The Florida Advanced Technological Education (FLATE) Center wishes to make available, for educational and non-commercial purposes only, materials relevant to the "EST1830 Introduction to Alternative/Renewable Energy" course comprised of images, texts, facilitator's notes, and other demonstration materials.

This instructional resource forms part of FLATE's outreach efforts to facilitate a connection between students and teachers throughout the State of Florida. We trust that these activities and materials will add value to your teaching and/or presentations.

FLATE
Hillsborough Community College - Brandon
10414 E Columbus Dr., Tampa, FL 33619
(813) 259-6575
www.fl-ate.org; www.madeinflorida.org; www.fesc.org

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Introduction to Alternative and Renewable Energy

EST1830

FESC Florida Energy Systems Consortium

FLATE FLORIDA ADVANCED TECHNOLOGICAL EDUCATION CENTER

3. Energy Production

3.2 Alternative Energy: New Directions

New Directions

- Thermoacoustics
- Thermoelectrics
- Magnetocalorics
- Sun Heat Thermochemical Storage
- Liquid Metal Battery
- Fusion
  1. Magnetic Confinement (Toroidal Magnets)
  2. Inertial Confinement (Lasers)

Thermoacoustics

•The cold heat exchanger (dark grey) is identical to the ambient heat exchanger.

•The cold heat exchanger plate is in contact with the “platform” plate (yellow) that contains the regenerator and sensor signal lines.

•A second thermally-insulating Ultem plastic plate (green) provides the contoured plenum space that directs the oscillating cold helium gas in and out of the thermal buffer spaces through the platform.

•A solid stainless steel plate (dark grey) is used to seal the platform, cold heat exchanger plate, and plenum plate to the pressure vessel (green).

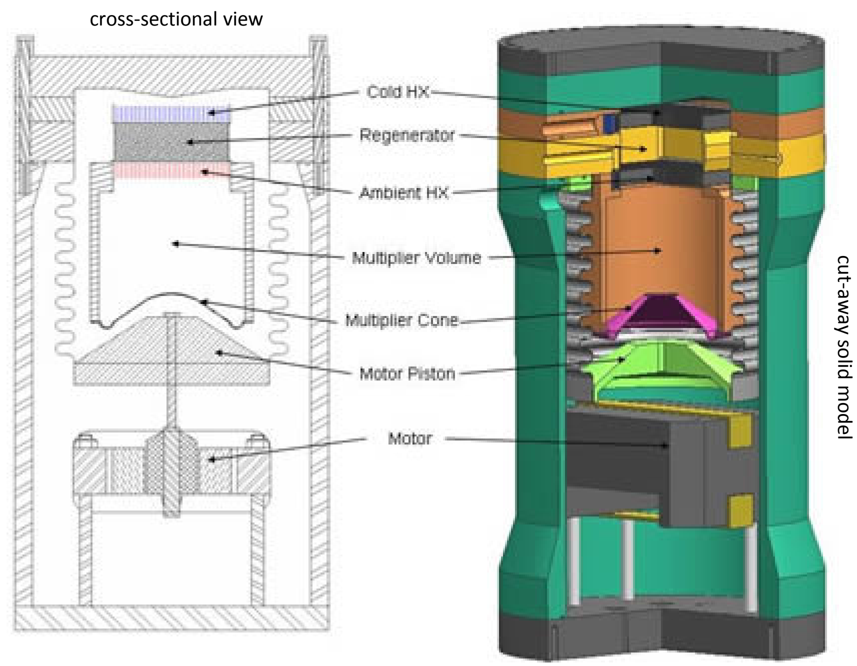
•Enclosing the ambient heat exchanger is the vibromechanical multiplier comprised of the compliance volume within the multiplier's cylinder (orange) and is terminated by an ordinary loudspeaker cone (purple).

•Directly below the speaker cone is the power piston cone (light green) that is attached to the bellows (gray).

•The moving-magnet linear motor, which moves the power piston cone, is shown as a gray rectangle with yellow straps. It is attached to the bottom plate (black) that forms the lower boundary of the pressure vessel.

•The cylindrical portion of the pressure vessel is shown in green.

Thermoacoustic refrigerator

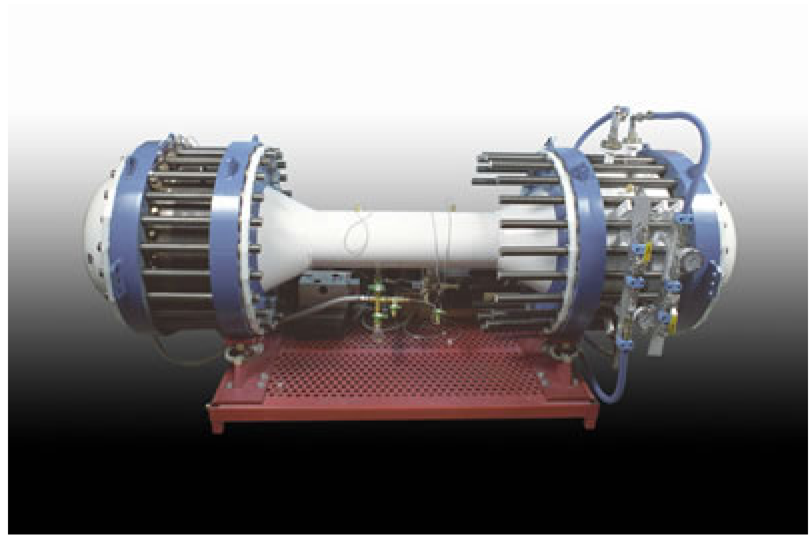


A prototype thermoacoustic chiller: 10 inches in diameter and about 19 inches tall with cooling capacity of 119 W at a temperature of -24.6 °C.

http://www.acs.psu.edu/thermoacoustics/refrigeration/benandjerrys.htm

Thermoacoustics

The TRITON thermoacoustic chiller is based on a double-Helmholtz resonator design that contains a high-power, high-efficiency moving-magnet electrodynamic loudspeaker in the left "bulb" and a pair of heat exchangers containing a ceramic Celcor™ stack in the right bulb.

