the ceramic is supposed to slide easily into the Pyrex test tube, you will have to use a hacksaw blade (and maybe some sandpaper) to re-shape the ceramic. The ceramic is easy to cut, so you do not need to put the hacksaw blade in a saw frame – gentle finger pressure on the blade is sufficient and the blade without the saw is easier to control.

*Original Shape**Ideal Shape**Approximate Shape*

One way to achieve the “ideal shape” is to use the hacksaw to create the “approximate (octagonal) shape” and then smooth the edges to approach the “ideal” cylindrical shape. The best way to proceed is to make small cuts and then check the shape by holding the ceramic up to the open end of the test tube. This process takes some time and skill. Take your time. When this step is completed, the ceramic stack material should nearly fill the test tube and slide easily in and out of the test tube.

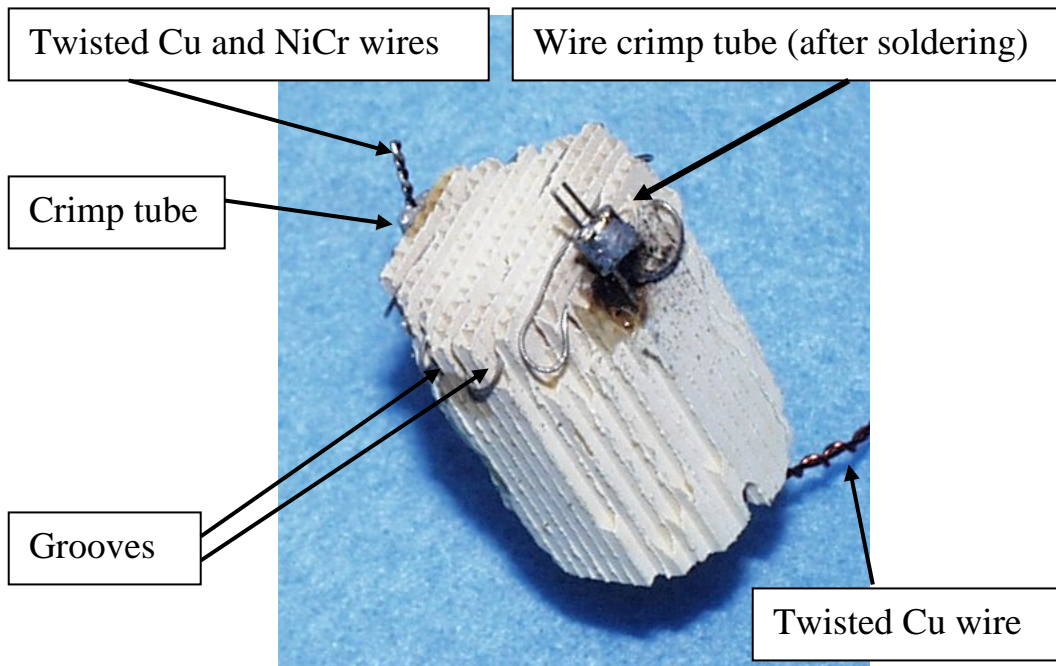


Figure 2. Close-up photo of the ceramic stack after it has been shaped into a cylinder (Step #3), grooved to accept the NiCr heater wire (Step #4), and had the NiCr wire (Step #5) and Cu wire (Step #6) inserted and joined with the crimp tube (Step #7).

4. **Place “heater wire grooves” in the ceramic cylinder.** Look at Fig. 3 on page 519 of the *American Scientist* article. You will see that there are about six grooves on the top surface of the ceramic cylinder. These grooves contain the serpentine winding of the nichrome (NiCr) heater wire. The grooves are about 3 mm (1/8 inch) deep. Using the lightest possible pressure on the hacksaw blade, it is easy to cut the heater wire grooves into the ceramic “stack.”
5. **Wind the heater wire.** The heater wire is the dull-silver colored wire provided in the kit. It is fairly stiff and will resist your attempts to confine it to the shallow grooves you just cut in Step #4. Start by unwinding the coil of wire that is provided and straightening it by drawing it between your thumb and a hard surface like a pencil or a screwdriver shaft to remove any bends or kinks. Place a right-angle (90°) bend ½ inch (1 cm) from one end of the wire. That end will stick up and be joined to one of the copper wires later in the assembly process (Step #6). Beginning at one of the shortest grooves at the end of the ceramic, start winding the heater wire into the grooves. If you have long-nosed pliers, you can use it to place a 180° bend at the end of the wire as it exits the first groove and starts its entry into the second groove.

