The South Korean Laser Isotope Separation Experience

By Mark Gorwitz (1996)

The literature concerning activities in the laser isotope separation area by South Korea has been limited in nature. Most important publications have been published in Korean and have not been translated.

The Laser Spectroscopy Laboratory and the Laboratory for Quantum Optics, Korean Atomic Energy Research Institute (KAERI) located in Taejon are the lead laboratories for research in the laser isotope separation area. Support is provided in the spectroscopy area by the Department of Physics, Korea Advanced Institute of Science and Technology, Taejon. TEA CO_2 laser research is done by the Department of Physics, Sogang University, Seoul. Copper vapor laser research is done by the Department of Phsics, Kyungpook National University, Daegu and the Department of Physics, Chonnam National University, Kwangju. Support in the dye laser area has been provided by the Department of Physics, University of Ulsan, Ulsan. Support in the optics area has been provided by the Korea Research Institute of Standards and Science, Taejon.

The early Korean effort during the mid 1970's was directed towards the separation of isotopes of light elements by the multiphoton dissociation process. TEA CO_2 lasers were developed for this purpose.

A 1981 KAERI document contained the following information about early laser isotope separation efforts:

"To achieve a separation of isotopes by multiphoton dissociation method, high power laser is needed. In our laboratory, a photoionizated TEA CO_2 laser which has a power of 1 Mega Watt was successfully constructed. In TEA CO_2 laser operation it is important for high power and high efficiency to establish a stable glow discharge uniformly, UV preionization employing a trigger wire was used. The uniformity of discharge between electrodes depended on the capacity of storage capacitor. And the number of initial electrons effective in the main gap discharge depended on the position of a wire. The electrode shape which have a Rogowski profile was an important parameter for the unifrom discharge. Optimum performance was obtained with 1:1:8 ratio of CO_2:N_2:He at atmospheric pressure. Also a discharge tube (68 cm in length) for a CW ion laser was made of quartz tubes. It consists of a small bored tube (5 mm i.d.), water jacket, gas return path, Brewster windows, and electrodes closed by a molybdenum foil seal. The current-voltage characteristics have been investigated up to current density of 66A/cm^2 for the tube filled with 0.1 torr Xe."

The effects of seeding on the stability and uniformity of the glow discharge in a TEA CO_2 laser and well as the output were

studied. Researchers at Sognag University studied the mechanism of decomposition of various additives and concluded that studying the decomposition products of tri-n-propylamine (current best quality seeding agent)will lead to a more effective seeding gas."

Some details of later TEA CO_2 have been published. The following information was obtained from a 1986 paper: "Our experiment is achieved sing a double-discharge TEA CO_2 laser with a hexagonal acrylic box having Brewster windows and a CO_2 cell. A gold-coated total reflector with 10-m radius of curvature and a ZnSe flat half mirror with 80% reflectivity mounted to the end of the cell are set 175 cm apart, forming an optical cavity. The electrodes of brass have a discharge length of 24 cm, a width of 2 cm, and a height of 3 cm. The preionization is achieved using two tungsten trigger wires with 330-pF trigger capacitors. The laser is energized using a two-stage Marx-Bank generator with a 26-nF capacitor per stage, and the voltage to the circuit is set at 18 kV. The laser medium introduced into the amplifier is a mixture of CO_2, N_2, and He gas, of which the ratio is 2:1:10."

"The CO_2 cell made of pyrex glass has a total length of 60 cm and a heating length of 35 cm. One end of the cell facing the cavity is blocked by an anti-reflecting-coated ZnSe flat window, and heating is done by a Ni-Cr wire and a transformer. Half of the CO2 gas flowing in the cell is exchanged per second."

"The laser operates a dominant 10.6-um P-20 and P-18 line in a low pressure of CO_2 cell and a single-line operation of P-20 at more high pressure."

Further information was contained in a 1985 KAERI document:

"Research on laser isotope separation of deuterium using Infrared Multi-Photon Absorption/Dissociation (IR MPA/D) and UV predissociation were reviewed and several kinds of lasers were built for this purpose. A tunable TEA CO_2 laser with power of about 10 MW was assmebled and a HF chemical laser with output energy of 300 mJ was built. These lasers are not ready to be used as sources for IR MPA/D experiment yet. The TEA CO_2 laser needs modification for more stable output and higher repetition rate and the HF chemical laser needs improvement for more output energy and tunability. Also a KrF excimer laser was built for UV predissociation experiment, but requires modification for stable output."