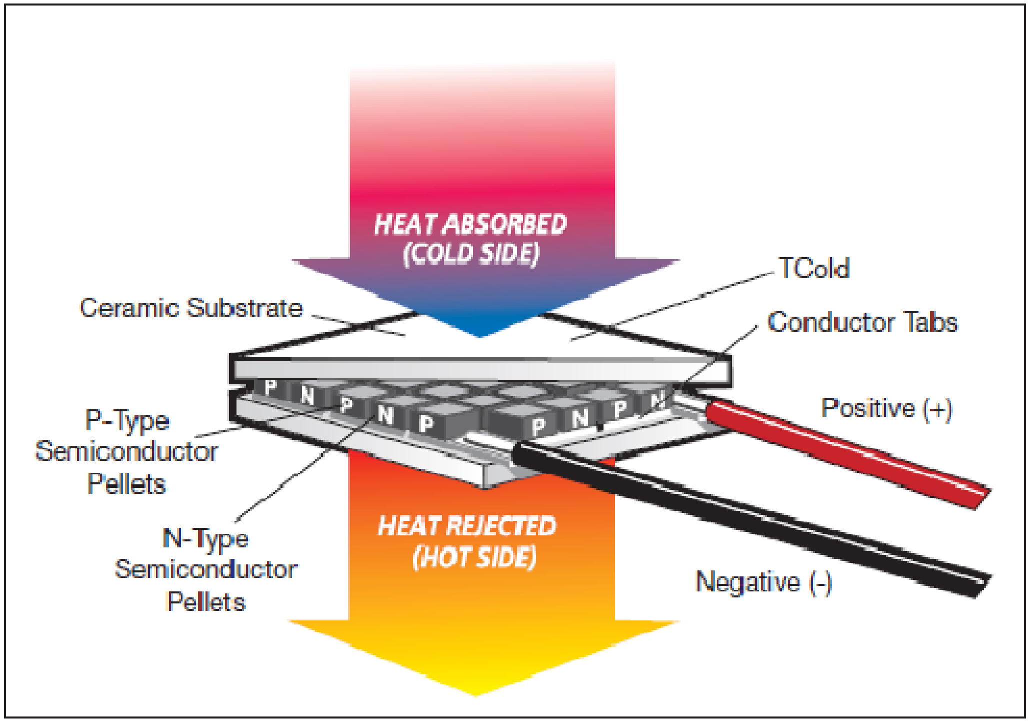


The blue hoses contain the 50/50 ethylene-glycol/water mixture (antifreeze) that transports heat to and from the heat exchangers.

The system was pressurized to 30 atmospheres with a mixture of 71% Helium and 29% Argon.

http://www.acs.psu.edu/thermoacoustics/refrigeration/benandjerrys.htm

Thermoelectrics



Thermoelectric Device

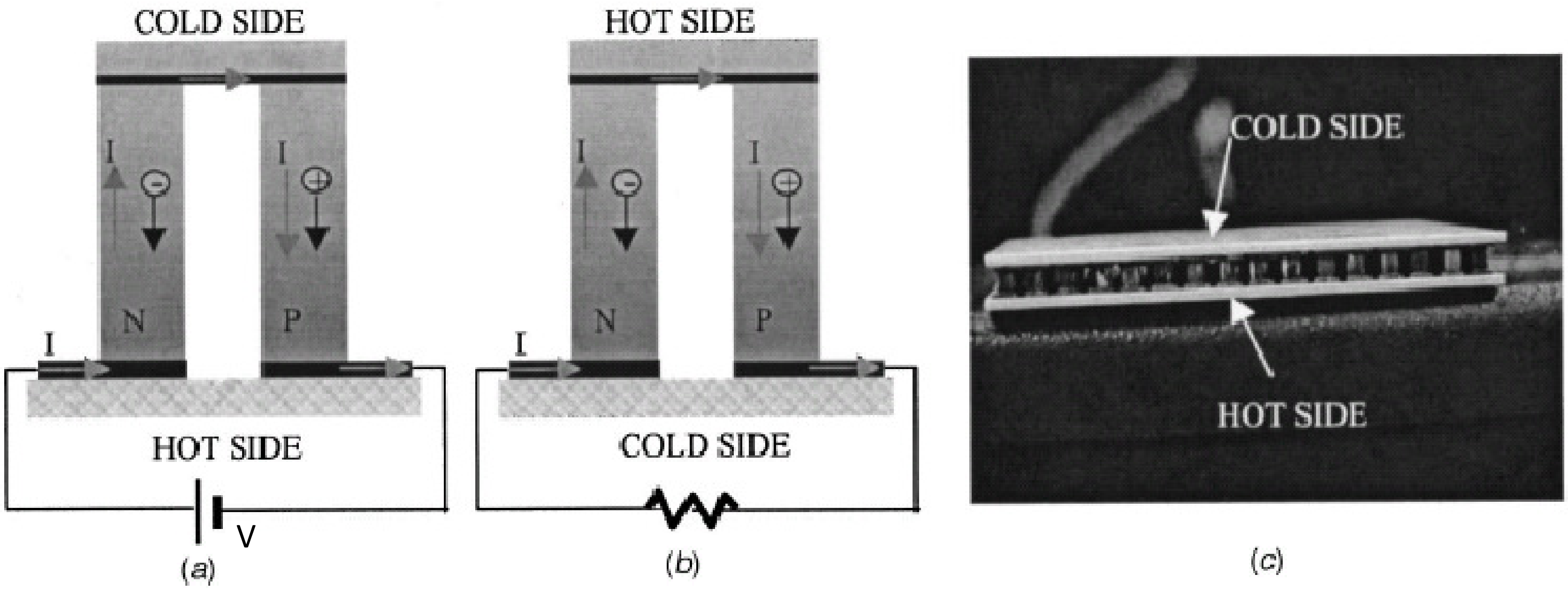


Fig. 1 Illustration of thermoelectric devices (*a*) cooler, (*b*) power generator, and (*c*) an actual device

(a) Peltier effect

•Current flows through n-type/p-type semiconductors.