Continue this process until all of the grooves have been filled with the NiCr wire. At the end, again place a right-angle bend ½ inch (1 cm) from one end of the wire and cut off the excess NiCr wire with a wire cutter. (Save the excess, it should be enough to build a second “stack.”) That end will stick up and be joined to the other copper wire later in the next step of the assembly.

The winding of the serpentine heater wire into the grooves of the ceramic is the most frustrating step in the assembly process. Be patient and gentle. If you use excessive force, you will crack the grooves in the ceramic. If the grooves do become cracked, you can start over (once or twice again) by sanding off or cutting off the remaining (broken) grooves and repeating Step #4 to re-groove the “stack.” The “stack” will be shorter, but should still function well as long as it is at least ½ inch (1 cm) long.

6. **Attach the copper lead wires to the NiCr heater wire.** Insert each of the “stripped” copper wires into one of the “channels” of the ceramic “stack” material and push through until the all of the uninsulated part of the wire is exposed on the “grooved” side of the ceramic. Choose a channel that puts the copper wire as close as possible to the 90° bend in the NiCr heater element. With the copper and NiCr wire ends side-by-side, twist the short lengths of stripped copper wire and NiCr wire together to make electrical contact. Be careful, the ends of the wires are sharp (like a hypodermic syringe) and *can puncture your skin* with very little force.
7. **Join twisted with the crimp tubes.** Secure this copper/NiCr wire junction by slipping one of the tiny crimp tubes over the twisted NiCr/copper wire. Use your pliers to crush the tube tightly around the twisted ends. The crushed tube insures good mechanical and electrical contact between the copper and NiCr wires. You may want to twist the two insulated copper wires together, starting on the un-grooved side

of the ceramic “stack.” This makes it easier to use the copper wires to position the stack in the test tube and gives the laser a neater appearance. Stop twisting about five inches (12 cm) from the uninsulated ends so that you can easily use those ends to make connection to your electrical power source.

If you have a soldering iron and solder, you can also solder the wires into the crimp tubes by placing a small amount of solder on the iron and touching it to the crimped tube while adding solder to the end of the tube. When the crimp tube heats up to the melting temperature of the solder, the solder that is touching the end of the crimp tube should flow easily into the crimp tube and further improve both mechanical strength and electrical continuity.

- 8. Insert the stack and heater into the test tube.** Hold the twisted copper wires and use them (or the eraser end of a pencil, if the fit is tight) to insert the stack a little more than halfway into the test tube; a bit closer to the closed end of the test tube than the open end. Bend the twisted copper wires around the lip of the test tube and fix them into place with a small piece of tape. This will keep the stack from sliding around in the tube or possibly falling out.

Congratulations! You have completed the assembly of the “acoustic laser.”

Operation and Experimentation

POWER SOURCES. To operate your “acoustic laser,” you will need a source of electrical power. It requires about 6 Volts at about 4 Amperes to heat the heater and create the spontaneous acoustic oscillations of the air within the test tube. There are many ways to obtain the required electrical power. Your choice should be based on safety consideration, the length of time and number of times you plan to operate the demonstration, availability of components, experience with electrical systems, and the number and variety of the experiments you would like to perform.

