LASER SCIENCE

Leonard Goldstein
1980 - 1981

A YEAR AGO (ALMOST TO THIS VERY DAY) I WALKED INTO A HOSPITAL OPERATING ROOM (WALKED NOT WHEELED) // SAT DOWN ON A STOOL / RESTED MY CHIN ON THE BAR OF A SMALL MACHINE, / SIGHTED DOWN A TUBE - AND MY OPERATION BEGAN. // A FEW MINUTES LATER (LESS THAN 10) - IT WAS OVER!

A TORN RETINA IN MY RIGHT EYE HAD BEEN REPAIRED. THERE WAS NO PATIENT PREPARATION, / NO CUTTING, SEWING, BLOOD, OR PAIN. // MY ONLY SENSATION WAS THAT OF A FLASH OF LIGHT [redacted] SO BRIGHT AND SO FAST / THAT I WAS NOT SURE I SAW IT. THE PROCEDURE WAS SIMILAR TO THAT OF SPOT-WELDING. AN EXTREMELY DIFFICULT AND PRESSURE-FILLED OPERATION THAT MY FRIEND, MAURICE ROTHBERG, USED TO PERFORM WITH NEEDLE AND SUTURE, / WAS NOW REDUCED TO A MUCH SIMPLER, MACHINE-PERFORMED ACTIVITY.

THE EYE REPAIRED, I STOOD UP AND WALKED OUT OF THE OPERATING ROOM, LEFT THE HOSPITAL - AND WENT HOME. NEEDLESS TO SAY, LASER TECHNOLOGY IMPRESSED ME!

"SUDDENLY THERE WAS A FLASHING OF LIGHT....AT THE SAME TIME A FAINT HISSING SOUND BECAME AUDIBLE.... // FORTHWITH FLASHES OF ACTUAL FLAME, A BRIGHT GLARE... SPRANG FROM THE GROUP OF MEN. // IT WAS AS IF SOME INVISIBLE JET IMPINGED UPON THEM / AND FLASHED INTO WHITE FLAME. IT WAS AS IF EACH MAN WERE SUDDENLY AND MOMENTARILY TURNED TO FIRE....IT WAS SWEEPING ROUND SWIFTLY AND STEADILY, THIS FLAMING DEATH, THIS INVISIBLE, INEVITABLE SWORD OF HEAT."

THAT IS HOW H.G. WELLS DESCRIBED THE "HEAT RAY" WEAPON / USED BY THE MARTIANS AGAINST THE EARTH MEN IN HIS BOOK, "THE WAR OF THE WORLDS" PUBLISHED IN 1898. ON JANUARY 12, 1970, THE MAGAZINE, AVIATION WEEK CARRIED A STORY ABOUT LASERS THAT SAID, "THESE RADIATION WEAPONS (OR 'DEATH RAYS', AN ENTICING TOPIC OF SCIENCE FICTION)...COULD HAVE A RESOUNDING IMPACT ON THE CONDUCT OF MODERN WARFARE....THIS FOLLOWS THE SUCCESSFUL SHOOTING DOWN OF A DRONE AIRCRAFT WITH A LASER."

IMAGINE A LIGHT SO INCREDIBLY POWERFUL / IT CAN MELT HOLES THRU STEEL GIRDERS, // A LIGHT SO INTENSE IT PRODUCES INSTANT BLINDNESS, // YET SO PRECISE IT

CAN REPAIR THE DELICATE RETINA OF THE EYE. THIS IS CERTAINLY NO ORDINARY LIGHT, NOR DOES IT EXIST SOLELY IN THE REALM OF SCIENCE FICTION. IT IS LASER LIGHT!

THIS AFTERNOON, I HOPE TO TELL YOU WHAT A LASER IS, ITS BASIC CHARACTERISTICS AND COMPOSITION, HOW IT IS BEING USED NOW AND WHAT ITS POTENTIAL MAY BE - AND IF WE LUCK OUT - PERHAPS A DEMONSTRATION AS WELL.

IT IS EASY TO THINK OF LASERS AS MAGIC WANDS. SOME LASERS ACTUALLY LOOK LIKE WANDS. SOME LASERS DO THINGS THAT SEEM LIKE FEATS OF MAGIC. FOR EXAMPLE:

→ AIM A LASER AT A STEEL RAZOR BLADE, PRESS A BUTTON, AND POP! A BEAM OF LASER LIGHT PUNCHES A HOLE IN A STEEL BLADE.

→ AIM A LASER BEAM AT A SHEET OF PRINTED PAPER. THE BEAM BURNS OFF THE PRINTING, LEAVING THE PAPER UNTOUCHED.

→ AIM THE BEAM AT A BALLOON INSIDE A WHOLE BUNCH OF OTHER BALLOONS. THE INNER BALLOON EXPLODES, WHILE THE SURROUNDING BALLOONS ARE UNAFFECTED.

BUT THESE ARE JUST STUNTS // WHAT USEFUL JOBS CAN A LASER DO? // THOUSANDS - ! I WILL LIST A FEW NOW AND GO INTO GREATER EXPLANATION LATER.

A SURGEON POINTS A LASER BEAM AT AN UGLY SKIN TUMOR ON A PATIENT'S FACE. IN A FEW MINUTES, WITHOUT PAIN AND WITH NO LOSS OF BLOOD, THE TUMOR IS BURNED AWAY, LEAVING NO SCAR.

AN ASTRONOMER DIRECTS A LASER BEAM AT THE MOON, WITH AN INSTRUMENT CALLED AN INTERFEROMETER. THE ASTRONOMER MEASURES THE EARTH - MOON DISTANCE AT AN ACCURACY OF 20 CM (ABOUT 8").

A MACHINIST POINTS A BEAM AT A WHEEL TO BE USED IN A GYROCOMPASS. WHILE THE WHEEL IS SPINNING 1000 TIMES A SECOND, THE BEAM FINDS ANY UNEVEN SPOTS ON THE WHEEL AND TRIMS THEM AWAY. THE WHEEL IS LEFT PERFECTLY BALANCED.

FEW SCIENTIFIC DEVELOPMENTS HAVE EXCITED THE IMAGINATION OF BOTH SCIENTISTS AND THE GENERAL PUBLIC AS HAS THE LASER.

A LASER BEAM IS LIGHT - A SPECIAL KIND OF LIGHT. A LASER APPARATUS IS AN ELECTRIC LAMP - A SPECIAL KIND THAT PRODUCES LASER LIGHT. // BEFORE WE UNDERSTAND LASERS, WE NEED TO EXAMINE ORDINARY LIGHT.

THERE ARE BASICALLY TWO KINDS OF LIGHT // THOSE WHICH ARE PRODUCED FROM HEAT (THERMAL LIGHT) // AND THOSE WHICH ARE LUMINESCENT.