•Electrons (n-type) and holes (p-type) carry heat away from top (metal/semiconductor) junction.

•Cooling effect: $\Delta V=-S\times\Delta T$

$\Pi=S \times T$

(b) Seebeck effect

•ΔT maintained between two ends of materials.

•Electrons/Holes diffuse to cold side. Mobility creates potential difference and Current.

•Power generation: $Q=\Pi \times I$

Figure of Merit

$$ZT = \frac{S^2\sigma}{k_e + k_p}T$$

Chen, G., Shakouri, A., Journal of Heat Transfer, Vol. 124, 242, 2002

Thermoelectrics

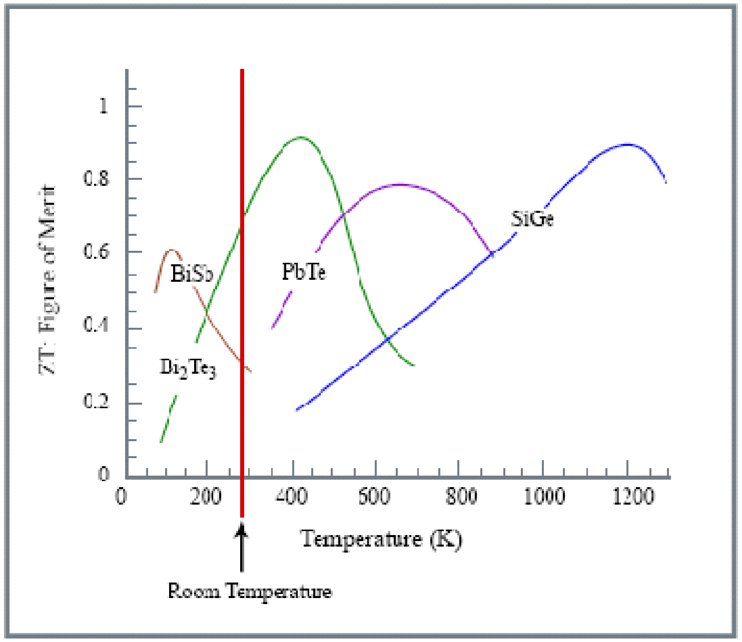
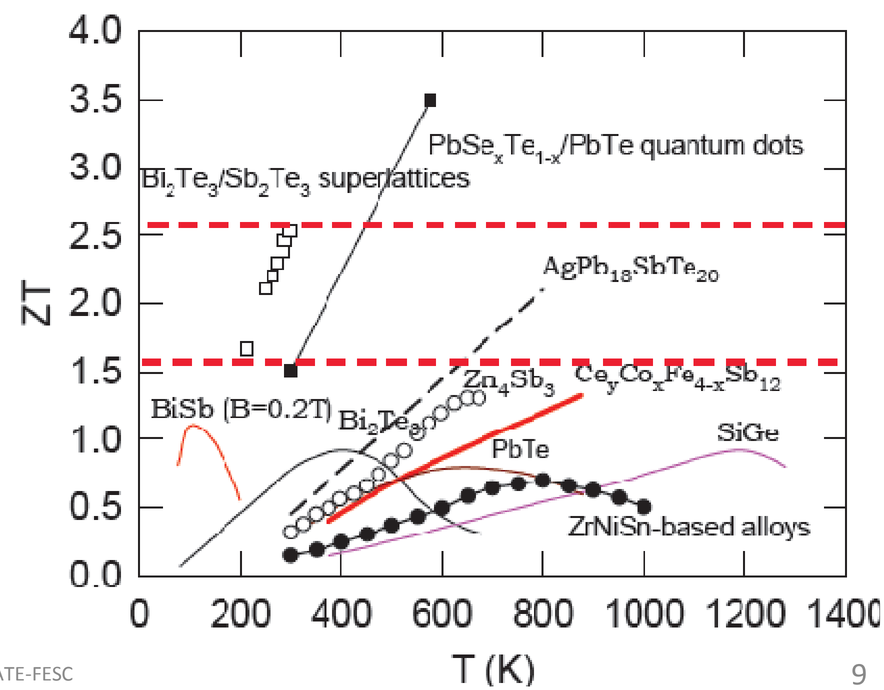


