

Physical Acoustics Timeline, 550 BC — Present

(Submissions courtesy of members of the Acoustical Society of America's Physical Acoustics Technical Committee)

- 550 BC Pythagoras relates length of vibrating string to pitch.
- 1400s (late) Leonardo da Vinci identifies an early form of the principle of superposition, shows that sound has a finite velocity, and uses a tube to listen to underwater sound.
- 1636 Mersenne describes the first absolute determination of the frequency of an audible tone.
- 1638 (circa) Galileo explains the relation of pitch to frequency, consonance, dissonance, the frequency ratios corresponding to musical intervals, vibratory resonance, sympathetic vibrations, and the quantitative dependence of the frequency of a vibrating string on its length, diameter, density, and tension.
- 1650 Kircher studies the acoustical horn and invents the loud-speaking trumpet. Additional studies were later done on horns by Morland in the 1670s.
- 1654 (circa) von Guericke and later Boyle & Hooke show that sound does not propagate in a vacuum.
- 1656 Viviani and Borelli measure the speed of sound in air to within 5% of its correct value.
- 1670s Hooke uses a rotating toothed wheel to produce sound (siren) and anticipates the use of the stethoscope for diagnostic purposes (later developed by Laennec around 1816).
- 1686 Newton characterizes sound as pressure pulses transmitted through neighboring fluid particles. Computes the speed of sound in a gas by assuming condensation is proportional to pressure with the result being lower than the correct value by around 16%.
- 1740 Bianconi and de la Condamine independently demonstrate that the speed of sound is a function of temperature.
- 1747 (circa) Franklin uses a Leyden jar and a light cork ball to demonstrate oscillating electromechanical transduction and later adapts the device to ring a bell.
- 1765 Euler publishes model equation for finite-amplitude waves.
- 1808 Poisson finds an exact solution to describe the propagation of finite-amplitude waves.
- 1816 Laplace correctly computes the speed of sound in a gas by assuming adiabatic conditions.
- 1826 Calladon and Sturm measure the speed of sound in the water of Lake Geneva.
- 1828-29 Cauchy and Poisson derive solution for elastic wave propagation in thin plates. Poisson shows elastic vibrations consist of both dilatational and distortional waves.
- 1831 Faraday observes acoustically-stimulated gas streaming above a vibrating plate.
- 1845 Stokes relates attenuation of sound to the viscosity of fluids.
- 1849 Stokes, George G., "On the dynamical theory of diffraction." The solution for a point load in an infinite elastic space is given. One of the first systematic studies of the excitation and propagation of elastic waves.

- 1850 Sondhauss studies heat-driven acoustic oscillations in tubes without flow.
- 1859 Rijke studies heat-driven acoustic oscillations in tubes with flow.
- 1860 Helmholtz publishes the theory of the resonator that now has his name.
- 1867 Toepler develops the schlieren method of sound visualization.
- 1868 Kirchhoff finds the spatial absorption for sound in a viscous, heat-conducting gas.
- 1870 Rankine publishes fundamental equations describing shock wave propagation (later also published by Hugoniot in 1889 and partially derived earlier by Stokes).
- 1877 The first edition of Rayleigh's *The Theory of Sound* is published.
- 1877 Cuttris & Redding and Siemens independently file for patents for moving-coil electroacoustic transducers, thereby paving the way for the development of loudspeakers.
- 1880 Brothers Curie discover the piezoelectric effect.
- 1880 A. G. Bell uses photoacoustic effects to transmit sound by modulation of light.
- 1889 Rayleigh and Lamb independently derive solutions for propagation of elastic waves in plates.
- 1898 A. W. Duff publishes "The attenuation of sound and the constant of radiation of air." Following a comment by Lord Rayleigh "On the cooling of air by radiation and conduction and on the propagation of sound," (1899) Duff reports a second set of measurements in "The attenuation of sound," (1900).
- 1904 Borne and subsequent researchers observe "abnormal" propagation in the atmosphere and thereby identify the existence of the stratospheric temperature inversion.
- 1904 Lamb, H. "On the propagation of tremors over the surface of an elastic solid." First systematic effort to solve the problem of a load applied to an elastic halfspace. In the course of solving the problem the emergence of an elastic surface wave is shown.
- 1911 Love describes propagation of elastic waves in a layered half-space and identifies the horizontally-polarized shear horizontal wave later to bear his name.
- 1917 Wente invents the condenser microphone.
- 1917 Lord Rayleigh publishes the first theoretical description of a collapsing cavity and uses the result to explain the erosion of high-speed ship propellers.
- 1917 (circa) Langevin observes numerous dead small fish and other marine animals in the vicinity of the transducers he built to begin studies leading to the detection of submarines.
- 1921 Cady discovers that quartz crystals can be used as stable electromechanical oscillators.
- 1924 Stoneley identifies the mode of wave propagation on solid-solid interfaces later to bear his name.
- 1927 W. Richards and A. Loomis publish the chemical effects of ultrasound.
- 1927 Wood and Loomis describe in detail their ultrasound studies including heretofore unfamiliar phenomena such as some chemical and thermal effects, acoustic production of emulsions and fogs, and biological effects.