Some additonal details describing the above lasers are available. The TEA CO_2 laser made in 1983 was reassembled to increase the output power and tune the wavelength. The HF chemical laser was produced for IRMPD of molecules with an -OH structure. And lastly the KrF excimer laser was to be used to pump a dye laser to generate 345 nm radiation for UV predissociation experiments.

Details are also available of hydrogen isotope separation

experiments. Both deuterium and tritium separation were looked at. For deuterium, the literature was reviewed and a state of the art report issued (KAERI/AR-248/84).

The absorption coefficient of CDF_3 neat and in the presence of CHF_3 was determined. The efects of added inert gas on CDF_3 absorption was also studied. Actual photochemical energy requirements for deuterium separation by multi-photon dissociation were calculated and compared to the H_2S/H_2O system.

A 1990 paper reports on the selective photodissociation of $^{32}SF_6$ by a TEA CO_2 laser. The following details are provided: The molecular selective photodissociation of $^{32}SF_6$ by IRMPD in natural SF_6 was investigated using a pulsed TEA CO_2 laser. The TEA CO_2 laser consisted of 2 stage Marx bank power supply and for uniform discharge, it was designed to use the UV preionization generated by corona discharge along the surface of glass sheets on both electrodes. The laser gave multimode energy of about 1.7 J/pulse, pulse width (FWHM) of less than 100 ns and overall efficiency of about 9.6%. The laser beam (10P(20) line) was focussed into the reaction cell filled with reactant mixture, SF_6/NO or SF_6/H_2; the $^{32}SF_6$ absorbs the laser photons through multiphoton absorption and dissociates, selectively. The study focused on the relative reaction selectivities of $^{32}SF_6$ under influence of additives, such as NO and H_2 which were expected to act as a radical scavenger of free radical energy generated from SF_6 dissociation. The relative reaction selectivity was determined by measuring the unreacted $^{34}SF_6/^{32}SF_6$ ratios using a mass spectrometer."

The following further information was contained in a 1991 KAERI document:

"For IRMPA/D studies, we measured IR fluorescence emitted from vibrationally excited DF* or HF* produced in IRMPD of CDF_3/CHF_3 using IR monochromator and InSb IR detector. We could detect the ir fluorescence of HF from the sample mixture CDF_3 /CHF_3 to which the CDF_3 was selectively irradiated. This means that the molecular selective excitation of CDF_3 in CDF_3/CHF_3 did not give miolecular selective dissociation of CDF_3 because of the fast intermolecular vibrational energy transfer from the excited state CDF_3 to the ground state CHF_3. This technique will play an important role for measuring isotope selectivity in IRMPD of CDF_3/CHF_3. We developed data analysis technique for the laser fluorometer to improve analytical speed and accuracy. We calculated a fluorescence intensity at time zero using two values obtained by intergration of two intervals on the time-resolved fluorescence signal. Applying this method, we could eliminate any interference effects from quenching elements or temperature fluctuations of samples, effectively."

Copper vapor laser research has been ongoing since the mid 1980's. This early effort was done at the University of new Mexico. The lead American researcher was J.J. Kim and the lead Korean researcher K. Im was on leave from Chonnam National

University. J.J. Kim later moved to the Center for Research in Electro-Optics and Lasers, University of Central Florida. N. Sung after completing work there on transverse-discharge copper vapor lasers returned to the Korea Advanced Energy Research Institute. The results claimed that the transverse-discharge CVL's could be developed for practical applications.

In a 1987 paper written with J.J. Kim, N. Sung stated that: The copper-vapor laser (CVL) has recently received a great deal of attention as a practical device for applications in dye-laser pumpimg for isotope separation..." A research contract from Lawrence Livermore provided part of the funding for this effort.

By 1987 researchers at Kyungpook National University had succeeded in developing a 1.5 W, 5 kHz repetition rate laser using xenon as the inert buffering gas.