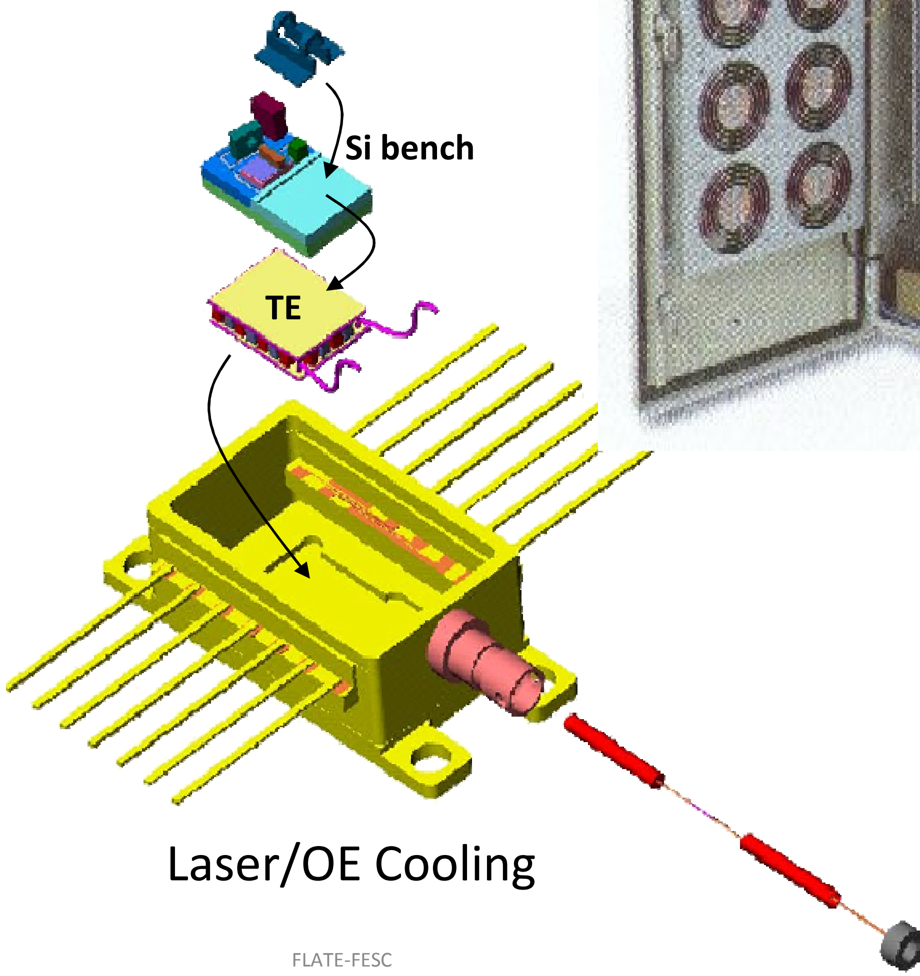
Figure by OCW. 2.57 Lecture 21



Applications

Water/Beer Cooler

Electronic Cooling



Cooled
Car Seat

Laser/OE Cooling

Waste Heat Power Generation

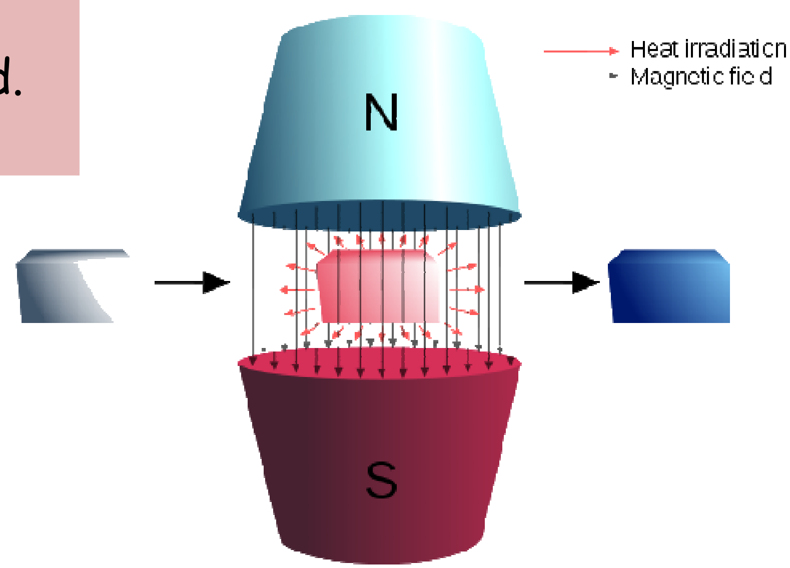
Figure 1 | Integrating thermoelectrics into vehicles for improved fuel efficiency. Shown is a BMW 530i concept car with a thermoelectric generator (yellow; and inset) and radiator (red/blue).

nature materials , *VOL 8, FEBRUARY 2009,* *www.nature.com/naturematerials*

Magnetocaloric Effect

Some magnetic materials heat up when they are placed in a magnetic field and cool down when they are removed from a magnetic field. This is known as the magnetocaloric effect.

This effect was discovered by E. Warburg in 1881 in pure iron. The size of the effect has been around .5 to 2°C per Tesla change in magnetic field. One Tesla is about 20,000 times the earth's magnetic field.

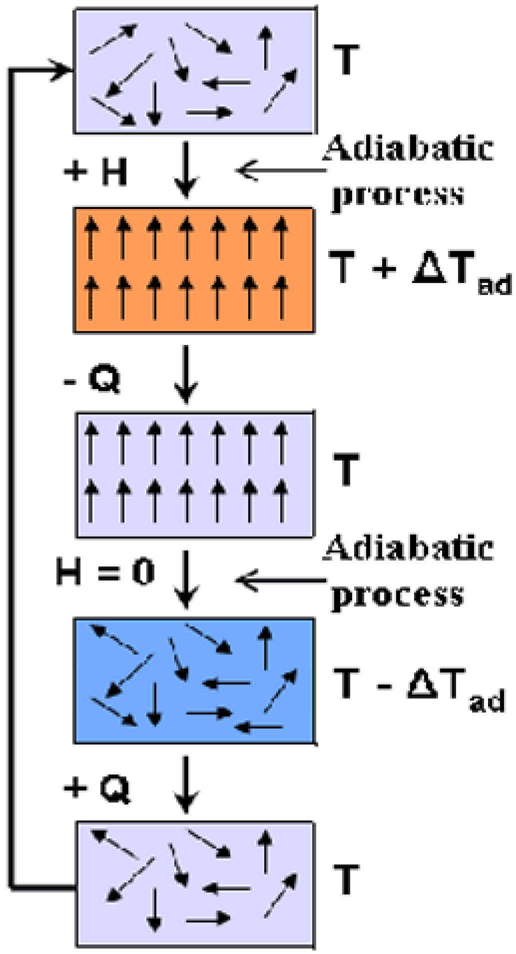


Gadolinium alloy heats up inside the magnetic field and loses thermal energy to the environment, so it exits the field cooler than when it entered.