WHEN YOUR HANDS ARE COLD, YOU RUB THEM TOGETHER - THE FRICTION PRODUCES HEAT. THE GREATER THE FRICTION, THE MORE HEAT! // THE SPARKS YOU SEE WHEN A GRINDSTONE IS SHARPENING A KNIFE ARE BITS OF STEEL GLOWING IN THE EXTREME HEAT PRODUCED BY THE FRICTION OF THE KNIFE AGAINST THE STONE. // THE LIGHT FROM A CANDLE COMES FROM BILLIONS OF TINY SPARKS OF CARBON. THIS LIGHT COMES FROM BURNING RATHER THAN FRICTION. ALMOST ALL FLAME SOURCES OF LIGHT WORK IN THE SAME WAY.

THE GLOW OF AN ELECTRIC BULB ALSO COMES FROM HEAT. AN ELECTRIC CURRENT CAUSES A THIN TUNGSTEN WIRE TO HEAT UP AND EMIT LIGHT. WHEN YOU TOUCH A LIGHTED, 100 WATT BULB, YOU MIGHT BE TEMPTED TO CALL IT A HEATER INSTEAD OF A LIGHT - (AND YOU WOULD NOT BE FAR OFF THE MARK.) THE BULB EMITS ABOUT 2% LIGHT AND 98% HEAT.

NEXT, TO IMPROVE THE ELECTRIC LAMP, WE MUST FIND ONE THAT GIVES MORE LIGHT AND LESS HEAT FOR THE MONEY. TO FIND IT WE GO FROM THE THERMAL, 2-STEP SYSTEM; ELECTRICITY TO HEAT, THEN HEAT TO LIGHT, TO A LUMINESCENT SOURCE, SUCH AS A FLUORESCENT TUBE.

IN A LUMINESCENT LIGHT SOURCE, NO HEAT IS REQUIRED TO PRODUCE LIGHT. THE FLUORESCENT TUBE IS ONE EXAMPLE. HERE AGAIN, HOWEVER, TWO STEPS ARE INVOLVED. ELECTRICITY IS USED TO PRODUCE AN ALMOST INVISIBLE, PALE BLUE LIGHT WHICH IS THEN CHANGED INTO A BRIGHT, VISIBLE LIGHT.

THE INTERIOR OF A FLUORESCENT TUBE IS FILLED WITH MERCURY VAPOR. ELECTRIC CURRENT CAUSES THE VAPOR TO GLOW - (THE FAINT BLUE LIGHT MENTIONED BEFORE.) THIS LIGHT STRIKES THE LINING OF THE TUBE - A LINING SIMILAR TO THE COATING OF YOUR TELEVISION TUBE. THE RESULT IS THE EMISSION OF A STRONG LIGHT - (THERE IS SOME HEAT TOO, BUT MUCH LESS THAN A TUNGSTEN BULB.)

LIGHT, (LIKE MANY OTHER THINGS,) OSCILLATES. // VISUALIZE WAVES OF WATER AT THE OCEANSIDE - THEY HAVE A REGULAR, REPEATING MOTION. // THIS IS BASIC TO ALL WAVES - WATER, SOUND WAVES, RADIO WAVES, AND LIGHT WAVES. THIS REGULAR, REPEATING MOTION - (HIGH TO LOW, FORWARD TO BACKWARD, SIDE TO SIDE - IS CALLED OSCILLATION.

THE WORLD OSCILLATES. YOU CAN SEE THE PENDULUM OF A CLOCK OSCILLATING - YOU CAN HEAR THE OSCILLATIONS MADE BY A VIOLIN STRING - YOU CAN FEEL THE OSCILLATIONS OF THE FLOW OF BLOOD IN YOUR PULSE. YOU CAN PLAN A BIRTHDAY PARTY BY THE OSCILLATION OF THE EARTH TRAVELING IN AN ECLIPSE AROUND THE SUN - ONE OSCILLATION TAKES ONE YEAR.

LET US LOOK AT SOME OSCILLATIONS MUCH SPEEDIER THAN THOSE WITH VERY HIGH FREQUENCIES.

EVERY ATOM CONSISTS OF A NUCLEUS SURROUNDED BY OSCILLATING ELECTRONS. ATOMS ARE VERY SMALL - THE DOT OVER AN "I" ON THE PRINTED PAGE CONSISTS OF ABOUT 50 BILLION ATOMS. THE ELECTRONS IN THESE ATOMS HAVE A FREQUENCY OF ABOUT 100 BILLION REVOLUTIONS PER SECOND.

THESE NUMBERS ARE NOT BEING CITED TO AMAZE YOU - THEY HAVE A DEFINITE RELATIONSHIP TO WHY AN EGG-YOLK IS YELLOW, WATER IS TRANSPARENT, AND HOW A LASER BEAM CAN DESTROY A SKIN TUMOR WITHOUT HARMING THE FLESH UNDERNEATH.

I HAVE FINALLY LEARNED THAT THE SOUND I HEAR WITH A SEASHELL AT MY EAR IS NOT THAT OF THE SEA, PRESERVED IN THE SHELL! IF YOU DO NOT BELIEVE ME, TRY IT WITH AN EMPTY GLASS OR CAN. OBVIOUSLY, IT IS NOT THE CONTAINER THAT MAKES THE SOUND - IT IS THE AIR AROUND THE CONTAINER, ALREADY FILLED FULL OF MANY FAINT SOUNDS OF DIFFERENT PITCH. ALL THESE SOUNDS ARE OSCILLATIONS OF THE AIR - OUTSIDE TRAFFIC, BREEZES, THE REFRIGERATOR - EVEN THE SOUND OF BLOOD CIRCULATING IN YOUR EARS. WHEN YOU HOLD THE SHELL OR CONTAINER AGAINST YOUR EAR, ONE OF THESE MANY SOUNDS IS FAVORED, OR REINFORCED. WHICH ONE? THE ONE WHOSE FREQUENCY - OR OSCILLATIONS PER SECOND - MATCHES THE SIZE OF THE CONTAINER.

WHAT HAPPENS IS THAT AN OSCILLATION - A SOUND WAVE - ENTERS THE OPEN END, RACES DOWN TO THE CLOSED END AND THEN BOUNCES BACK. IT REACHES THE OPEN END AGAIN JUST AS THE NEXT WAVE IS ABOUT TO ENTER - THE TWO THEN TRAVEL DOWN AND BACK TOGETHER AND PICK UP ANOTHER - AN ANOTHER, AND ANOTHER - ADDING UP AND GETTING LOUDER UNTIL YOU HEAR SOUNDS THAT WOULD BE TOO FAINT TO HEAR WITHOUT REINFORCEMENT. SHORT CONTAINERS REINFORCE SOUNDS OF HIGH FREQUENCY - LONG

CONTAINERS, LOW FREQUENCY. IF YOU HAD A CONTAINER WHOSE LENGTH COULD BE CHANGED, YOU COULD CHOOSE DIFFERENT FREQUENCIES TO REINFORCE. THE SAME PRINICPLE APPLIES TO THE EMISSION OF SOUND. A SLIDE TROMBONE IS A GOOD EXAMPLE. TONES OF DIFFERENT PITCH ARE ACHIEVED BY ADJUSTING THE LENGTH OF THE AIR SPACE IN THE INSTRUMENT - NAMELY SLIDING THE TUBE IN OR OUT. THIS CHANGES THE LENGTH OF THE TUBE AND HENCE THE FREQUENCY OF THE SOUND.