A 1978 paper provided details of a tunable dye laser pumped by a pulsed N_2 gas laser suitable for spectroscopic experiments. "The dye laser is transversely pumped by the focused 3371 AA emission line of a pulsed N_2 gas laser. The N_2 laser's peak power output is 1 MW at the repetition rate up to 100 pulses/sec. The dye laser output power is 1.36 kW at 2.5 ns pulse width, the spectral bandwidth is 3.3 x10-2/AA centered at 5900 AA, the emission wavelength is variable over the visible range by choosing one of seven dyes such as PPO, PBBO, POPOP, 4-methyl umbelliferone, Rhodamine 6G, Rhodamine B and cresyl violet perchlorate. Using the present tuning method, with the holographic grating, the prism and the etalon, the tunable dye laser with a short cavity, 15 cm in length is realized."

A KrF excimer laser for pumping a dye laser was developed in the early 1980's. The 345 nm generated laser radiation was to be used for UV preissociation experiments. Problems however arose in assembling the grating required for the dye laser.

Considerable work has also been done on the development of XeCl excimer lasers. Experiments have focused on the development of controllable long pulse lasers using a simple capacitor-dischrage circuit. An injection locked laser with a modified-branch conformal unstable resonator was also developed and characterised. Lastly a UV-preionized discharge-pumped laser was developed. The following design details were provided: "A maximum ouput energy of 96mJ/pulse, pulse duration of 20 ns (FWHM) and beam cross section of 7*17 mm^2 have been extracted from the gas mixture of HCl/Xe/He = 0.2/3.1/96.7% in total pressure of 3.5 atm, which was pumped with 26 kV of charging voltage.

Frequency has been controlled in pulsed dye lasers by the use of a volume holographic transmission grating along with a tuning mirror. The purpose of the grating was to maximize energy conversion and to minimize linewidth distortion. A Nd:YAG laser was used to pump a dye cell containing Rhodamine 6G.

"The energy conversion efficiency is greatly improved compared with that of the grazing incidence type, and the linewidth is reduced compared with that of the Hansch type." The Hansch type was used is early Israeli pulse dye lasers.

Argon ion lasers

Argon ion pumped dye laser research has been by T.S.Kim of the Department of Physics, University of Ulsan in collaboration with the University of Rochester, Rochester, New York. These experiments involved measuring the photon-number fluctuations in a single-mode dye jet laser. Argon ion pumped lasers are known to have been used by many groups in atomic vapor spectroscopic studies. Recent experimental results are described in the Israel section of this report.

Ti:Sapphire lasers suitable for spectroscopic have been developed by KAERI. The following details have ben provided concerning this laser: "We have constructed a self-seeded T:sapphire laser oscillator by using a dual-cavity configuration that consists of a Littman configuration cavity and a partially reflecting feedback mirror. This configuration can be decomposed with two kinds of cavity, a grazing-incidence cavity and a standing-wave cavity. The former behaves as an injection seeder and the latter as a slave oscillator. This Ti:sapphire laser system is capable of delivering a continuously tunable laser pulse with a narrow linewidth. Injection at the laser emission region of the free-running Ti:sapphire laser resulted in essentially complete energy extraction."

South Korea has a very active program in the laser isotope separation area. Scientific support has been provided by both American and Russian researchers. American support has been in the area of laser development and Russian support has been in the AVLIS area. This AVLIS program aimed at separating isotopes of the lanthanide elements for use as burnable poisons in nuclear reactors has been under development for a number of years.

Arisawa stated "that tunable lasers for AVLIS application require high repetition rate, high average power, high reliability and high stability. Ti:sapphire laser or F-center laser could be candidates, but each needs a good pumping sourceand nonlinear crystal for converting the wavelength from fundamental IR wavelength to visible one at high efficiency. A direct application of the diode laser as a tunable source might be promising in the future, if wavelength range coverage , average power and price are satisfied."

Results were published in 1990 on selective photoioniation of magnesium atoms. The abstract presented the following information: "A spectroscopic study of photoelectrons arising from nonresonant multiphoton ionization of magnesium atoms in a high intensity laser field is performed experimentally. Both the 532 nm and 1064 nm excitations in the intensity region of 10^{10-13} W/cm^2 are used for single and double ionization. The emphasis is

placed on the photoelectron spectra and their their variations with laser wavelength, intensity, and polarization. Also, the ionization process of doubly charged ions which can be produced either by a stepwise process or by the simultaneous removal of two electrons is discussed."