Recently, alloys of gadolinium, germanium and silicon have produces a much larger effect size of 3 to 4°C per Tesla change.

http://en.wikipedia.org/wiki/Magnetocaloric_effect

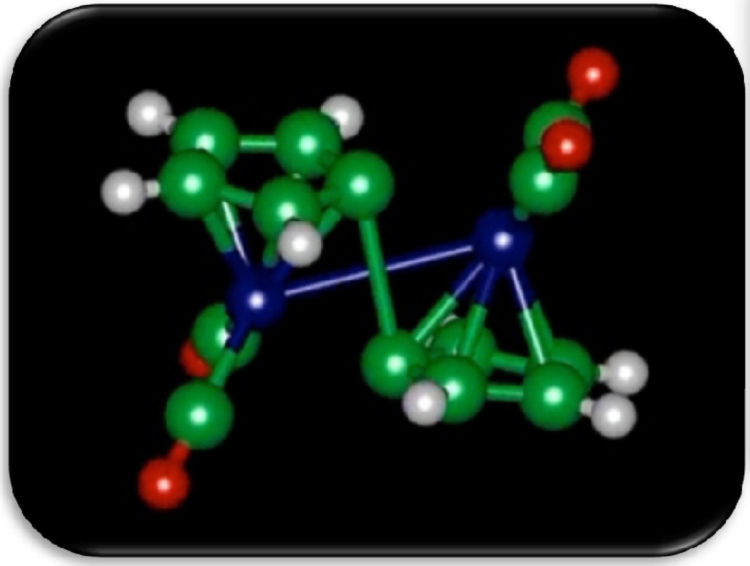
Magnetocaloric Effect



Flowchart of magnetic refrigeration in $Sm_{0.52}Sr_{0.48}MnO_3$. Here, H is the magnetic field, Q is the heat transfer, T is the temperature and ΔT_{ad} is the temperature change when the spins depolarize (with no heat transfer).

http://www.natureasia.com/asia-materials/highlight.php?id=231

Sun Heat Thermochemical Storage



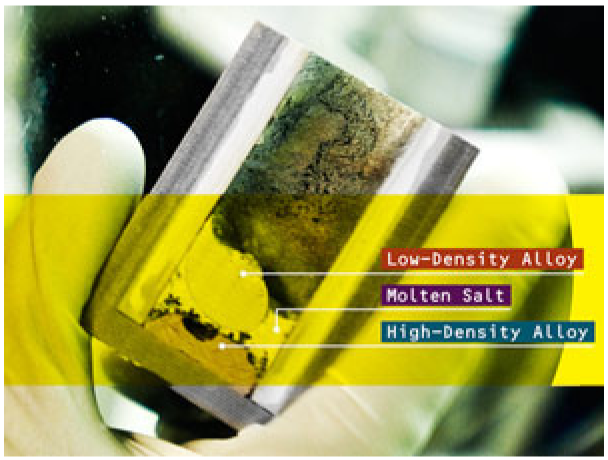
A molecule of fulvalene diruthenium, shown in this diagram, changes its configuration when it absorbs heat, and later releases heat when it snaps back to its original shape.

In Thermo-chemical storage, solar energy is captured in the configuration of certain molecules which can then release the energy on demand to produce usable heat. And unlike conventional solar-thermal systems, which require very effective insulation and even then gradually let the heat leak away, the heat-storing chemicals can remain stable for years.

Essentially, the molecule undergoes a structural transformation when it absorbs sunlight, putting the molecule into a higher-energy state where it can remain stable indefinitely. Then, triggered by a small addition of heat or a catalyst, it snaps back to its original shape, releasing heat in the process.

http://web.mit.edu/mitei/research/spotlights/suns-heat.html

Liquid Metal Battery



Scientists at MIT slice super-cooled liquid-metal batteries in half to study the way the material inside behaves. Thi s battery has charged and discharged many times, but the three layers remain intact.

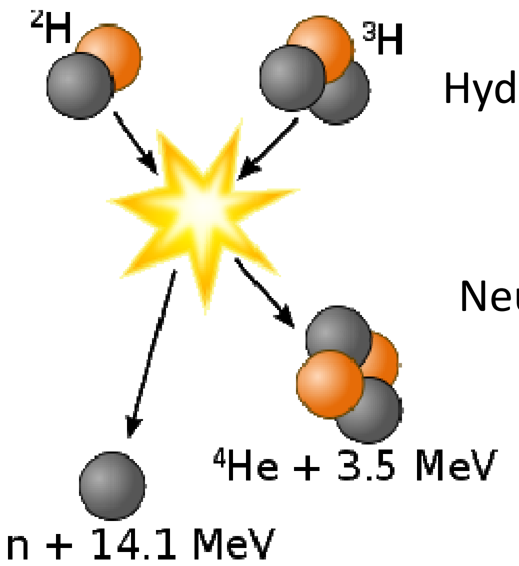
Two electrodes exchange electrons through an electrolyte to complete a circuit. But by using liquid metals for electrodes and molten salt as an electrolyte, this Liquid Metal battery can absorb electrical currents that are 10 times higher than present-day high-end batteries.

Only the different densities of the liquids keep them separated inside the battery, which means it would be a poor choice for most mobile applications--but smart for a fixed location, such as an electrical installation.

