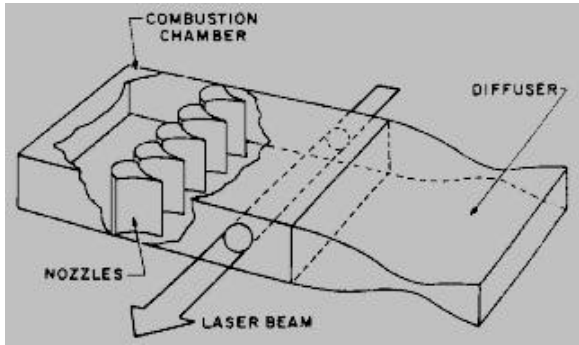


GAS DYNAMIC LASER

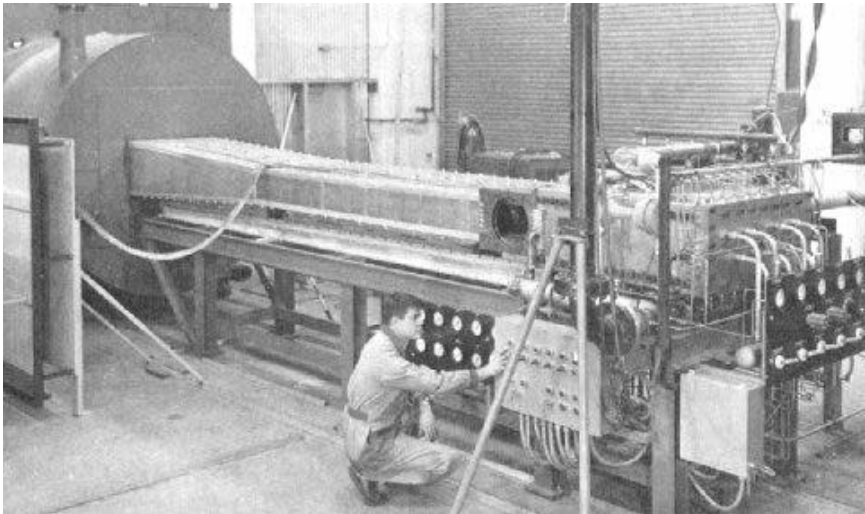
In 1962 Basov and Oraevskii proposed that rapid cooling could produce population inversions in molecular systems. A few years later others suggested that this could be accomplished by expansion of a hot gas through a supersonic nozzle. And in 1966, the first gasdynamic laser was successfully operated at the Avco Everett Research Lab. (Gerry, 1970).

According to Anderson (1976) gas dynamic lasers are first cousins to rocket engines. They also share design similarities with [supersonic wind tunnels](#). In rocket nozzles, aerodynamicists work hard to create equilibrium flows so as to obtain maximum specific impulse; on the other hand in a laser, all possible efforts are made to produce a highly *non-equilibrium* expansion.



Adiabatic Expansion Cooling Gasdynamic Laser : Hot gases expand through appropriately shaped nozzles from a high pressure, high temperature chamber into a low pressure chamber. This creates a highly non-equilibrium region where a strong population inversion takes place. Very high laser output power can be achieved. The diffuser is used to shock down the supersonic flow to subsonic speeds, then the gases are generally exhausted to the atmosphere.

Population inversions require that the lasing medium be *forced* as far as possible from equilibrium. In equilibrium, statistical thermodynamics tells us that the upper levels have an exponentially decreasing population as a function of increasing energy, which means that the lower quantum levels have a larger population than the upper levels, thus a photon is more likely to cause an absorption. In highly non-equilibrium situations, the populations are reversed and the upper level is overpopulated relative to the lower level, and a photon is more likely to induce a stimulated emission, hence laser action is possible.



Large scale 135 Kilowatt gasdynamic laser at Avco Everett Research Lab, Inc. was among the first very high power lasers. Initially this research was classified by the U.S. government, even today information on these types of lasers is scarce. (Gerry, 1970)

Non-equilibrium turbulent flows are much more likely to occur in rapidly expanding stellar atmospheres where *ideal* equilibrium flows are rarely encountered. If adiabatic expansion alone can produce one of the most powerful lasers on earth; this mechanism should also be one of the most prevalent astrophysical means of producing laser action.