- 1. Battery operation.** The simplest and safest way to power your “acoustic laser” is from a pair of alkaline 6 Volt “lantern batteries.” It is also the least reliable, since the state of the battery is difficult to determine and a weak battery will not produce sufficient heating. Lantern batteries are readily available at most hardware stores, Wal-Marts, K-Marts, discount stores, etc. They typically have spring or screw-type connectors at the top and frequently are sold in two-packs. The Energizer No. 529 (Wal-Mart, about \$6.95 ea.) is a common variety.

Longer and louder operation can be obtained if two or more lantern batteries are connected in parallel: positive (+) battery terminals are connected together and connected to one copper wire from the laser while the negative (-) battery terminals connected together and connected to the other copper wire.

2. Step-down transformer operation. Although “lantern batteries” are very safe and easy to obtain, frequent operation or long duration experiments can become expensive using battery power. Another possibility is to purchase a step-down transformer that can provide 6 Volts from the standard 115 V_{ac}, 60 Hz power line (220 V_{ac}, 50 Hz, in Europe). Such transformers, usually known as 6.3 volt “filament transformers” (because they were commonly used to heat the filaments of vacuum tube prior to the “transistor” era), are sometimes available for only a few dollars from electronic repair businesses or at weekend flea markets. Be sure that the transformer can supply at least 4.0 Amperes of current. New step-down transformers can be purchased from electronic supply houses such as Digi-Key (www.digikey.com, 800-344-4539) or Allied Electronics (www.alliedelec.com, 800-433-5700). Some suitable units are included in the following table:

Digi-Key Part No.	Description	Current (Amps)	Price (\$)
HM-508-ND	Filament Transformer	4.0	17.22
Allied Part No.	Description	Current (Amps)	Price (\$)
836-6030	Low Voltage Transformer	4.0	13.94
967-8366	Power Transformer	4.0	8.85
927-3171	Variable (Auto) Transformer	1.8	59.17
645-0011	Variable (Auto) Transformer	3.0	62.00

If you choose to power your laser from the power mains (wall electrical outlet) with a step-down transformer, be sure to have a person who is **competent in electrical circuit fabrication** add the power cord, fuse, and switch to the transformer. You will also need (screw) terminals for attachment of the copper wires to the step-down transformer output. The transformer should be placed in a box that will prevent accidental contact with the transformer terminals that are connected to the AC wall socket (power mains)! The transformer should be grounded for safety. (See Figure 3 on the following page.) Sloppy or thoughtless wiring of any device that connects directly to the power mains is a recipe for a serious **ELECTROCUTION** or **FIRE** hazard.

3. Variable voltage operation. Some of the more advanced experiments, such as the investigation of the limit-cycle behavior and oscillation onset power, require a variable voltage source. This can be provided if the step-down transformer is plugged into an “autotransformer” that can adjust the voltage that comes from the power mains. ***Never connect the laser directly to the autotransformer without a step-down transformer.*** Autotransformers provide no isolation from the power mains and it is easy to accidentally turn them up to a voltage that is dangerously high, causing the heater to burn out or vaporize explosively and exposing the experimenter to a serious **ELECTROCUTION** or **EXPLOSION** hazard.

4. Laboratory power supply operation. Most school and college laboratories have adjustable ac or dc power supplies that can provide (and sometimes display!) voltages around 6 Volts at currents around 4 Amperes. For example, an Agilent™ (formerly Hewlett-Packard) Model E642A, 50-Watt power supply can provide 0-8 V_{dc}, at up to 5 A_{dc}. Unfortunately, the “list price” of that power supply, which has direct digital read-out

of both current and voltage, is \$695 (www.agilent.com, 800-452-4844). Similar power supplies are often available on the used and/or reconditioned equipment market (e.g., Test Equity, 800-475-3457; Tucker Electronics, 800-527-4642) at substantially lower cost.