- 1929 The beginning of disinfection using cavitation. Reduction in light emission from a suspension of *Bacillus Fisheri* in sea water. Bacteria were killed by sonication. "The destruction of luminous bacteria by high frequency sound waves" E.N. Harvey and A.L. Loomis.
- 1932 The diffraction of light by ultrasound is studied by P. Debye and F. W. Sears and (in a different publication) by R. Lucas and P. Biquard.
- 1933 Vern Knudsen makes the first accurate measurements of atmospheric absorption using vacuum tube technology in a reverberation room.
- 1933 H. O. Kneser develops the first theoretical model of the molecular relaxation part of atmospheric absorption considering only oxygen relaxation.
- 1933 Minnaert suggests flowing water noise associated with bubble motion.
- 1934 Discovery of sonoluminescence by Frenzel and Schules.
- 1934 L. V. King calculates the acoustic radiation force on a rigid sphere.
- 1935-36 E. Fubini-Ghiron works out the theory concerning the anomalies in the propagation of finite-amplitude acoustic waves.
- 1936 (circa) Pohlman develops an ultrasonic imaging method based on transmission using acoustical lenses and conversion of the resulting acoustical image into a visually observable image in the same volume of interest. In Germany, his image converting apparatus becomes known as 'Pohlman cell.' Used extensively near the end of WW2 in Germany when ultrasonic NDT material testing became essential in the selection of ammunitions for the flak defense of Berlin. Flaws in the brittle steel caused in that time a demoralizing decimation of artillery crews due to gun explosions at low temperatures, so that ultrasonically tested grenades had to be reserved for such conditions.
- 1937-39 L. Landau, G. Rumer, and A. Akheiser, the beginning of theory for attenuation of ultrasonic waves in solids due to interaction with thermal phonons.
- 1938 Pohlman introduces ultrasonic physiotherapy as a medical practice at the Charité in Berlin. His rule was that the power of the transducer should be limited to 5 W/cm^2 , the transducer must be kept in motion, and insonifying the bone must be avoided (indicating knowledge that bone exhibits much greater absorption).
- 1939 Pohlman reports observing the linear dependence of the ultrasound absorption coefficient on frequency, and that different tissues exhibit different rates of energy absorption.
- 1939 Cagniard's thesis discusses the waves excited by a transient, point load embedded in one elastic halfspace that is in contact with a second.
- 1944 Peshkov observes second (thermal) sound in superfluid helium.
- 1945 Landau measures weak shocks at large distances from an explosion site.
- 1946 H. Eyring publishes his classic study of sound propagation in a jungle.
- 1946 Blokhintsev suggests that audible sound is scattered primarily by the inertial subrange of turbulence.