THIS METHOD OF CHANGING FREQUENCY BY CHANGING SIZE IS USED IN MANY DEVICES. FOR EXAMPLE, WHEN YOU TUNE A RADIO TO 700 ON THE DIAL - WLW - YOU HAVE CHANGED THE SIZE OF A PART (THE VARIABLE CONDENSER) SO THAT IT RESONATES TO RADIO WAVES WHOSE FREQUENCY IS 700,000 OSCILLATIONS PER SECOND. THE SAME THING HAPPENS WITH THE CHANNEL SELECTOR ON YOUR TELEVISION SET AND IT ALSO HAPPENS WITH A TUNABLE LASER. TURNING THE KNOB CHANGES THE FREQUENCY OF THE EMITTED LASER BEAM. THEREFORE, WE CAN PICK THE FREQUENCY THAT DESTROYS THE INK ON A PAGE BUT LEAVES THE PAPER UNHARMED. ~~OR VICE VERSA~~.

COLOR OF LIGHT VARIES WITH FREQUENCY OF LIGHT WAVES WHICH PRODUCE THE COLOR. RED IS PRODUCED BY LIGHT OSCILLATING AT 400 TRILLION WAVES OR CYCLES PER SECOND. AT THE HIGH END OF THE SCALE IS VIOLET, PRODUCED BY LIGHT OSCILLATING AT 800 TRILLION CYCLES PER SECOND. THE HIGHER THE FREQUENCY, THE BLUER THE LIGHT - THE LOWER THE FREQUENCY, THE REDDER THE LIGHT. A PROPER MIXTURE OF ALL COLORS PRODUCES WHITE LIGHT. NOW I KNOW WHAT INFRARED AND ULTRAVIOLET MEAN. INFRARED IS LIGHT WITH FREQUENCIES UNDER 400 TRILLION CYCLES PER SECOND AND ULTRAVIOLET HAVING FREQUENCIES OF OVER 800 TRILLION. SINCE BOTH ARE BEYOND THE VISIBLE SPECTRUM, NEITHER CAN BE SEEN. STILL HIGHER FREQUENCIES THAN ULTRAVIOLET PRODUCE X-RAYS.

TO THIS POINT, WE HAVE TALKED ABOUT ORDINARY LIGHT AND SOME OF ITS CHARACTERISTICS. NOW LET US LOOK AT LASER LIGHT AND HOW IT IS PRODUCED.

WHAT, EXACTLY, IS A LASER? A LASER IS A HIGH INTENSITY LIGHT BEAM, CONCENTRATED ON A SMALL SURFACE, FREQUENTLY, AT VERY HIGH TEMPERATURE. LASER

LIGHT IS DISTINGUISHABLE BY FOUR MAJOR DIFFERENCES FROM ALL OTHER LIGHT SOURCES - LAMPS, FLAMES, STARS, ETC.

1. IT IS MONOCHROMATIC (ONE COLOR)
2. IT IS COHERENT
3. IT COMES OUT IN A NARROW BEAM
4. IT IS MORE INTENSE

MONOCHROMATIC

WHILE LIGHT FROM MANY LASERS DOES NOT EXHIBIT ALL OF THESE PROPERTIES, ALL LASER LIGHT POSSESSES AT LEAST ONE. THAT IS MONOCHROMATICITY - ONE COLOR. ORDINARY LIGHT, FROM THE SUN OR A LAMP, CONTAINS MANY COLORS AND IS CALLED "WHITE LIGHT".

THE PERFECTLY MONOCHROMATIC BEAM CONTAINS INDIVIDUAL LIGHT WAVES OF PRECISELY THE SAME WAVELENGTH. A HELIUM-NEON LASER CAN PRODUCE A BEAM OF INCREDIBLY PURE RED LIGHT, ALL OF THE WAVELENGTHS OF WHICH, ARE ALMOST IDENTICAL. THIS IS A LIGHT MANY MILLIONS OF TIMES PURER THAN ANY OTHER; WHICH MAKES POSSIBLE DOZENS OF APPLICATIONS, ABOUT WHICH WE WILL SPEAK LATER, WHICH CANNOT BE ACCOMPLISHED WITH ORDINARY LIGHT.

COHERENCE

LASER LIGHT IS COHERENT - THIS MEANS THAT THE WAVES OF LIGHT COMING OUT OF A LASER, IN ADDITION TO BEING THE SAME LENGTH, ARE ALSO PRECISELY SPACED AND LINED UP TOGETHER, IN STEP.

PICTURE THE SYMPHONY ORCHESTRA TUNING UP BEFORE THE CONCERT. EACH MUSICIAN PLAYS, TUNES, AND RETUNES THE INSTRUMENT - THE RESULTS ARE A CACOPHONY - CHAOTIC NOISE. WHEN THE CONDUCTOR DIRECTS THE ORCHESTRA, ALL THE INSTRUMENTS ARE PLAYED IN PHASE WITH ONE ANOTHER AND THE RESULT IS AN ORDERLY MUSICAL MELODY. ORDINARY LIGHT IS LIKE NOISE. COHERENT LIGHT IS LIKE AN EXQUISITELY PURE TONE FROM AN ORCHESTRA IN HARMONY - BETTER YET, LIKE THE VOICE OF A SINGLE VIOLIN IN THE HANDS OF A YITSHAK PERLEMAN.

IF WE COMPARE WAVES OF LIGHT TO WAVES OF WATER, THE LIGHT PRODUCED BY AN ELECTRIC LAMP BEST RESEMBLES THE CONFUSED SCRAMBLE OF WAVES PRODUCED WHEN RAINDROPS SPLASH INTO A PUDDLE. THIS CONTRASTS WITH LASER LIGHT WHICH IS LIKE THE ORDINARY CIRCLES OF WAVES PRODUCED WHEN A SINGLE STONE IS TOSSED INTO A POND.

DIRECTIONALITY

LASERS CAN BE MADE TO EMIT VERY NARROW BEAMS OF LIGHT WHICH SPREAD VERY LITTLE. REMEMBER THE LAST TIME YOU AIMED A FLASHLIGHT AT A DISTANT, DARK TARGET? HOW FAR DID IT GO BEFORE FADING INTO DIMNESS BECAUSE THE SPREADING BEAM COVERED A GREATER AREA FOR A MORE DISTANT TARGET. YET LOW-POWERED LASERS PUTTING OUT ONLY A FEW WATTS OF LIGHT ENERGY HAVE BOUNCED THEIR BEAMS OFF THE MOON. ONE OF THE MAJOR REASONS FOR THIS PHENOMENOM IS THE NARROWNESS OF THE BEAM - IT DOES NOT SPREAD MUCH AT ALL.