The team's first prototypes were small and made with costly ingredients such as pure magnesium and pure antimony, but it is now seeking the right mix of alloys for optimal performance and cheap manufacture.

http://www.popularmechanics.com/science/energy/next-generation/liquid-metal-batteries-storage-breakthrough

Fusion



Hydrogen Isotopes: Deuterium & Tritium

Neutrons + Helium-4 + Energy

The ratio of naturally occurring Deuterium to Hydrogen atoms is about 1:6000. Said another way, there are more than *10^{13} tons of Deuterium in the surface waters of the earth.*

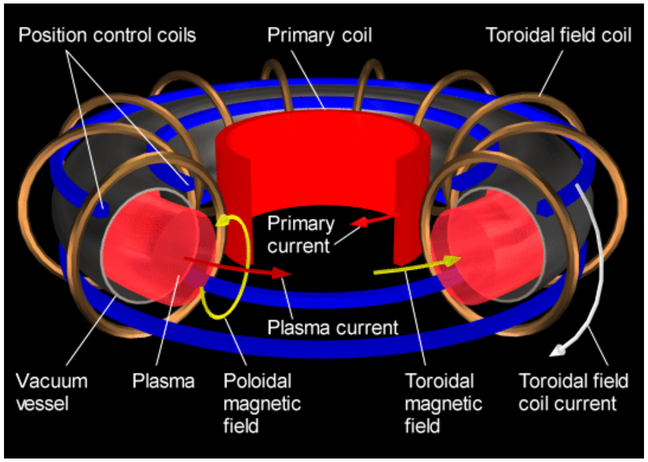
Tritium is radioactive (β-emitter) and decays with a half-life of about 12 years. It does not occur naturally and must be bred in the fusion reactor, for example through the nuclear reactions:

$$^{7}\text{Li} + \text{neutron} \Rightarrow {}^{4}\text{He} + \text{T} + \text{neutron} - 2.49 \text{ MeV}$$

$$^{6}\text{Li} + \text{neutron} \Rightarrow {}^{4}\text{He} + \text{T} + 4.8 \text{ MeV}$$

Therefore the primary fuel supply for a D-T fusion reactor is Deuterium (from water) and Lithium (~ 93% 7Li) from the Earth's crust.

Fusion

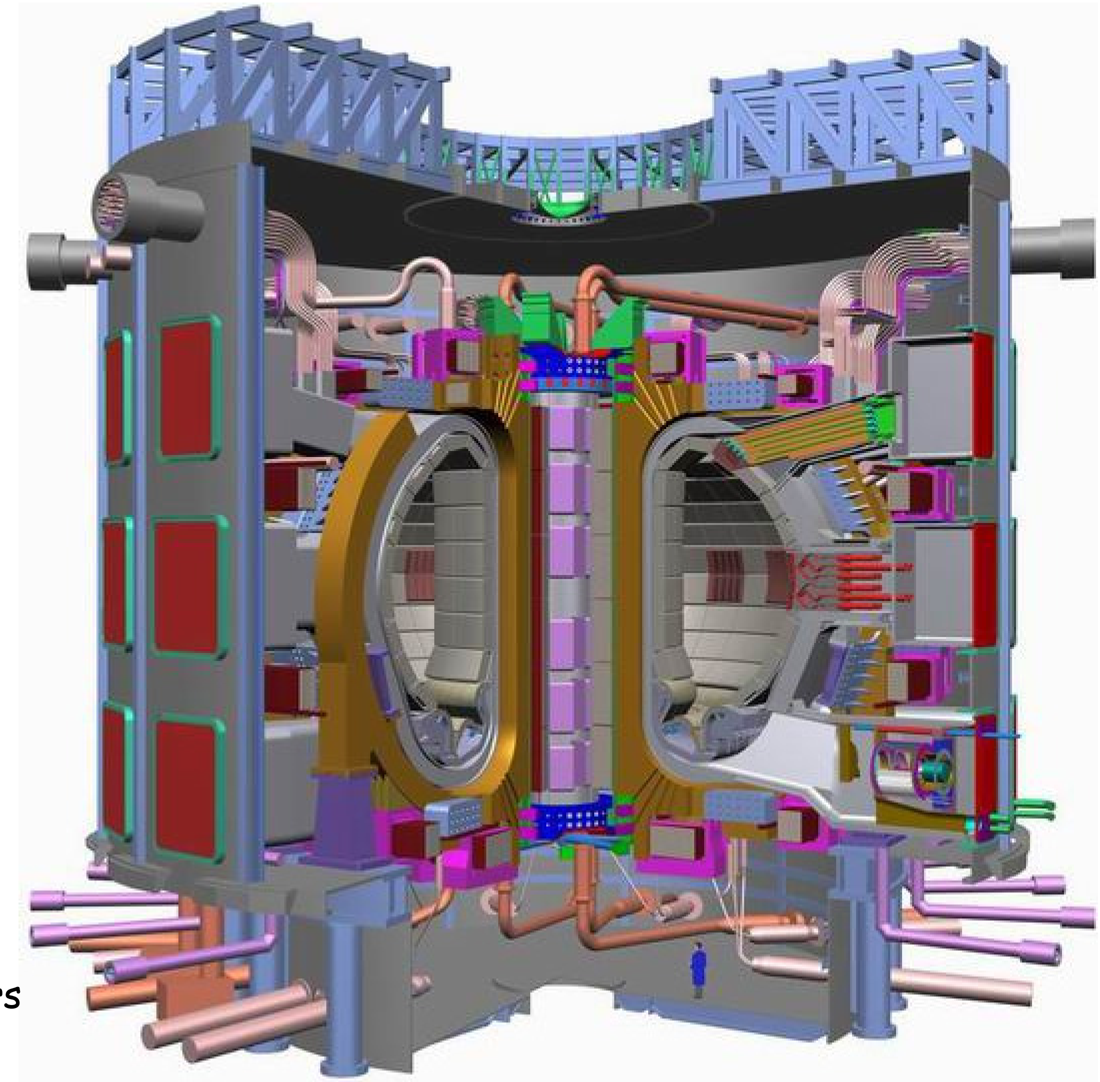


Magnetic Confinement of Plasma

ITER, the International Thermonuclear Experimental Reactor, will be the world's first fusion experiment designed to produce net fusion power.