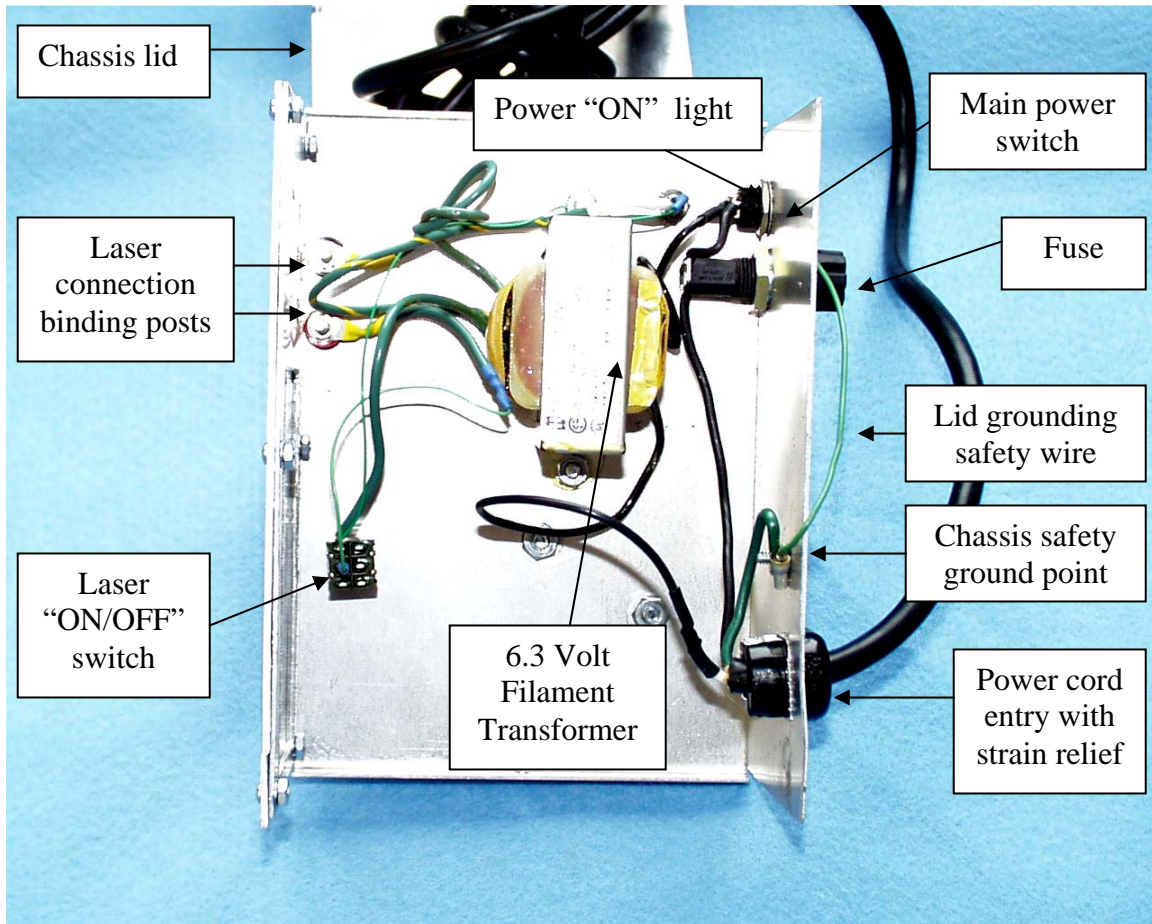


Figure 3. Photo of an installation layout for the inside of a metal enclosure containing the filament transformer. Note that the power line ground (green wire) is connected to both halves of the metal enclosure to protect against electrocution if the 115 V_{ac} “wall electrical power” should accidentally contact the enclosure.

START YOUR “ACOUSTIC LASER.” Before connecting the copper wires from your “acoustic laser” to the power source, be sure the “acoustic laser” is in a place where it will not start a fire or burn the experimenter. *Remember – once started, do not touch the part of the test tube which contains the heater wire, it’s hot!* Hold the test tube near the (cool) open end.

Connect the laser to the power source. Within 10 seconds, you should see the heater wire start to glow orange in some places, usually near the 180° degree bends at the ends of the grooves. Once you see the glow, it will only be about 10 more seconds before the laser starts to emit a loud, pure tone.