INTENSITY

BECAUSE OF ITS MONOCHROMATICITY AND DIRECTIONALITY, THE LIGHT FROM EVEN THE SMALLEST OF LASERS IS INCREDIBLY MORE INTENSE THAN FROM ANY OTHER LIGHT SOURCE. THIS IS EASY TO UNDERSTNAD WHEN YOU COMPARE ORDINARY LIGHT SOURCES AND LASERS TO THE ADJUSTABLE NOZZLE ON A GARDEN HOSE. THE NOZZLE, WHEN ADJUSTED TO THE FINE SPRAY MIST, IS LIKE ORDINARY LIGHT - IT IS LIKE A LASER WHEN IT PRODUCES A NARROW, PENCIL THIN JET OF WATER. BOTH ADJUSTMENTS USE THE SAME AMOUNT OF WATER, BUT THE JET IS FAR MORE POWERFUL THAN THE MIST.

THE COMPARISON OF ORDINARY LIGHT INTENSITY TO LASER LIGHT IS MIND BOGGLING.

IF WE TOOK THE FILAMENT OF AN ELECTRIC LAMP AND HEATED IT TO AN IMPOSSIBLE TEMPERATURE OF 10 MILLION, BILLION DEGREES CENTIGRADE, THEN FILTERED IT TO A SINGLE WAVELENGTH AND CONCENTRATED IT WITH LENSES, WE MIGHT THEN EQUAL THE INTENSITY OF A BEAM PRODUCED BY A SMALL HELIUM-NEON LASER WHICH USES A TENTH THE WATTAGE OF A POCKET FLASHLIGHT.

A FEW YEARS AGO, SOME STUDENTS PLACED A SMALL HELIUM-NEON LASER ATOP AN OFFICE BUILDING IN ALBEQUERQUE. THEY POINTED IT AT A PARKING LOT AT THE FOOT OF A MOUNTAIN TRAMWAY 12½ MILES AWAY. THEY DROVE TO THE TRAMWAY AND WERE AWED BY

THE DAZZLING RED BEAM OF THE LASER. ALTHOUGH THE BEAM CONTAINED ONLY 1/1000TH OF A WATT OF OPTICAL POWER, IT EASILY OUTSHONE EVERY LIGHT IN THE CITY - EVEN THE FLASHING BEACON FROM THE CITY AIRPORT.

TO SUMMARIZE THE DEFINITION AND DESCRIPTION OF LASER LIGHT, WE CAN SAY THAT LASERS PRODUCE A LIGHT OF UNEQUALLED INTENSITY, LIGHT BEAMS THAT ARE HIGHLY DIRECTIONAL AND LIGHT THAT IS MONOCHROMATIC AND COHERENT.

BY THIS TIME, YOU HAVE NO DOUBT FIGURED OUT THE LASER ACRONYM. THE PROCESS OF LIGHT (L) AMPLIFICATION (A) BY STIMULATED (S) EMISSION (E) OF RADIATION (R) WAS FIRST NOTICED AND DESCRIBED BY ALBERT EINSTEIN IN 1966. OTHER SCIENTISTS INCLUDING CHARLES TOWNES, GENE GOULD, AND ARTHUR SCHAWLON BEGAN SOLVING PROBLEMS WHICH HAD PREVIOUSLY KEPT THE LASER ONLY A THEORY, AND A WORKING UNIT WAS DEVELOPED IN THE MID FIFTIES.

FROM THEIR WORK, AND THAT OF OTHERS AS WELL, IT WAS LEARNED THAT THE THREE ESSENTIAL INGREDIENTS OF THE LASER WERE: 1. A FLUORESCENT MATERIAL THAT WOULD EMIT LIGHT WHEN STIMULATED BY RADIATION FROM AN EXTERNAL SOURCE, 2. TWO FACING MIRRORS ON EITHER SIDE OF THE FLUORESCENT MATERIAL, AND 3. AN EXTERNAL ENERGY SOURCE.

IN 1960, THEODORE H. MAIMAN, A SCIENTIST AT HUGHES AIRCRAFT, ILLUMINATED A RUBY WITH A SLEDGEHAMMER-LIKE BLAST OF BRILLIANT LIGHT FROM A POWERFUL STROBE LAMP, LIKE ONE USED BY PROFESSIONAL PHOTOGRAPHERS, AND PRODUCED A BLINDING FLASH OF INCREDIBLY PURE RED LIGHT, MILLIONS OF TIMES BRIGHTER THAN SUNLIGHT, AND IT WAS ACHIEVED WITH A GADGET NO LARGER THAN A CHILD'S LUNCH BOX.

AS SCIENTISTS GAINED EXPERIENCE WITH THE EARLY LASERS, THEY SOON FOUND MANY FLUORESCENT MATERIALS, LIKE MAIMAN'S RUBY, THAT COULD BE MADE TO LASE. ARGON BROUGHT BRILLIANT BEAMS OF BLUE AND GREEN, KRYPTON, IN ADDITION TO BLUE AND GREEN, GAVE YELLOW AND RED. LIQUIDS, GASSES, METALLIC VAPORS, SEMI-CONDUCTORS AND CRYSTALS GAVE OPTICAL WAVELENGTHS RANGING FROM INFARED AND ULTRAVIOLET. ADJUSTING FREQUENCIES, LIKE MOVING THE TROMBONE SLIDE, PRODUCES DIFFERENT COLORS FROM THE SAME MATERIAL.

How Lasers Work

Remember, regardless of the kind of laser, each requires 3 basic components - a fluorescent substance, a pair of mirrors, and a source of energy. Maiman's first laser used a synthetic ruby rod, with each end coated with silver to provide the mirrors. The rod was placed inside the glass coils of a photographer's strobe lamp. The brilliant flash of white light from the strobe produced the energy input for the rod and fulfilled the third requirement.

The "stimulated emission of radiation", the "SER" of laser is a very complicated scientific phenomena that evokes the "excitement" of electrons from their normal or natural relationship to the nucleus of a given atom. When this occurs with certain materials, very strange and exciting results come about. The excited atoms of fluorescent substances, like the ruby, give off energy in packets of light which are called photons - and it is these photons that constitute laser light.

To attempt a more complete AND A detailed explanation would require a physics instructor and a lot more time than we have. Nevertheless, I will try to describe, briefly, what happens to "turn on" the electrons to producing such fascinating results.

Under normal conditions, most atoms, or molecules, remain quiescent at their lowest energy level, or ground state. But if these particles are excited into higher energy states - by an intense flash of light, an electrical charge, or other means - they will, in dropping back to their normal ground state, emit incoherent light in the process. (This is what happens to fluorescent lamps and some types of street lights.)

In a laser cavity, these photons are trapped between the highly polished mirrors, forcing them to bounce back and forth in the cavity. Whenever a photon passes close to another excited particle of the same wavelength, the second particle will also be stimulated to emit a photon that is of identical wavelength, phase and coherence to the first. Both photons are now capable of stimulating

THE INVASION OF MORE PHOTONS LIKE THEMSELVES AND THESE, TOO, BECOME PART OF THE GROWING WAVE BETWEEN THE MIRRORS.

LASING BEGINS WHEN ENOUGH PHOTONS ARE PRESENT, AND IF ONE OF THE MIRRORS IS PARTIALLY TRANSPARENT, A HIGHLY DISCIPLINED, INTENSE, AND COHERENT BEAM IS EMITTED.