PRACTICAL USE

High power CO2 lasers are used in manufacturing for drilling, cutting, welding, heat-treating and alloying (LaRocca, 1982). Some of these lasers are so powerful that beams emerging from the chamber could potentially destroy the optics. For a time the gasdynamic laser was seriously considered for use in the space based [Strategic Defence Initiative \(SDI\) or Star Wars program](#).

REFERENCES

1. Anderson,J.D.: 1976, *Gasdynamic Lasers: An Introduction* , Academic Press, New York.
2. [1996 papers](#) and [1997 papers](#)
 - o Takaishi,T., Mizuno,M., Watanuki,T., Kubota,H. *et al.* : 1995, *Proc. 39th Space Sci. Tech. Conf., Osaka, 1995* , 627 (Japanese) Study of the Multiple Nozzles of a Combustion Driven CO₂ Gasdynamic Laser
 - o Takaishi, T., Watanuki, T., Kubota, H. *et al.* : 1995, *AIAA Paper 95-1996, 26th AIAA Plasmadyn. and Lasers Conf.* , San Diego Numerical Simulation of Power Extraction of CO₂ Gasdynamic Laser
 - o Takaishi, T., Sugitaya, T., Watanuki, T., Kubota, H. *et al.* : 1995, *AIAA Paper 95-1997, 26th AIAA Plasmadyn. and Lasers Conf.* , San Diego (Japanese) The Effect of Nozzle Shapes on the Performance of the Combustion Driven CO₂ Gasdynamic Laser
 - o Watanuki, T., Mizuno, M., Takaishi, T., Kubota, H. *et al.* : 1996, *Proc. 45th Nat. Cong. of Theor. and Appl. Mech., Tokyo, 1996* , 301 (Japanese) Characteristics of Combustion Driven CO2 Gasdynamic Laser
 - o Shinjo,J., Mizuno, M., Watanuki,T., Kubota, H. *et al.* : 1996 *Proc. 27th JSASS Annu. Meet.* , 72 (Japanese). Experimental Study on the Performance of Multiple Nozzles for CO2 Gasdynamic laser
 - o Mizuno, M., Shinjo, J., Watanuki, T., Kubota, H. *et al.* : 1996 *20th Int. Symp. on Space Tech. Sci., Gifu, 1996* , Paper ISTS 96-d-28. Numerical Simulation of Laser Propagation with Multiple Nozzles of CO2 Gasdynamic Laser
 - o Shinjo, J. : 1996, *20th Int. Symp. on Space Tech. Sci., Gifu, 1996* , Paper ISTS 96-n-02. Performance of Multiple Nozzles of Gasdynamic Laser for Re-entry Simulation
 - o Mizuno, M., Shinjo, J., Watanuki, T., Kubota, H. : 1996 *Proc. 28th Fluid Dyn. Conf., Toyama, 1996* , 79 (Japanese). Flow Visualization for supersonic Flow Field in a Resonator of Combustion Driven CO2 Gasdynamic Laser
 - o Mizuno, M., Shinjo, J., Watanuki, T., Kubota, H. : 1996 *Proc. 40th Space Sci. Tech. Conf., Morioka* , 249 (Japanese). Effects of Supersonic Diffuser Design on Working Characteristics of Combustion Driven CO2 Gasdynamic Laser
 - o Shinjo, J., Mizuno, M., Watanuki, T., Kubota, H. *et al.* : 1996 *Proc. 27th JSASS Annu. Meet.* , 72 (Japanese). Experimental Study on the Performance of Multiple Nozzles for CO2 Gasdynamic laser
3. [RFNC-VNIIEF research on gas dynamic CO₂ lasers](#)
4. [Convective & Wave Processes Laboratory, Belarus National Academy of Sciences](#)
 - o Soloukhin, R.I., Fomin, N.A. : 1984, *Mixing Gasdynamic Lasers* , Minsk, Nauka i Technika Press.
 - o Novikov, S.S., Koudriavtsev, N.N. : 1985, *Diagnostics of Non-Equilibrium Molecular Distributions in Laser Systems* .
 - o Soloukhin, R.I., Fomin, N.A., N.N.Kudriavtsev,N.N., Novikov, S.S.: 1987, *Diagnostics of Molecular Levels in a Nonequilibrium Flows* ,
 - o Fomin, N.A.: 1989, *Speckle Interferometry of a Gasdynamic Flows* . Nauka i Technika Publ. House, Minsk
 - o [Achasov,O.V.: Heat and Mass Transfer Institute, Belarus Academy of Sciences](#)