Acoustically-enhanced heat transfer. You should notice that the “heater glow” would cease, or diminish substantially, once the laser starts to radiate sound. This is due to the enhancement of the air’s ability to transport heat that occurs when it is oscillating acoustically.

Acoustically-induced streaming. You should also place your hand about an inch in front of the open end of the test tube. The acoustic radiation is sufficiently large to cause streaming of the air outside the tube away from the sound source. You can also observe this “acoustically-driven streaming” by placing a lighted match just in front of the test tube. The streaming should be sufficient to push the flame away from the mouth of the test tube or blow it out entirely.

The streaming is an important part of the laser. It is this steady airflow that serves to cool the cold-side of the ceramic stack that is not being heated by the heater wire. The generation of sound depends upon there being a large temperature difference between the hot and cold ends of the ceramic “stack” material. In high-power laboratory thermoacoustic sound sources [G. W. Swift, “Analysis and performance of a large thermoacoustic engine,” *J. Acoust. Soc. Am.* **92**(3), 1551-1563 (1992)], and in larger solar-powered thermoacoustic sound sources [R-L. Chen and S. L. Garrett, “Solar/heat driven thermoacoustic engine,” in *Proc. 16th Int. Cong. Acoust.* Vol. 2:813-814 (1998), Eds., P. K. Kuhl and L. A. Crum (Acoustical Society of America, Melville, NY)], a separate cold-side heat exchanger, usually cooled with flowing water, is required to keep the cold-side of the stack from heating up.

To stop the sound, disconnect the laser from the electrical power source.

SOME SUGGESTIONS FOR EXPERIMENTS. Once you start to become comfortable with the operation of your “acoustic laser,” there are many experiments you can perform which will provide insight into its operation and lead to a better understanding of this novel thermoacoustic transducer. Quantitative measurement may require additional instrumentation, such as a microphone or sound level meter, frequency counter, voltmeter, oscilloscope, etc. Some of these suggestions would be suitable for high school science fair projects, others might require instrumentation available only in a college, university, or industrial laboratory.

Effect of stack position in the tube. Vary the location of the stack within the test tube and observe the change in the pitch and the amplitude of the sound radiated by your laser.

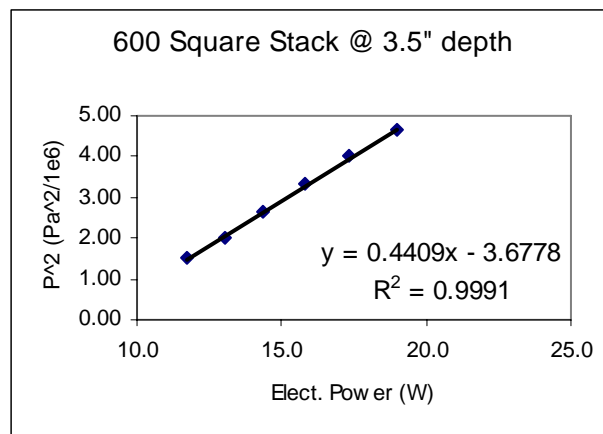
Onset power. If you have the ability to vary the power (voltage multiplied by current) input to the laser using an autotransformer and step-down transformer or a laboratory power supply, you can determine the power required for onset of acoustic oscillation as a

function of stack position. At any stack location, start from a low power and increase it slowly until the "acoustic laser" begins its self-maintained oscillations. At power levels just below onset, you can "flick" the rim of the test tube and you will notice that the "note" it produces will "ring" for a much longer time than if there were no power applied to the heater. When you are just at the onset power level, a "flick" may not ever decay. A plot of the position of the stack (as measured from the hot end of the stack to the closed end of the tube?) as a function of the power to reach onset might be interesting.