THERE ARE FOUR GENERAL CATEGORIES OF LASERS: SOLID STATE ION, GAS, SEMI-CONDUCTOR, AND LIQUID.

SOLID STATE ION LASERS USE A GLASS OR CRYSTAL FLUORESCENT MATERIAL WHICH HAS BEEN LACED WITH SOME METALLIC OR RARE EARTH IONS. THE RUBY ROD IS AN EXAMPLE - THE RUBY IS A SAPPHIRE, CONTAMINATED WITH A SMALL AMOUNT OF CHROMIUM. ALTHOUGH THEY HAVE MANY SIMILARITIES, SOLID STATE ION LASERS COME IN A WIDE RANGE OF SHAPES, AND SIZES FROM A TOOTHPICK TO A BROOMSTICK, IN SIZE.

THE GAS LASER IS ONLY A STEP OR TWO BEYOND THE NEON ADVERTISING TUBES, WITH WHICH WE ARE ALL FAMILIAR. THEIR ENERGY SOURCE IS HIGH VOLTAGE ELECTRICITY CONNECTED TO WIRE TERMINALS INSIDE A GLASS TUBE. THE ACTIVE MATERIAL IS THE FLUORESCENT GAS INSIDE THE TUBE. THE GLOWING TUBE INDICATES THAT THE ATOMS OF GAS ARE BEING STIMULATED TO HIGHER THAN NORMAL ENERGY LEVELS. ALL THAT IS NEEDED TO CONVERT A NEON ADVERTISING SIGN INTO A LASER IS TO ADD A SMALL AMOUNT OF HELIUM AND PLACE PARALLEL MIRRORS AGAINST THE TUBE. THE HELIUM ALLOWS THE NEON TO BE STIMULATED TO MUCH HIGHER THAN NORMAL ENERGY LEVELS, WHILE THE MIRRORS SET UP THE OSCILLATING LIGHT WAVES NECESSARY FOR THE LASER ACTION.

TYPICAL HELIUM-NEON LASERS EMIT LESS LIGHT THAN A TWO CELL FLASHLIGHT, BUT SINCE ALL OF IT IS CONCENTRATED INTO A NARROW BEAM, THE DIAMETER OF A PENCIL LEAD, IT IS EXCEPTIONALLY BRIGHT.

HELIUM-NEON LASERS ARE THE MOST COMMON, BUT THERE ARE HUNDREDS OF OTHER GASES AND GAS MIXTURES USED IN MAKING GAS LASERS. THE MOST SPECTACULAR ONE IS THE CARBON-DIOXIDE LASER. AMONG THE SIMPLEST, IT IS ALSO ONE OF THE MOST EFFICIENT. MOST GAS LASERS CONVERT ONLY A TINY FRACTION OF THEIR INCOMING ELECTRICITY INTO LASER LIGHT, BUT THE CARBON-DIOXIDE LASER CONVERTS 20% TO 30%

OF THE ELECTRICITY THAT POWERS IT, INTO A STRONG BEAM OF INVISIBLE INFRARED LIGHT. MANY PRODUCE BEAMS CONTAINING TENS, OR EVEN HUNDREDS OF WATTS OF POWER. THESE LASERS ARE EXTREMELY DANGEROUS SINCE THE INVISIBLE BEAM CAN QUICKLY BURN EXPOSED SKIN AND IGNITE CLOTHING. THE MILITARY POTENTIAL BECOMES APPARENT AND I SHALL DISCUSS THIS ASPECT LATER ON.

SEMI-CONDUCTOR LASERS ARE SO DIFFERENT FROM GAS LASERS THAT IT IS EASY TO OVERLOOK THEIR SIMILARITIES. DESPITE THEIR MINISCULE SIZE, THE SEMI-CONDUCTOR LASER INCLUDES THE FLUORESCENT MATERIAL AND MIRRORS NECESSARY FOR LASER ACTION. HUNDREDS OF SEMI-CONDUCTOR LASERS CAN BE MADE FROM A SINGLE WAFER OF GALLIUM ARSENIDE AND THEY ARE MUCH CHEAPER THAN ANY OTHER LASER. THE SMALL, HELIUM-NEON LASERS CAN BE BOUGHT FOR LESS THAN $10.00.

THERE ARE TWO MAJOR KINDS OF LIQUID LASERS - ORGANIC AND INORGANIC. THE INORGANIC LIQUID LASER USES NEODYMIUM DISSOLVED IN A SOLVENT. OTHER THAN THE USE OF A LIQUID, THIS LASER FUNCTIONS MUCH THE SAME AS A SOLID LASER.

THE MOST IMPORTANT LIQUID LASERS ARE THOSE WHICH USE AN ORGANIC DYE. LASERS USING DYES WITH UNPRONOUNCABLE NAMES LIKE DIPHENYL-ISOBENZOFURAN, CAN PRODUCE LASER LIGHT OF ANY COLOR FROM VIOLET TO RED. THE PRECISE COLOR WAVE LENGTH CAN EVEN BE SELECTED (OR IS "TUNABLE") WITH THE HELP OF A PRISM - WHICH MAKES DYE LASERS IMPORTANT RESEARCH TOOLS.

IN ADDITION TO SOLID STATE, GAS, SEMI-CONDUCTOR, AND LIQUID LASERS, THERE ARE METAL VAPOR LASERS, AERODYNAMIC LASERS AND CHEMICAL LASERS. SOME OF THEM CAN PRODUCE CONTINUOUS POWER REACHING MORE THAN 100,000 WATTS.

NOW THAT WE KNOW A LITTLE BIT ABOUT WHAT A LASER IS, HOW THEY ARE MADE AND WHAT THEY ARE MADE OF, LET US FIND OUT WHAT LASERS CAN DO. ONE OF THE MOST EXCITING THINGS ABOUT LASERS IS THEIR ALMOST UNLIMITED POTENTIAL. SINCE I STARTED THE READING FOR THIS PAPER A FEW MONTHS AGO, I AM SURE THERE HAVE BEEN DOZENS OF NEW USES FOUND FOR LASER BEAMS.

THE MAJOR AREAS IN WHICH LASERS ARE NOW USED ARE INDUSTRY, MEDICINE, COMMUNICATIONS AND THE MILITARY. THERE IS NOT ENOUGH TIME TODAY TO DO MUCH MORE

THAN LIST SOME MAJOR APPLICATIONS IN EACH OF THESE FIELDS, WITHOUT ANY IN-DEPTH EXPLANATION OF HOW A PARTICULAR FUNCTION IS ACCOMPLISHED.