5. [Dr. N. K. Mitra, AOR Institut für Thermo- und Fluidodynamik Ruhr-Universität Bochum](#)

- Mitra, N.K., Fiebig, M.: 1974, *Proc. 9th International Symposium on Rarefied Gas Dynamics* , S. B **21** p.1, Göttingen. Low Reynolds Number Vibrational Nonequilibrium Flow in Laval Nozzle
- Mitra, N.K., Fiebig, M.: 1975, *Proc. 1. GAMM Conference on Numerical Methods in Fluid Mechanics* , Okt., Köln, p.98. Flowfield Computation through Sonic Saddle Point in Viscous Frozen and Nonequilibrium Nozzle Flows
- Mitra, N.K., Fiebig, M.: 1975, *Nozzle Flows, ZfW* , Feb., p.39. Low Reynolds Number Hypersonic
- Mitra, N.K., Fiebig, M.: 1975, *DLR-FB 75-64*, DFVLR, Köln. Comparision of Slender Channel Computations with Experiments for Low Reynolds Number Hypersonic Nozzle Flows
- Mitra, N.K., Fiebig, M.: 1976, *AIAA Journal* , März. p.406. Determination of Stagnation Chamber Temperature in High Enthalpy Nozzle Flows
- Mitra, N.K., Fiebig, M.: 1976, *Nichtgleichgewichtsprobleme in der Strömungsmechanik* , herausgegeben von K. Robert, DFVLR, Press Köln,, p.211 Nozzle Flows with Vibrational Dissociational Nonequilibrium
- Mitra, N.K., Fiebig, M.: 1976, *Proc. Gasdynamic and Chemical Laser, 1. International Symposium* , Okt., Köln, S. 298-340, DFVLR Press Viscous Nozzle Flows and CO₂ Gasdynamic Laser
- Mitra, N.K., Fiebig, M.: 1977, *ZAMM* **57**, p.293. Effects of Wall Temperature on CO₂ Gasdynamic Laser Performance
- Mitra, N.K., Fiebig, M.: 1977, *Progress in Astronautics and Aeronautics* , v. **51**, Part , AIAA, p.885. Effects of Vibrational Wall Accommodation on Small Signal Gain in CO₂-N₂-H₂O Gasdynamic Laser (GDL),
- Mitra, N.K., Fiebig, M.: 1977, *DLR FB 77-36*, p.133. Similarity in Nozzle Flows with Vibrational Nonequilibrium
- Mitra, N.K., Fiebig, M.: 1978, *ZAMM* **58**, T 269. Similarity Considerations for Nonequilibrium Nozzle Flows
- Mitra, N.K., Fiebig, M.: 1978, *Proc. Eleventh International Symposium on Rarefied Gasdynamics, Cannes* , p.857. Low Reynolds Number Nozzle Flows with Vibrational Dissociational Nonequilibrium,
- Mitra, N.K., Fiebig, M.: 1978, *Proc. 2nd International Symposium on GCL* , J. Wendt (ed), von Karman Institute, Brussels. Small Signal Measurements in High Area CO₂ GDL Nozzle,
- Mitra, N.K., Fiebig, M.: 1979, *Recent Developments in Theoretical and Experimental Fluid Mechanics* , p.157, Springer Verlag, Supersonic Nozzle Flowfields: A Comparison on Fully Viscous and Navier-Stokes Solution
- Mitra, N.K., Fiebig, M.: 1979, *Forschungsberichte 2845 des Landes NRW* , Westdeutscher Verlag. Untersuchungen zum Gasdynamic-Laser

6. Basov, N.G., Oraevskii, A.N.: 1963, *Sov. Phys. JETP.* , **17**, 1171.

7. Gerry, E.T.: 1970, *IEEE Spectrum* , **7**, 51.

8. LaRocca, A. V.: 1982, *Scientific American* , (March) page. 94, 'Laser Applications in Manufacturing',

9. [Industrial Laser Review](#) (from [PennWell Publishing Co.](#))