The effects of the AC-Stark shifts on the selective resonant ionization of both Li and Sr was studied. The abstract of a 1993 paper reads as follows: "The authors show that the ionization rate and the isotope selectivity become sensitive functions of the wavelength and intensity of the laser due to the AC-Stark shifts of the energy levels involved in the two-photon resonant three-photon ionization of Li and Sr atoms. They also examine the optimum conditions for isotope separation."

A paper contained in the same journal presented details of numerical calculations. The following abstract was given: " The authors present results of numerical calculations obtained through solving integro-diferential equations for the electron density matrices $sigma_{11}$ and $sigma_{22}$ and the ionization rate P in two-photon resonant three-photon ionization of Li and Sr, as well as the selectivity S for isotope separation. They also compare their results with the predictions from quasi-stationary solutions based on the rate approximation. Their numerical results for P and S show that the quasi-stationary solutions are valid at very high and very low laser intensities when the isotope shift is large as in the case with 4s of ^{6}Li and ^{7}Li, and that the validity is rather limited in the cases with small isotope shift as in $5p/_{2}/_{1/S}$ of ^{88}Sr and ^{90}Sr."

These calculations were performed on a CRAY C90 YMP supercomputer.

The most important work in the area of atomic vapor laser isotope separation (AVLIS) has involved the rare earth metals especially ytterbium. This work carried out at the Korea Atomic Energy Research Institute has been a partial collaborative effort with the General Physics Institute, Moscow. Support has been in both the theoretical and experimental areas.

Information on the selectivity of photo ion extraction for isotopes of the rare earth elements has been published. The abstract presented the following details: "An analysis of selectivity of three-stage photoionization for isotopes of rare-earth atoms with (1-2) GHz isotopic shifts in the absence of polarization effects is performed. Because of field broadening, a sufficiently high selectivity eta > or = 100 is achieved only for low average laser intensities, I < or = 10 mW/cm^2. The excitation of ions produced in photoionization of atoms by an electric field is investigated. The dependence of the selectivity on ion and gas densities, as well as on parameters of the external field, is calculated."

Experimental details were presented in 1995 on actual three-

photon polarization spectroscopy of ytterbium vapor. The General Physics Institute, Moscow was thanked for useful discussions.

The following experimental details were provided: The first (Lambda Physik FL3002/E) and second (Lumonics HD-300) dye lasers were pumped by the second harmonic of a Nd:YAG laser (Lumonics HY750). The wavelength of dye laser 1 was 555.648 nm, and that of dye laser 2 was 581.067 nm. Ytterbium atoms are excited to the intermediate state, $4f^{13}(^2F_{7/2})6s^26p_{3/2}$ (J=2) by these two dye laser pulses. Atoms in the intermediate state are excited to the autoionizing state by the third laser (Lumonics HD-300), which was pumped by the third harmonic of the Nd:YAG laser. the wavelength of the third laser was scanned from 430 to 660 nm using the dye Rhodamine 640, 610, and 590 and Coumarine 540A, 500, 480, 460, and 440."

"The laser have pulse durations of about 8 ns and are pulsed at the rate of 10 Hz. The laser pulses which are used for the excitation of intermediate states arrived at the chamber simultaneously. Approximately 8 ns later, the third laser pulse arrived at the chamber, to avoid the two-photon process. All lasers were incident to the chamber, with an angle of less than 2E between them."

"The linear polarization of lasers was improved by a Glan polarizer placed at the exit of each laser. Circular polarizations of the first and second lasers were made by lambda/4 waveplates. For the third laser, we used lambda/2 or lambda/4 Fresnel rhomb phase retarders. Each polarizer was placed in front of the chamber."

"The linewidth of the exciting laser was 5 GHz, and those of the other lasers were 3 GHz. The wavelengths of the third laser was calibrtaed by recording the optogalvanic signals from an Ar-Yb hollow cathode lamp (Cathodeon) simultaneously with the ion signal. The iar wavelengths of the Ar lines listed in the NBS table were converted into vacuum wavelengths before evaluating the energy levels of the autoionizing states."