IN A FACTORY, LASERS CAN CUT, WELD, DRILL, MELT AND VAPORIZE ANY SUBSTANCE. UNLIKE CONVENTIONAL FRICTION AND CUTTING TOOLS, LASERS CUT, SCRIBE, DRILL, WELD, OR TRIM WITHOUT MAKING PHYSICAL CONTACT. AS A RESULT, [redacted] MECHANICAL VIBRATION IS NON-EXISTENT AND HIGH TEMPERATURES GENERATED BY THE FRICTION OF MACHINE TOOLS, ARE AVOIDED. THE NON-CONTACT NATURE OF THE OPERATION ALSO ELIMINATES THE WEAR AND TEAR EXPERIENCED BY CONVENTIONAL TOOLS. SINCE THE BEAM DOES NOT DISTURB THE MATERIAL BEING PROCESSED, IT IS RARELY NECESSARY TO CLAMP IT IN PLACE. BECAUSE MOST SUBSTANCES ARE VAPORIZED WHEN STRUCK BY LIGHT FROM A HIGH POWER LASER, SHAVINGS OR DUST IS AVOIDED - THE VAPORIZED MATERIAL IS SIMPLY SUCKED UP IN AN EXHAUST FAN. THE LASER'S SELECTIVITY FEATURE IS ALSO VALUABLE. THE CARBON DIOXIDE LASER, FOR EXAMPLE, CAN REMOVE PLASTIC INSULATION FROM COPPER WIRE WITHOUT HARMING THE WIRE - AN INEXPENSIVE WAY TO SALVAGE COPPER CABLE. THEN TOO, THE SHAPE OF THE BEAM CAN BE CHANGED TO MEET THE JOB REQUIREMENTS - THUS A SINGLE LASER CAN BE USED FOR MANY DIFFERENT JOBS.

IT USED TO TAKE NEARLY TWO DAYS OF VERY CAREFUL DRILLING OF ONE HOLE FOR A DIAMOND DIE, A LASER BEAM DOES THE JOB IN TWO MINUTES - AND THERE IS NO DANGER OF SHATTERING THE DIAMOND THROUGH VIBRATION. A LASER BEAM CAN WELD A HAIR-THIN WIRE FROM A SEMI-CONDUCTIVE CRYSTAL TO A METAL SUPPORT WITHOUT HEATING THE CRYSTAL. IT CAN WELD METALS OF VERY HIGH MELTING POINTS WITHOUT HEATING NEARBY AREAS. THIS CHARACTERISTIC OF LASER WELDING AVOIDS WARPAGE AND SEVERE BUILT-IN STRESSES OFTEN CAUSED BY THE EXPANSION OF METALS IN CONVENTIONAL WELDING TECHNIQUES. A LASER CAN ALSO WELD TWO DIFFERENT METALS THAT WILL NOT JOIN AT USUAL WELDING TEMPERATURES.

THE HIGH CUTTING SPEED OF LASERS IS USEFUL IN GARMENT FACTORIES WHERE THE CLOTH IS LAID OUT ON A TABLE, A LASER BEAM, GUIDED BY A COMPUTER, SNAKES A FINE CUT, THEN AS A THREAD - AND PRESTO, ALL THE PIECES FOR AN ENTIRE SUIT OF CLOTHES ARE CUT IN LESS THAN TWO MINUTES.

LASER BEAMS CUT GLASS, STEEL DIES AND LUMBER. A SHOE MANUFACTURER USES A LASER TO CUT PATTERNS AND THIN PAPER USED IN IGNITION COILS IS CUT BY ANOTHER TYPE OF LASER.

THERE ARE DOZENS OF WAYS LASERS ARE USED FOR MEASURING; THE WIDTH OF A RIVER, THE HEIGHT OF A MOUNTAIN ON THE MOON, MARKING A PERFECTLY STRAIGHT LINE MORE THAN 5 MILES LONG TO GUIDE A MACHINE FOR BORING A TUNNEL, PRICING PACKAGED MERCHANDISE IN THE SUPERMARKET - THAT IS WHAT THOSE LINES ON THE BOX ARE FOR. THE THIN RED BEAM OF THE HELIUM-NEON LASER IS REPLACING THE SURVEYOR'S TRADITIONAL TRANSIT AND LEVEL.

THE FIRST TELEPHONE LINES 100 YEARS AGO CARRIED ONE MESSAGE IN ONE PAIR OF WIRES. THEN A METHOD WAS DEVELOPED FOR FEEDING SEVERAL MESSAGES INTO ONE PAIR OF WIRES, WITHOUT MIXING THEM UP. AT THE OTHER END THEY WERE SELECTED OUT AND SEPARATED BY FILTER DEVICES. THE PRINCIPLE IS SIMILAR TO THAT OF YOUR RADIO TUNER OR CHANNEL SELECTOR, WHERE YOU SELECT A PARTICULAR PROGRAM OUT OF MANY BROADCASTS.

THE LIMIT TO THE NUMBER OF MESSAGES SENT THROUGH ONE PAIR OF WIRES AT THE SAME TIME, IS A CONDITION CALLED THERMAL NOISE - SIZZLING, SPUTTERING, STATIC. THERE IS NO THERMAL NOISE WITH LASER LIGHT - AND THOUSANDS OF MESSAGES CAN BE CARRIED BY A LASER LIGHT IN A SINGLE GLASS FIBER, ALMOST AS THIN AS A HAIR. CURRENT LASER TECHNOLOGY PERMITS 20 TV CHANNELS OR MORE THAN 30,000 TELEPHONE CONVERSATIONS TO BE SENT THROUGH ONE GLASS FIBER. THIS MEANS THAT A BUNDLE OF OPTICAL FIBERS ABOUT THE THICKNESS OF A PENCIL, CAN CARRY MORE INFORMATION THAN A HUGE, UNDERGROUND STANDARD CABLE SYSTEM. YOU CAN IMAGINE THE ENORMOUS SAVINGS IN MATERIALS, LABOR, AND SPACE WHEN GLASS FIBERS REPLACE COPPER CABLES AND LASER LIGHT REPLACES ELECTRIC CURRENT.

IN MEDICINE, I HAVE ALREADY DESCRIBED THE PHOTOCOAGULATION PROCESS USED TO REPAIR TORN OR DETACHED RETINAS. IN HIS BOOK, "LASERS THE INCREDIBLE LIGHT MACHINES", FOREST MIMS WRITES, "SEVERAL YEARS AGO I STOOD BEHIND A LARGE PROTECTIVE SCREEN AND WATCHED DR. LEON GOLDMAN, ONE OF THE WORLD'S FOREMOST AUTHORITIES ON THE USAGE OF THE LASER, HOVERING OVER AN ELDERLY PATIENT.

DR. GOLDMAN POINTED A CONE-SHAPED OBJECT, HANGING FROM AN OVERHEAD RUBY LASER AT THE PATIENT'S SHOULDER, WHILE AN ASSISTANT COUNTED DOWN, "5, 4, 3, 2, 1, FIRE!" SUDDENLY THERE WAS A BRILLIANT FLASH OF RED AND THE PUNGENT ODOR OF BURNED FLESH. USING A POWERFUL LASER, DR. GOLDMAN HAD JUST VAPORIZED A SMALL PATCH OF CANCEROUS TISSUE FROM THE PATIENT'S SHOULDER."