Construction time is scheduled to be 8 years starting in 2007, with first plasma in 2015.

It will be built as an international consortium involving the US, Europe, Japan, Russia, Korea, China and India.



Scientific American: Fusion Reactor Tour

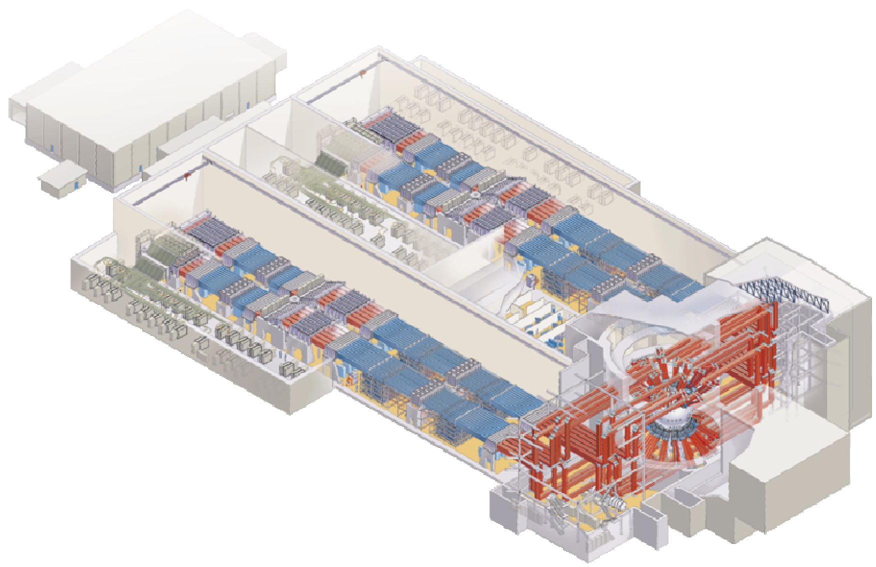
http://video.google.com/videoplay?docid=-1297117137837778403#

Total fusion power: 500 MW (700MW)

Fusion

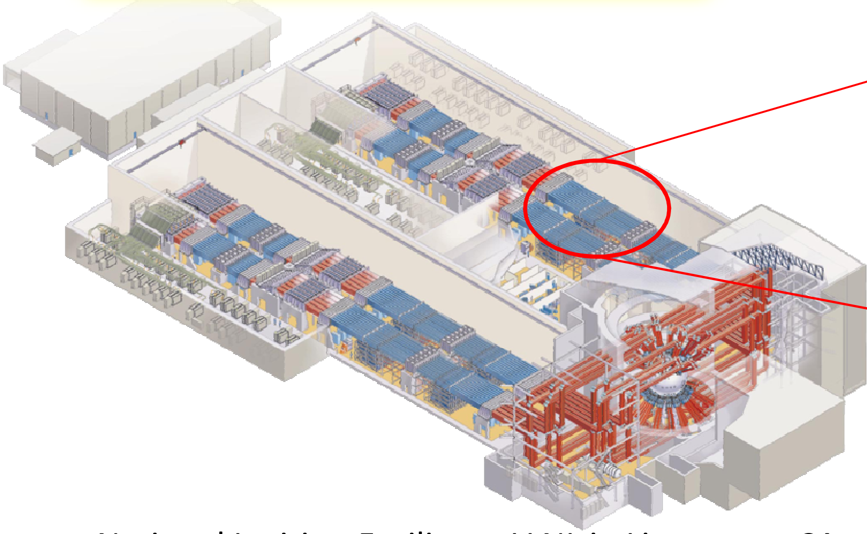
Inertial Confinement Fusion

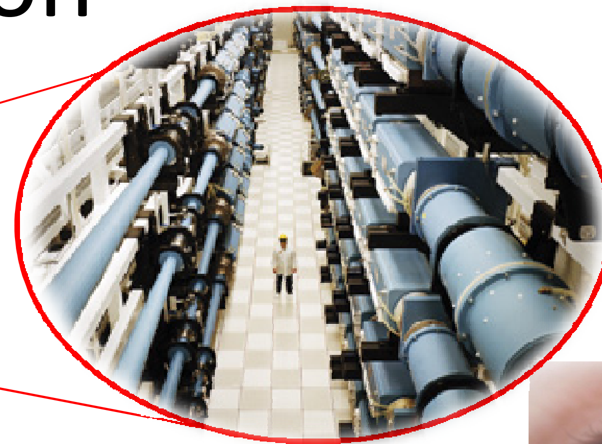
The National Ignition Facility (NIF), a laser-based Inertial Confinement Fusion (ICF) experiment designed to achieve thermonuclear fusion ignition and burn in the laboratory, has been completed at the Lawrence Livermore National Laboratory. Fusion yields of the order of 10 to 35 MJ with laser energies of 1.0 to 1.3 MJ are expected by 2011, and it is anticipated that fusion yields of 150-200 MJ could ultimately be obtained with NIF-based indirectly driven targets at 2-3 MJ.