10. [WWW : NASA Technical Reports on aerodynamic research \(NTRS\)](#)

11. [Minucci, M.A.S., Oliva, J.L.S.: 1993, AIAA PAPER 93-3187, 24 th Plasmadynamics and Lasers Conference](#) On the development of a gas generator for CO₂-N₂ gas dynamic lasers utilizing liquid fuel and liquid oxidizer

12. [Biriukov, A.S., Konoplev, N.A., Shcheglov, V.: 1981, Pis'ma v Zhurnal Tekhnicheskoi Fiziki , 7, 482.](#) Energy capabilities of a three-frequency periodic-pulse CO₂ gas-dynamic laser

13. [Krause, S., Maisenhaelder, F.: 1980, Applied Optics , 22, 421.](#) Gasdynamic CO laser with closed-cycle gas flow

14. [Huegel, H., Schall, W., Hoffmann, P.: 1976, DFVLR-Nachrichten , \(Nov\), 784.](#) Gas dynamic CO₂ laser output increase with the aid of appropriate supersonic mixing techniques

15. [Murthy, S.N.B.: 1976, in High-power gas lasers , Summer School \(IOP\), Capri,, Italy, September 1975, p.222](#) Gas-dynamic and chemical lasers - Gas dynamics

16. [Fournier, G., Morency, J.P.: 1975, NASA DREV-4011/75](#) Preliminary analysis of a light-gas gun-driven gas dynamic laser

17. [Cavalleri, R.J.: 1975, in Hydrogen energy , Proc., Miami Beach,, Fla., Plenum Press, p. 677](#) A hydrogen-fueled gas-dynamic laser

18. [Shmelev, V.M., Vasilik, N.I.A., Margolin, A.D.: 1974, Kvantovaja Elektronika \(Moscow\), 1, 1711.](#) Gas dynamic CO₂+N₂+CO+H₂O laser

19. [Genaralov, N.A., Kozlov, G.I., Selezneva, I.K.: 1974, NASA AD-783445, Air Force Systems Command, Wright-Patterson AFB, OH.](#) Estimate of the characteristics of a gas-dynamic laser

20. [Biryukov, A.S., Marchenko, V.M., Shelepin, L.A.: 1974, NASA JPRS-63317, Joint Publications Research Service, Arlington, VA.](#) Gas dynamic laser with electric excitation of a thermally ionized gas

21. [Pallay, B.G., Zovko, C.T.: 1973, AIAA PAPER 73-1233](#) Fuels, oxidizers and gas generators for gas dynamic lasers

22. [Yatsiv, S., Greenfield, E., Dothan-Deutsch, F., Chuchem, D.: 1972, in Laser Engineering and Applications IEEE Journal of Quantum Electronics, vol. QE-8, Feb. 1972, pt.2, page 161.](#) Experiments with a pulsed CO₂ gas dynamic laser. (combustion driven)

23. [McMahan, W.H.: 1971, Optical Spectra , 5, 30.](#) High-power, visible-output, gas-dynamic lasers.

Supersonic Wind Tunnels

- Flow field diagrams of hypersonic nozzles by H.L.Boerrigter,
- [Soeder, R.H.: 1992, NASA TM-105626.](#) Lewis 10 X 10-Foot Supersonic Wind Tunnel
- NASA Wind Tunnels, in particular the 9 X 7 foot Supersonic test section
- [EL-1996-00048 - The NASA Langley Research Center Unitary Plan Wind Tunnel](#)
- [Transonic and Supersonic Wind Tunnels](#)
- NASA MSFC 14 inch Trisonic Wind Tunnel and Nozzle test facilities (Fluid Dynamics Division)
- Davidian *et al.* : 1987, *Rocket Nozzle Tests*, NASA TM 89814 AIA-87-2971 (from Liquid Rocket Engine Performance Research)
- [Nonstationary Gasdynamics, Computational Fluid Dynamics and Hypersonics - J.J.Gottlieb](#)
- [Supersonic Wind Tunnel Computational Fluid Dynamics - Korte et al. \(NASA\)](#)
- [Virtual Wind Tunnel](#) and Ideal Flow Machine (Java applets)
- [Computational Fluid Dynamics Online Resources](#)