ONE OF THE MOST DRAMATIC APPLICATIONS OF THE LASER IN MEDICINE IS BLOODLESS SURGERY. TESTS HAVE INDICATED THAT THE CARBON DIOXIDE LASER CAN BE USED TO PERFORM SURGERY ON ORGANS WITH HIGH BLOOD CONTENT SUCH AS THE LIVER, WITH MUCH LESS BLEEDING THAN WHEN A SCALPEL IS USED. THE HEAT OF THE LASER CAUTERIZES THE EXPOSED TISSUE AND PREVENTS BLEEDING. THE PROCEDURE WAS STILL EXPERIMENTAL AT THE TIME MY SOURCE MATERIAL WAS WRITTEN - ABOUT 18 MONTHS AGO. THERE WERE STILL MAJOR PROBLEMS TO BE SOLVED - SMOKE DURING THE OPERATION BEING ONE OF THEM.

SINCE A LASER BEAM CAN BE FOCUSED TO AN INCREDIBLY SMALL POINT, IT IS POSSIBLE TO USE THE LASER TO PERFORM SURGERY ON INDIVIDUAL CELLS. THIS CAPABILITY PERMITS SCIENTISTS TO STUDY THE FUNCTION OF VARIOUS STRUCTURES WITHIN THE CELL BY DESTROYING THEM WITH A LASER AND STUDYING THE RESULT. LASER CELL SURGERY IS BEING USED IN SEVERAL ONGOING MEDICAL RESEARCH PROJECTS, INCLUDING THE INVESTIGATION OF THE CAUSE AND SPREAD OF CANCER.

THE LASER HAS BEEN USED IN PATHOLOGY, AS WELL. BIOMEDICAL RESEARCHERS AT THE SOUTHWEST RESEARCH INSTITUTE ARE EMPLOYING LASER BEAMS TO IDENTIFY DISEASES SUCH AS MONONUCLEOSIS, SICKLE CELL ANEMIA, ACUTE LYMPHATIC LEUKEMIA AND OTHERS. THE UNIVERSITY OF ROCHESTER HAS DEVELOPED A METHOD FOR IDENTIFYING INDIVIDUAL CANCER CELLS TAKEN FROM HUMAN PATIENTS.

THERE ARE ALSO MEDICAL MECHANICAL APPLICATIONS OF THE LASER - DRILLING SEVERAL HOLES IN A CATHETER, PERMITTING IT TO FUNCTION PROPERLY SHOULD ONE OR MORE BECOME BLOCKED. TINY HOLES, WITH DIAMETERS OF 1/10 OF A MILLIMETER ARE DRILLED ALONG THE EDGES OF CONTACT LENSES. THESE REDUCE IRRITATION BY ADMITTING FLUID TO THE SPACE BETWEEN THE EYE AND THE LENS. LASERS ARE USED TO SEAL SURGICAL DRAPES AND PLASTIC BAGS PROTECTING SURGICAL TRAYS.

SOON AFTER THE LASER WAS INVENTED IN 1960, SOME MILITARY RESEARCHERS MADE ENTHUSIASTIC PREDICTIONS ABOUT THE POSSIBILITY OF BULDING A LASER "DEATH RAY" TO DESTROY ENEMY SOLDIERS, KNOCK OUT TANKS, AND DEFLECT INCOMING ICB WARHEADS. IT DID NOT TAKE TOO MANY YEARS BEFORE IT BECAME APPARENT THAT THERE WAS A GREAT GULF BETWEEN THE THEORETICAL AND THE PRACTICAL.

THE MONEY SPENT ON EARLY WEAPONRY WORK WAS NOT WASTED HOWEVER, BECAUSE IT WAS LEARNED THAT THE HIGH-POWERED BEAM FROM SOME LASERS IS AN EXCELLENT TOOL FOR SIMULATING THE THERMAL EFFECTS OF NUCLEAR BLASTS. THUS, WHILE THE TEST BAN TREATY WITH THE SOVIET UNION RESTRICTS NUCLEAR EXPLOSIONS, LABORATORY LASERS PROVIDE A CONVENIENT WAY TO STUDY BOMB BLAST RESULTS.

OTHER MILITARY APPLICATIONS FOR LASERS WERE FOUND DURING THE VIET NAM WAR. RADAR-LIKE RANGE FINDERS, LASER GUIDED BOMBS AND LASER COMMUNICATIONS GEAR WERE DEVELOPED. THE LASER HAS MADE POSSIBLE THE SO-CALLED "SMART BOMBS"— AND ROCKETS WITH UNPRECEDENTED ACCURACY. BY ILLUMINATING A TARGET WITH INVISIBLE LIGHT FROM AN INFRARED LASER, A BOMB OR MISSILE, EQUIPPED WITH A LASER SEEKER, CAN FIND ITS QUARY WITH PIN-POINT PRECISION.

RELATIVELY SMALL CARBON-DIOXIDE LASERS CAN IGNITE CLOTHING AND BURN EXPOSED SKIN FROM A DISTANCE OF MORE THAN 100 YARDS.

HIGH ENERGY LASERS ARE THE CENTER OF INCREASED INTEREST BY THE DEFENSE DEPT. AND CONGRESS. LASER WEAPONS HOLD POTENTIAL FOR AN EXTRAORDINALLY EFFECTIVE DEFENSE OF ALL NATIONAL ASSETS AGAINST BOTH ICBM AND SLBM ATTACK. THESE SYSTEMS WOULD BE TRIGGERED BY SATELLITE DETECTION LAUNCH OF USSR MISSILES AND WOULD REACH OUT THOUSANDS OF MILES TO DESTROY THEM IN MID-COURSE. DESTRUCTION WOULD OCCUR BY HEATING THE MISSILE'S SKIN AND REDUCING MATERIAL STRESS TO THE POINT OF STRUCTURAL FAILURE.

BASED ON THE CURRENT TIMETABLE, IT WILL NOT BE POSSIBLE TO PLACE LASER BATTLE STATIONS IN SPACE UNTIL THE MID 1990'S. THE THEORY IS THAT TWO DOZEN SUCH SATTELITES COULD NEUTRALIZE SOVIET INTERCONTINENTAL BALLISTIC MISSILES BY "ZAPPING" THEM IN BUCK ROGERS FASHION AS SOON AS THEY WERE LAUNCHED. FAR FROM

BEING A STAR WAR FANTASY, SUCH WEAPONS ARE NOW SEEN AS CERTAIN OF EVENTUAL DEVELOPMENT. ON A WALL IN THE OFFICE OF PHYSICIST, J. RICHARD AIREY, HEAD OF THE U.S. DIRECTED ENERGY DEPT., HANGS THIS QUOTATION: "IT IS STILL A MATTER OF WONDER HOW THE MARTIANS ARE ABLE TO SLAY MEN SO SWIFTLY AND SO SILENTLY. A BEAM OF HEAT IS THE ESSENCE OF THE MATTER. HEAT AND INVISIBLE, INSTEAD OF VISIBLE LIGHT." H.G. WELLS "WAR OF THE WORLDS", 1898.