- 1946 Givens, Nyborg and Schilling report theory for a study of sound propagation through the scattering and absorbing medium that exists near the ground..
- 1947 Isador Rudnick publishes the pioneering work on sound propagation from a point source over a locally reacting acoustic impedance plane based in part, on prior research on propagation losses of EM waves by Sommerfeld (1909), van der Pol (1935) and Norton (1937).
- 1947 Scholte identifies the mode of wave propagation on solid-liquid interfaces later to bear his name.
- 1948 Hillary St. Clair levitates copper in a standing wave at atmospheric pressure using sound from a siren.
(circa)
- 1948 C. Zener, introduced the concept of anelastic property of solids is introduced.
- 1948 M. Greenspan tracks propagation in gas from the hydrodynamic to the collisionless regime.
- 1949 Kyame provides full description of bulk wave propagation in piezoelectric crystals.
- 1950 M. Greenspan decreases the acoustic cavitation threshold in clean water to -200 atmospheres.
(circa)
- 1950 Ludwig shows that the speed of ultrasound and acoustic impedance values of high-water-content tissues do not differ greatly from those of water, and that anisotropic structural features do not contribute greatly to these parameters.
- 1950 Fry, Wulff, Tucker and Fry explore the role of ultrasonically produced temperature changes in functional excised preparations and compare with other means of introducing heat, though temperature is not considered responsible for the observed effects.
- 1950s Noltingk, B.E. and Neppiras, E.A. develop theory for cavitation bubble in ultrasound field.
- 1951 A. Kastler, the theory of interaction between ultrasonic waves and nuclear spins published.
- 1951 Fry, Tucker, Fry, and Wulff show that the observed functional effect in frogs exposed to ultrasound is not due to cavitation, as the endpoint was observed under a hydrostatic pressure sufficient to prevent its occurrence. The existence of threshold phenomena associated with ultrasound effects in biological systems is introduced here.
- 1951 Wulff, Fry, Tucker, Fry, and Melton produce ultrasonic effects on nerve activity and show that temperature increase is not responsible.
- 1952 Hueter reveals the much greater absorption exhibited by bone and its different frequency dependence, compared with soft tissues.
- 1952 Esche describes the first attempt to examine cavitation thresholds in mammalian blood and tissue near the megahertz frequency range.
- 1952 Lighthill founds the study of aeroacoustics.

- 1953 Carstensen, Li, and Schwan, in studies with blood and various blood proteins in solution, show that a major fraction of the absorption in biological materials occurs at the molecular level.
- 1953 and later Lighthill, Batchelor, Obukhov, Monin, and others determine the scattering cross section for sound waves by turbulence
- 1953 Kornhauser publishes the correct ray equations for sound propagation in a moving medium.
- 1953 Renaud reports the first acceleration of liquid-solid reactions using ultrasound.
- 1953 Mazoué, Chauchard and Busnel, using an *in vitro* rat preparation, further argue against the effects upon nerve as being of a thermal nature.
- 1954 Lehmann and Biegler explore biophysical events, in response to ultrasound exposure, occurring at, or otherwise involve, the ubiquitous biological membrane; mechanical events are attributed to a stirring effect depleting concentration gradients at the membrane surface and thermal events are attributed to affects on electric charges on membrane proteins.
- 1954 Musgrave begins publication of a series of studies on elastic wave propagation in bulk crystals.
- 1950s Zarembo and Krasil'nikov experiment with nonlinear acoustics in solids.
- 1954 H. Bömmel and, independently, L. Mackinnon observe effect of superconductivity on ultrasonic attenuation. Results in accord with BCS theory.
- 1955 (circa) R. K. Cook uses infrasound to detect California surf at the Bureau of Standards in Washington, DC.
- 1955 Fry, Bernard, Fry, Krumins and Brennan show the kinds of localized effects that can be produced selectively in gray and white matter of cat brain *in vivo* when more sophisticated radiation techniques (focusing) are employed.
- 1955 K. Yosioka and Y. Kawasima analyze the long wavelength radiation force on compressible spheres opening up a wider range of applications of radiation pressure.
- 1956 A.V. Granato and K. Lücke, vibrating string model of dislocation damping in solids.
- 1956 Fry and Dunn show that precision data can be obtained with a suitable biological preparation.
- 1956 Biot's theory on a porous medium.
- 1956 Hueter, Ballantine and Cotter conclude, after a detailed study of dosage factors, that the mechanism(s) of cell destruction is a temperature-dependent mechanical effect originating at weak points in the tissue.
- 1956-59 W. G. Proctor, W. H. Tantilla, D. I. Bolef, M. Menes, experimental observation of interaction between nuclear spins and ultrasonic waves.
- 1957-59 K. N. Baranskii, H. E. Bömmel, E. H. Jacobsen, generation of microwave frequency in solids.