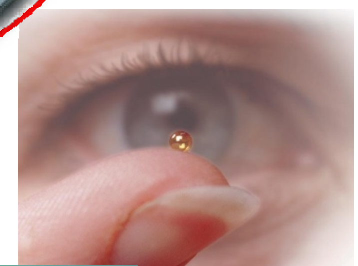


Fusion

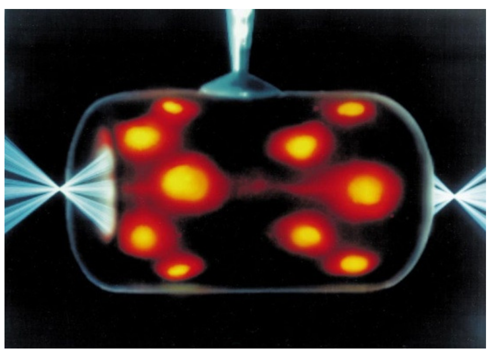
Inertial Confinement Fusion



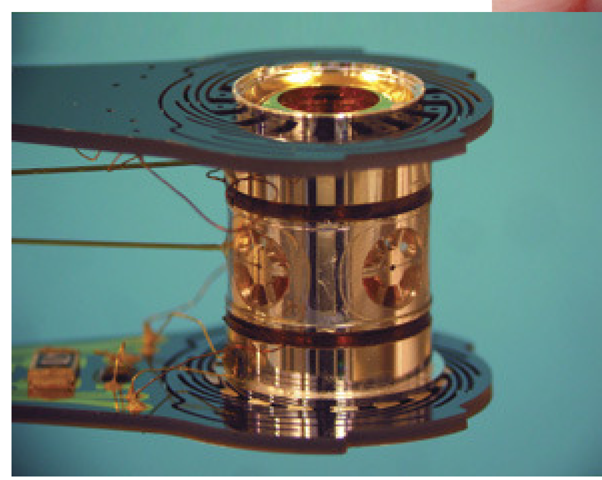




National Ignition Facility at LLNL in Livermore, CA

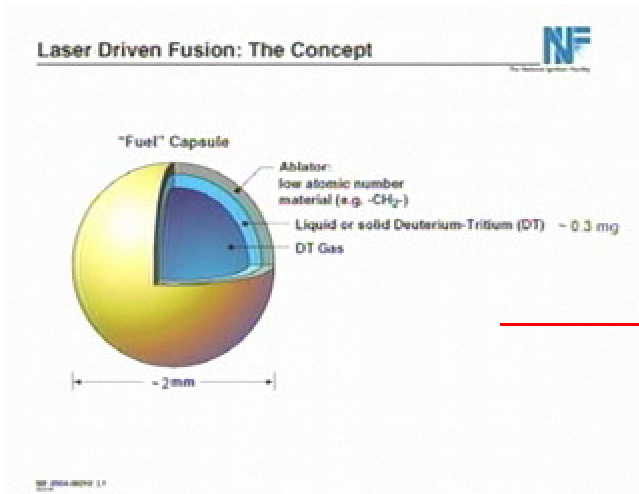


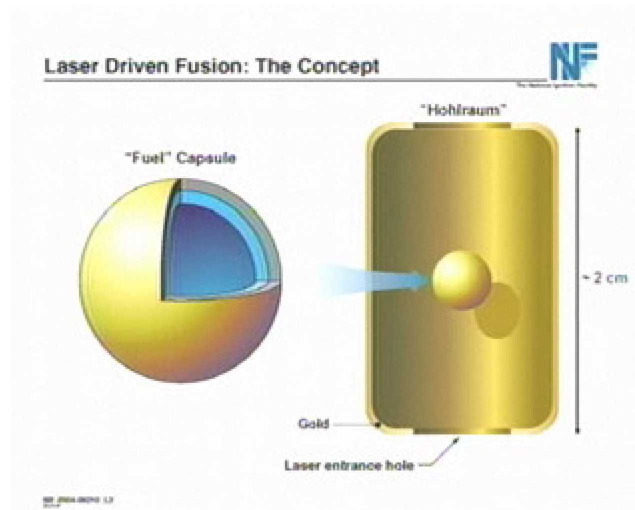
Indirect drive laser ICF uses a "hohlraum" which is irradiated with laser beam cones from either side on its inner surface to bathe a fusion microcapsule inside with smooth high intensity X-rays. The highest energy X-rays can be seen leaking through the hohlraum, represented here in orange/red

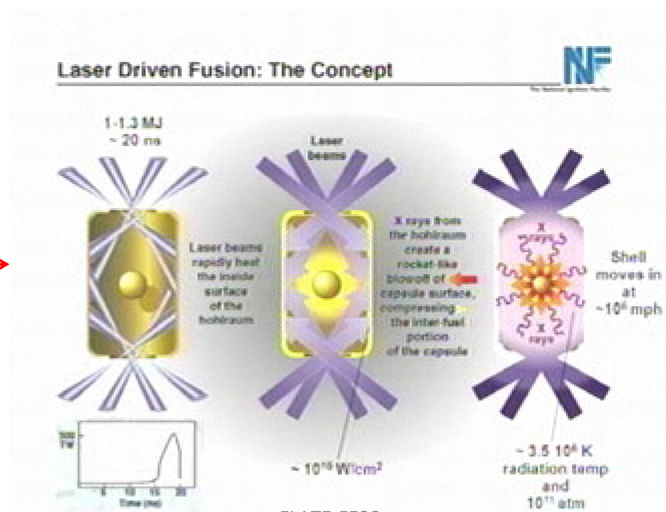


A metallic case called a hohlraum holds the fuel capsule for NIF experiments. Target handling systems precisely position the target and freeze it to cryogenic temperatures (18 kelvins, or -427 degrees Fahrenheit) so that a fusion reaction is more easily achieved.

Inertial Confinement Fusion







Compresses at 1,000,000 miles/hr, then releases energy

http://www.parc.com/event/1005/life.html