BUT THIS MILITARY POTENTIAL OF THE LASER IS ALSO KNOWN TO THE "OTHER SIDE". IN 1975, THE INFRARED SENSORS OF A SATELLITE, DESIGNED TO PROVIDE EARLY WARNING OF A MISSILE ATTACK, WERE DAMAGED BY A BLAST OF ENERGY, THOUSANDS OF TIMES BRIGHTER THAN THE EXHAUST FLAMES OF A MISSILE, A FOREST FIRE OR AN ACTIVE VOLCANO. THE ONLY KNOWN ENERGY SOURCE POWERFUL ENOUGH TO DISABLE SUCH A SATELLITE IS A HIGH ENERGY LASER THERMAL WEAPON.

SHORTLY AFTER IT WAS INVENTED, THE LASER WAS CALLED AN IDEA IN SEARCH OF AN APPLICATION. TODAY, AS WE HAVE NOTED, THERE ARE DOZENS OF PRACTICAL APPLICATIONS FOR THE LASER IN EVERY DAY USE - AND THE LIST CONTINUES TO GROW AS PHYSICISTS DEVELOP NEW LASERS AND ENGINEERS THINK OF NEW WAYS TO USE THEM. SOME OF THE NEWER APPLICATIONS ARE:

1. LASER SYSTEMS FOR AIR TURBULENCE DETECTION - IMPORTANT IN THE SAFETY OF SMALL PLANES.
2. SIMILAR DEVICES FOR DETECTION OF AIR POLLUTION.
3. INVISIBLE LASER FENCES PROTECT MILITARY INSTALLATIONS, FACTORIES, STORES AND SOME PRIVATE HOMES.
4. LASER PRODUCED HOLOGRAMS, MADE WITHOUT CAMERAS OR LENSES. AS MANY OF YOU KNOW, HOLOGRAMS ARE 3 DIMENSIONAL PHOTOGRAPHS. AN ENTIRE PAPER COULD BE DEVOTED TO LASER HOLOGRAPHY ITSELF.
5. TRACKING SYSTEMS - FOLLOWING HIGH SPEED ROCKET SLEDS DOWN TEST TRACKS; STUDYING THE OPERATION OF MOVING AIRCRAFT AND AUTOS; SATELLITE TRACKING.

FINALLY, PROBABLY THE MOST IMPORTANT POTENTIAL USE OF LASERS IS THAT OF LASER FUSION. A TOTALLY NEW FORM OF ENERGY, LASER FUSION MAY PROVIDE US WITH A

SUBSTANTIAL PART OF THE ANSWER TO OUR ENERGY PROBLEM. LASER FUSION DUPLICATES THE ENERGY OF THE SUN IN THE FORM OF MICROSCOPIC NUCLEAR EXPLOSIONS. UNLIKE THE NUCLEAR FISSION IN TODAY'S ATOMIC POWER PLANTS, LASER FUSION PRODUCES NO RADIOACTIVE WASTES AND THE WORLD'S OCEANS CONTAIN A VIRTUALLY UNLIMITED SUPPLY OF FUSIONABLE MATERIAL, DEUTERIUM.

IN THE SEPTEMBER 19 ISSUE OF THE WALL STREET JOURNAL, JERRY BISHOP WROTE, "FROM THE TIME THE "A" BOMB WAS CONCEIVED, SCIENTISTS HAVE DREAMED OF FUSING HYDROGEN ATOMS UNDER CONTROLLED CONDITIONS, SO THAT ENERGY COULD BE CHANNELED INTO DRIVING, SAY, AN ELECTRIC POWER PLANT. AS HYDROGEN IS THE MOST COMMON ELEMENT ON EARTH, CONTROLLED HYDROGEN FUSION WOULD MEAN AN INEXHAUSTIBLE SOURCE OF ENERGY.

NOW SCIENTISTS MAY HAVE A PROMISING TOOL TO HELP CONVERT THE HYDROGEN BOMB INTO A BENIGN POWER SOURCE." HE GOES ON TO SAY, "LIKE THE 'PHASERS' OF TV'S STARSHIP ENTERPRISE, THE NEW LASER EMITS A PULSE LASTING LESS THAN A BILLIONTH OF A SECOND, BUT WITH A POWER MEASURED IN TRILLIONS OF WATTS.

WHAT IS EXCITING TO SCIENTISTS IS THAT THIS LASER'S BEAM IS ULTRAVIOLET LIGHT. IT IS THE FIRST TO PRODUCE AN ULTRAVIOLET BEAM OF SUCH POWER. AS A RESULT, IT PROMISES TO OVERCOME A PROBLEM THAT HAS THREATENED TO BOG DOWN THE NATION'S LASER-HYDROGEN FUSION PROGRAM."

DR. MOSHE LUBIN, DIRECTOR OF THE UNIVERSITY OF ROCHESTER'S LABORATORY FOR LASER ENERGETICS, WITH SOME OPTIMISM SAID, "THE FIELD IS EXTREMELY UPBEAT RIGHT NOW."

ALTHOUGH HYDROGEN FUSION HAS BEEN ACHIEVED WITH LASERS SOME TIME AGO, UNTIL NOW, MORE ENERGY HAD TO BE POURED INTO THE HYDROGEN FUEL PELLET BY WAY OF LASER BEAMS, THAN WAS PRODUCED FROM THE RESULTING FUSION. UNIVERSITY OF ROCHESTER SCIENTISTS BELIEVE THE NEW ULTRAVIOLET LASER WILL BE 80 TO 90% EFFICIENT IN JAMMING ENERGY INTO THE HYDROGEN PELLET, COMPARED TO THE 30% EFFICIENCY OF INFRARED LASERS PREVIOUSLY USED. IF THIS IS CONFIRMED BY CURRENT

EXPERIMENTS, IT WILL MEAN THAT IT WILL NOT BE NECESSARY TO BUILD HUGE INFRARED LASERS TO REACH NECESSARY EFFICIENCY.

THERE YOU HAVE IT - I HOPE I HAVEN'T CONFUSED YOU AND THAT YOU KNOW A BIT MORE ABOUT THE LASER THAN YOU DID A SHORT WHILE AGO. IF YOU WANT MORE, "LASERS THE INCREDIBLE LIGHT MACHINES" BY FOREST MIMS, "THE AMAZING LASER" BY BEN BOVA AND "LASER LIGHT" BY HERMAN SCHNEIDER ARE THREE GOOD, EASILY UNDERSTOOD SOURCES.

LIKE MOST IMPORTANT SCIENTIFIC ACHIEVEMENTS, THE LASER HAS OBVIOUS POTENTIAL FOR IMPROVING THE QUALITY OF LIFE. UNFORTUNATELY, ALSO LIKE OTHER GREAT SCIENTIFIC ACHIEVEMENTS, THE LASER HAS ENORMOUS DESTRUCTIVE POWERS. I PRAY THAT AT SOME TIME SOON, OUR SOCIAL CAPACITY - OUR ABILITY TO LIVE WISELY AND AT PEACE WITH EACH OTHER, WILL REACH THE HIGH LEVELS OF OUR SCIENTIFIC SUCCESS.