- 1956-60 H. E. Bömmel, R. W. Morse, and others find oscillatory magnetic field effects for ultrasonic attenuation in metals at low temperatures. Effects became an important method to study Fermi surfaces in metals.
- 1958 A. T. deHoop, *Representation theorems for the displacement in an elastic solid and their application to elastodynamic diffraction theory*. Doctoral Dissertation. Delft: Delft Technological University. The thesis shows how to form an integral equation for two-dimensional diffraction from a semi-infinite stress-free slit embedded in a infinite elastic space.
- 1958 Fry, Ades and Fry report the first demonstration of reversible functional changes in an *in vivo* preparation, viz., the lateral geniculate nucleus of the cat brain, was irradiated ultrasonically while cortical potentials, evoked by light flash, were monitored.
- 1959 Weissler reports first quantitative analysis of oxidation of iodide in water during ultrasonic irradiation.
- 1959 Carstensen and Schwan show that a small contribution to absorption in blood arises from viscous interaction between the intact cells and their environment. They also show that the absorption per wavelength and the velocity dispersion of hemoglobin solutions can be related through relaxation theory by assuming a broad distribution of relaxation times.
- 1959 Wiener and Keast observe refractive shadow zones for propagation near the ground.
- 1959 Maluyzhinets derives parabolic equation for acoustic beams.
- 1959-61 E. H. Jacobsen, E. B. Tucker, M. E. Browne, W. I. Dobrov, the interaction between electron spins and phonons observed.
- 1959-62 Zverev and Kalachev develop transmitters and receivers based on nonlinear sound-sound interaction (in USA-parametric antennas) (done in parallel with Westervelt in USA but declassified and published later in 1970).
- 1960 Dyer and Nyborg describe studies in which a localized divergent sound source is brought into contact with the cell wall and suggest that intracellular motions are related to acoustic streaming and can be explained in terms of acoustic streaming theory.
- 1961 Viktorov publishes monograph describing his extensive studies of Rayleigh and Lamb waves.
- 1961 Dunn and Fry measure the absorption and reflection of excised lung.
- 1961 S. A. Al'schuler, B. I. Kochelaev, A. M. Leushin, a more complete theory of interaction of ultrasonic waves and nuclear spins.
- 1961-62 Hutson and White provide theory of elastic wave propagation in piezoelectric semiconductors and, along with McFee, later describe ultrasonic amplification in CdS.
- 1961-67 T. O. Woodruff, H. Ehrenreich, H. Maris, P.G. Klemens develop a more complete theory of interaction of ultrasonic waves with thermal phonons.
- 1962 Dunn obtains evidence that the absorption coefficient, *in vivo*, increases with increasing temperature of the specimen.

- 1962 Hughes and Nyborg show that collapse-type cavitation is not a necessary condition for ultrasound to damage cells in suspension and macromolecules in solution; they speculate that such damage may "result from the shearing action associated with bubble-induced eddying and relative motions."
- 1963 Tiersten publishes studies on thickness vibrations and wave propagation of piezoelectric plates.
- 1963 Westervelt publishes theory of the parametric array.
- 1963 Hawley, Macleod, and Dunn degrade DNA by backbone scission in aqueous solution in the absence of cavitation and suggest that the mechanism is relative motion between the solvent and the more dense molecule.
- 1964 Hawley and Dunn, using rotifers and ultrasound frequencies of 270 and 510 MHz and very low amplitude, show that biological effects are produced in the absence of cavitation and thermal processes.
- 1964 L. E. Hargrove, R. L. Fork, and M. A. Pollack introduce acousto-optic mode locking of lasers.
- 1965 Publication of a transducer technique that needs no physical contact or any coupling medium for transmission and reception of ultrasound in non-magnetic metals.
- 1965 Hrazdira examined the question of whether cellular damage (in suspension) was directly on the cell or indirectly by affecting the suspending medium.
- 1965 Shapiro and Rudnick observe fourth sound in superfluid saturated porous media.
- 1965 White and Voltmer invent the interdigital transducer for generation of surface acoustic waves.
- 1966 Pritchard, Hughes and Peacocke subject a solution of DNA to "stable cavitation" and, by applying the theory of acoustic streaming, the velocity gradient in the neighborhood of the bubble is calculated and a relationship between the number of breaks in the molecule and the calculated velocity gradient is obtained.
- 1966 Wilson, Wiercinski, Nyborg, Schnitzler and Sichel apply a special case of Embleton's theory of the mean force acting on a rigid sphere to explain the attraction phenomenon of intracellular particles toward a vibrating needle source.
- 1967 Greenspan and Tschiegg measure tensile strength of water.
- 1967 Marsh first to develop Fast Fourier Program for underwater propagation through layered media.
- 1968 Nyborg details the biophysical action of a single bubble vibrating under the influence of an ultrasonic field.
- 1968 Macleod and Dunn conclude that the ultrasonic denaturation of enzymes (molecular weight approximately 60,000) in solution occurs only in the presence of cavitation.
- 1968 McAllister invents the acoustic atmospheric sounding (sodar).
- 1969 Pickar and Adkins observe third sound in atomically-thin films of superfluid helium.
- 1969 P. C. Waterman introduces the T-matrix formulation of acoustic scattering.