Limit-cycle behavior. At power levels very close to onset, you can observe an interesting cyclic behavior of the acoustic signal. The first time you energized your "acoustic laser," before the sound was generated, the heater wire glowed brightly. Once the sound started, the glow diminished or ceased due to the acoustically-enhanced heat transfer from the wire to the oscillating gas. If the power level is very close to onset, then the wire will heat up and produce a temperature difference across the stack. When this temperature difference is sufficient, sound will be produced. The sound will increase the heat transfer rate and reduce the temperature difference across the stack to a level that is below onset and the sound will cease. With no sound, the temperature difference will increase again and the sound will re-start, and again will quench the temperature difference. See how the period (several tens of seconds) of this limit-cycle varies with stack position and power level.

Energy and Power Measurements. To make quantitative measurements, it is convenient to be able to measure either the radiated acoustic power or the acoustic pressure amplitude at the closed end of the test tube. To make radiated power measurements, a sound level meter can be placed a meter from the end of the tube. If spherical spreading is assumed, the acoustic intensity ($I = p_{\text{rms}}^2 / \rho_0 c$) can be integrated over the surface area of the sphere ($4\pi \text{ m}^2$ at a radius of 1.0 meter) to provide a useful (if not exact) measurement of the total radiated acoustic power.

Another alternative is to install a microphone in the back of the test tube. A glass blower can attach a "stem" to the back of the test tube to simplify attachment of the microphone. The square of the acoustic pressure can be plotted against the electrical power provided to the heater as shown in the graph below:



Extrapolation of the "best fit" line to the "Electrical Power" axis provides an accurate measurement of the onset electrical power. The onset power can then be studied as a function of stack position in the test tube or stack length. The best paper for discussion of these results was written by G. W. Swift, "Analysis and performance of a large thermoacoustic engine," *J. Acoust. Soc. Am.* **92**(3), 1551-1563 (1992). Needless to say, Swift's level of analysis is appropriate for advanced undergraduate students of science or engineering.

Change the pitch of the sound. The frequency (or pitch) of the sound radiated by the "acoustic laser" depends upon the length of the test tube. You can change that pitch by sticking a pen or pencil into the open end of the test tube or by attaching a tube of rolled-up paper tightly to the end of the test tube using ordinary adhesive tape. If you place measured marks on the paper and start the laser, you can increase the pitch of the sound by cutting the paper tube shorter and shorter with a scissors. The frequency can be measured electronically, but if you do not have access to a microphone and an electronic frequency counter, you can measure the frequency quite well by matching the tone to the note produced by a piano or electronic keyboard instrument. The table below provides the frequencies of musical notes. Middle-C (C₄) has a frequency of 261.63 Hz. You can then plot the overall length of the tube (glass + paper) vs. frequency.