- 1969 Hawley and Dunn show that beyond a molecular weight corresponding to approximately 100 monomer units of random coil polymers in solution, ultrasonic absorption becomes independent of molecular size.
- 1969 Khokhlov and Zabolotskaya develop the model equation for nonlinear acoustic beams.
- 1969 Kojima and Rudnick use Doppler shift to measure the decay time of superfluid persistent currents.
- 1969 Joe Piercy defines the role of nitrogen molecular relaxation in atmospheric absorption.
- 1970 Delaney and Bazley develop a pioneering empirical model for the acoustic impedance of porous materials that was widely used for evaluation of sound propagation over an absorbing ground plane.
- 1970 Rooney demonstrated "single-bubble hemolysis;" i.e., hemolysis produced by micro-streaming near a single vibrating bubble.
- 1970 Farnell describes the propagation of surface acoustic waves (SAWs) in crystals and demonstrates that no forbidden directions exist, work that is later important for the development of SAW devices.
- 1970 Fry, Kossoff, Eggleton and Dunn show that threshold for irreversible structural changes produced by focused ultrasound, *in vivo*, have only a very small dependence upon frequency in the low-megahertz range (includes data from Lele and Pond).
- 1970 Williams, Hughes and Nyborg, inspired by the Rooney findings (1970), develop a system employing a transversely oscillating wire to determine the critical shear stress of hemolysis.
- 1970 Ravitz and Schnitzler show that irreversible changes can occur in tissue in the absence of heat and transient cavitation.
- 1970 Robert Apfel experimentally measures the homogeneous nucleation threshold (tensile strength) of liquids.
- 1970 Clarke and Hill discovered the "rotation effect:" when a cell suspension in a test tube is exposed to a beam of ultrasound, effects on the cells (attributed to cavitation activity) are greatly increased if the tube is rotated slowly about its axis.
- 1971 Coakley, Hampton and Dunn demonstrate a strong correlation between ultrasonically produced cavitation events and cell survival, though the data do not rule out a noncavitation contribution to cell death.
- 1971 Zabolotskaya, Khokhlov, and Kuznetsov develop the equation for nonlinear acoustic beams with dissipation, now called the KZK equation.
- 1971 Pauly and Schwan find that approximately two-thirds of the total absorption in liver arises at the macromolecular level.
- 1971 Coakley and Dunn show that transient cavitation will degrade DNA in solution but, at ultrasonic amplitudes where transient cavitation is not detectable, greater denaturation of the molecule occurs.
- 1971 H. H. Demarest and O. L. Anderson make breakthrough advances leading to Resonant Ultrasound Spectroscopy.

- 1972 Ostrovsky, Soustova, and Sutin develop parametric generators of sound in a resonator with water; later, in a metallic resonator, 1978.
- 1972 Farnell and Adler publish extensive study of surface acoustic waves in layered crystalline half-spaces.
- 1974 Lemons and Quate invent the modern scanning acoustic microscope, first suggested by Sokolov in the 1940s.
- 1974 Dyson, Pond, Woodward, and Broadbent announce their production of blood flow stasis as a clear demonstration of what might be a pure mechanical effect, without contribution from thermal or cavitation processes.
- 1974 R. A. Lemons and C. F. Quate introduce high-frequency scanning acoustic microscopy.
- 1976 I. Ohno publishes a major paper on the vibrational frequencies of rectangular parallelepipeds.
- 1977 Achenbach, J. D. and Gutesen, A. "Geometrical theory of diffraction for 3D elastodynamics." The solution to a plane wave striking a semi-infinite stress-free slit, at an arbitrary angle is given. The solution involves one of the earliest splittings of a matrix Wiener-Hopf kernel. The solution to this canonical problem allowed the widespread use of the geometrical theory of diffraction to elastic-wave problems.
- 1977 T. G. Wang, H. Kanber, and I. Rudnick study the torques on cylinders in intense sound fields.
- 1978 Exploration of the claimed effects of intense ultrasound on the plastic deformation dynamics of metals (aborted the dislocation resonance concept).
- 1978 Daigle, Piercy, and Embleton observe turbulence-induced decorrelation of direct and ground-reflected sound energy outdoors.
- 1978 Rudnick uses 3rd sound to verify Kosterlitz Universality in 2-D phase transitions.
- 1978 Flax, Dragonette, Uberall, and Gaunaurd analyze the scattering by elastic objects in water using resonances.
- 1979 J. D. Maynard, G. A. Williams, S. J. Putterman, and I. Rudnick discover Fifth sound in superfluid helium.
- 1979 Marston and Apfel publish the excitation of capillary modes of levitated drops using modulated radiation pressure.
- 1980 Crum measures the growth of bubbles by rectified diffusion.
- 1980 N. Rott publishes his theory of thermoacoustics.
- 1980 Muir and Carstensen discuss importance of nonlinear effects in tissue.
- 1981 Plona measures the slow compressional wave.
- 1982 P. Riesz finds evidence for radicals production in an ultrasound field.
- 1982 Determination of human threshold of hearing and of equal loudness curves for free field airborne ultrasound (Basis for International Standard IEC 61012).
- 1982 Kojima and Wheatley observe superfluidity in ^3He using 4th sound.

- 1983 Patent on first thermoacoustic refrigerator issued to Wheatley, Swift and Migliori.
- 1983 Raspet, et al adopt the FFP program to propagation in a layered atmosphere over an impedance plane.
- 1983 Full understanding of wave interaction with ground surface evolves from several investigators including Attenborough, Bass, Raspet, Lee, Hayek, etc.
- 1983 J. D. Maynard and E. G. Williams patent Nearfield Acoustic Holography.
- 1984 H.E. Bass, L.C. Sutherland, J. Piercy and L. Evans publish the detailed theory of sound absorption supported by an extensive review of available laboratory and field measurements.
- 1984 Wang flies on Shuttle STS-24 to conduct acoustic levitation experiment (1st ASA member in space).
- 1984 Junru Wu, Robert Keolian and Isadore Rudnick observed "nonpropagating hydrodynamic solitons."
- 1986 Suslick publishes first determination of temperature during sonochemical reaction.
- 1988 Discovery of stable single-bubble sonoluminescence by Felipe Gaitan.
- 1988 Moldover et al. at NIST use a spherical, argon-filled acoustic resonator to re-determine the universal gas constant R with a standard uncertainty of 1.7 parts per million. CODATA recommends their result in 1998.
- 1988 Marston gives a geometrical theory of diffraction (GTD) for elastic wave contributions to the scattering by smooth elastic objects in water.
- 1989 Holland and Apfel propose an index to gauge the likelihood of cavitation. It is adopted as the Mechanical Index by the FDA and all commercial clinical ultrasound scanners are required to display it.
- 1989 White and Gilbert introduce numerical solution of the parabolic equation to atmospheric acoustics.
- 1989 K.W. Commander and A. Prosperetti publish "Linear pressure waves in bubbly liquids: Comparison between theory and experiments."
- 1990 Suslick and Grinstaff report sonochemical preparation of protein microspheres, a synthesis of ultrasonic echo contrast agents.
- 1991 E. Flint and K. Suslick determine the temperature inside a cavitation bubble.
- 1999 Moldover et al at NIST combine acoustic and microwave resonances to measure the errors of the International Temperature Scale of 1990 from 217 K to 303 K with a relative standard uncertainty of 2.5×10^{-6} .
- 1991 Putterman and Barber observe picosecond flashes from stable single-bubble sonoluminescence.
- 1996 McCall and Guyer publish the first paper on the Preisach-Mayergoyz model of hysteretic elastic nonlinearity.

- 1996 Based on experimental findings of Holt and Gaitan (1996), Lohse and Hilgenfeldt predict that dissociation of diatomic species is occurring in single bubble sonoluminescence. The hypothesis is later proved by Matula and Crum (1998), Ketterling and Apfel (1998), and quantified by Didenko and Suslick (2002).
- 1996 TenCate and Shankland publish first observations of "slow dynamics" in complex materials.
- 1997 Field, Johnson, Beresnev, and Zeng prove that elastic nonlinear behavior takes place in strong ground motion.
- 1997 Development of acoustic compressor and achieving macrosonic pressures in air in shaped resonators.
- 1999 Backhaus and Swift publish thermoacoustic-Stirling engine.
- 2002 Taleyarkhan et al. report in Science evidence of nuclear emissions during acoustic cavitation in deuterated liquids. To date, unconfirmed.