EQUAL TEMPERED CHROMATIC SCALE

A₄ = 440

American Standard pitch. Adopted by the American Standards Association in 1936

Note	Fre- quency	Note	Fre- quency	Note	Fre- quency	Note	Fre- quency
C ₀	16.35	C ₂	65.41	C ₄	261.63	C ₆	1046.50
C# ₀	17.32	C# ₂	69.30	C# ₄	277.18	C# ₆	1108.73
D ₀	18.35	D ₂	73.42	D ₄	293.66	D ₆	1174.66
D# ₀	19.45	D# ₂	77.78	D# ₄	311.13	D# ₆	1244.51
E ₀	20.60	E ₂	82.41	E ₄	329.63	E ₆	1318.51
F ₀	21.83	F ₂	87.31	F ₄	349.23	F ₆	1396.91
F# ₀	23.12	F# ₂	92.50	F# ₄	369.99	F# ₆	1479.98
G ₀	24.50	G ₂	98.00	G ₄	392.00	G ₆	1567.98
G# ₀	25.96	G# ₂	103.83	G# ₄	415.30	G# ₆	1661.22
A ₀	27.50	A ₂	110.00	A ₄	440.00	A ₆	1760.00
A# ₀	29.14	A# ₂	116.54	A# ₄	466.16	A# ₆	1864.66
B ₀	30.87	B ₂	123.47	B ₄	493.88	B ₆	1975.53
C ₁	32.70	C ₃	130.81	C ₅	523.25	C ₇	2093.00
C# ₁	34.65	C# ₃	138.59	C# ₅	554.37	C# ₇	2217.46
D ₁	36.71	D ₃	146.83	D ₅	587.33	D ₇	2349.32
D# ₁	38.89	D# ₃	155.56	D# ₅	622.25	D# ₇	2489.02
E ₁	41.20	E ₃	164.81	E ₅	659.26	E ₇	2637.02
F ₁	43.65	F ₃	174.61	F ₅	698.46	F ₇	2793.83
F# ₁	46.25	F# ₃	185.00	F# ₅	739.99	F# ₇	2959.96
G ₁	49.00	G ₃	196.00	G ₅	783.99	G ₇	3135.96
G# ₁	51.91	G# ₃	207.65	G# ₅	830.61	G# ₇	3322.44
A ₁	55.00	A ₃	220.00	A ₅	880.00	A ₇	3520.00
A# ₁	58.27	A# ₃	233.08	A# ₅	932.33	A# ₇	3729.31
B ₁	61.74	B ₃	246.94	B ₅	987.77	B ₇	3951.07
						C ₈	4186.01

Lots more experiments! Scientists have been experimenting with thermoacoustic sound sources and thermoacoustic refrigerators for nearly twenty years. Many of these can be located by checking the references in “The Power of Sound” article from *American Scientist Magazine* **88**(6) 516-525 (2000). There are several nice experiments on thermoacoustic refrigeration (the opposite of an “acoustic laser” – put in sound and pump heat from hot to cold) in an article by J. Wheatley, *et al.*, “Understanding some simple phenomena in thermoacoustics with applications to acoustical heat engines,” *Am. J. Phys.* **53**(2), 147-162 (1985).

Acoustic Laser Kit Ordering Instructions

Use the form on the following page of to order kits or replacement parts for other experiments. Make your check payable to “Penn State” and send the check and form to the address below:

Acoustic Laser Kit
Graduate Program in Acoustics
P. O. Box 30
State College, PA
16804-0030

Item Descriptions:

1. **Complete “acoustic laser” kit.** The kit includes one test tube, one “cube” of ceramic stack material; two crimp tubes, two lengths of copper magnet wire, and one length of nichrome heater. Also included is a reprint of “The Power of Sound” by S. Garrett and S. Backhaus from *American Scientist Magazine* **88**(6), 516-525 (2000) and detailed instructions for assembly, along with suggestions for experiments.
2. **Ceramic stack cubes.** One of the “cubes” we provide in the kit of Item #1.
3. **Nichrome heater wire.** Three-foot length of the same #26 gauge nichrome (NiCr) heater wire that is included with the laser kits of Item #1. It is enough heater wire for at least four demonstration devices.
4. **Copper crimp tubes.** Same short lengths of copper tube as included in Item #1 used as a crimp connector to join the copper lead wire to the NiCr heater wire.
5. **Eight-inch Pyrex™ test tubes.** Same tube as included in Item #1.

"Acoustic Laser" Kit and Parts Order Form

Shipping Instructions:

Name _____

Institution _____

Street Address _____

City, State ZIP Code _____

E-mail address _____

Phone number () -

Item	Quantity	Description	Price(\$)/Unit	Total (\$)
1		Complete laser kit	14.00/ea.	
2		Ceramic stack cubes	2.00/ea.	
3		Three foot length of #26 NiCr heater wire	5.00/piece	
4		Crimp connectors	1.00/pair	
5		8" Pyrex test tube	3.00/ea.	
			Sub-Total	
		Packaging and postage for US or Canada		10.00
		Packaging and postage outside the US or Canada		20.00
			Total	

Please allow six weeks for delivery.

Any comments or suggestions about the instructions or materials and your experiences building or using the kit would be appreciated.