"An atomic vapor of Yb was generated by heating pure Yb metal (99.9%) in a tantalum oven. Atoms were collected by two circular apertures placed before the electrodes of a time-of-flight mas spectrometer (TOF MS). 1 us later, atoms were ionized by three dye lasers, and the ions were extracted by applying a voltage pulse of 200-V/cm amplitude to the electrode for 10 us to reduce the perturbation due to a dc electric field. The extracted ions were analyzed by TOF MS (flight length: 1.5 m). Because we used natural Yb, a mass analyzer was needed for angular momentum idnetification. The ion signals were integrated by a boxcar (Stanford SR245) and stored in a computer."

"When an autoionizing state has a broad linewidth, the peak positions and the intensity of the ion signals are affected by the variation of the dye laser energy. Thus the laser energy was

also recorded as a function of wavelength, and ion signals normalized by the laser energy were used for analysis. The intensity of the third laser was attenuated with a neutral density filter enough to avoid depletion broadening of the line profile."

"As a result of this experiment, 17 autoionizing states were found in the investigated energy range from 50400 to 58000 cm^{-1}. The line profiles of the autoionizing states were nearly symmetric, and some states had very narrow linewidths comparable to those states observed by Bekov. The results of angular momentum identification required revision of electronic configuration assignments of the states investigated by Borisov. We propose that some autoionizing states with large excitation cross sections be used for efficient photionization."

A later paper added the following comment: "Some scheme of Yb has the possibility to yield high efficiency in selective ionization of an isotope."

Section 10: South Korean Laser Isotope Separation Work

Documents:

KAERI/RR-256/80 Apparatus for the Isotope Separation
D.W. Suh 1981

KAERI/AR-248/84 Isotope Separation of Deuterium Using Lasers
No Author 1984

KAERI/RR-437/84 Development of Applied Optical Techniques Using Lasers
C.J. Kim 1985

KAERI/RR-939/90 Research on the Optical Application in Nuclear Industry
C.J. Kim 1991

KAERI/RR-1007/91 Development of Nuclear Fuel. Development of Laser Spectroscopic Technology in Nuclear Industry
J.M. Lee 1991

KAERI/RR-1117/92 Development of Laser Spectroscopic Technology in Nuclear Industry
J.M. Lee 1992

KAERI/RR-1166/92 Study on Laser Atomic Spectroscopy
H.K. Cha 1993

KAERI/RR-1231/92 Development of Atomic Spectroscopy Technology
J.M. Lee 1993

KAERI/TR-367/93 Magnetic Field Effect on Selective Photoionization
J.M. Lee 1993

Conference Papers:

Proceedings of the Los Alamos Conference on Optics '83, Los Alamos, NM, 1983, J.J. Kim
The Copper Vapor Laser Pumped by a Fast Transverse Electrical Discharge

New Developments and Applications in Gas Lasers, Los Angeles, CA, 1987, J.J. Kim
Transverse-Discharge Copper-Vapor Laser

High-Power Gas Lasers, Los Angeles, CA, 1990, J.J. Kim
Observation of Collisional Excitation Energy Transfer in a Transverse-Discharge Copper Vapor Laser

Papers:

Area I: Laser Related

Journal of the Korean Physical Society, 1976, Vol. 8, p141-2, Ke Chul Lee
Electrical Control of Laser Oscillation in Periodic Structures

Journal of the Korean Physical Society, 1976, Vol. 8, p143-5, Ke Chul Lee
The Performance of High Power TEA CO_2 Laser

New Physics (Korean Physical Society), 1977, Vol. 17, p197-203, Tae-Soo Kim
Construction and Characteristics of High Power TE N_2 Laser Using a Blumlein Transmission Line

New Physics (Korean Physical Society), 1978, Vol. 18, p8-14, Doo-Hwan Suh
Tunable Dye Laser Excited by a Pulsed Nitrogen Gas Laser

New Physics (Korean Physical Society), 1980, Vol. 20, p6-12, In Won Lee
Performance of the Double Helical TEA CO_2 Laser

New Physics (Korean Physical Society), 1980, Vol. 20, p131-4, In Won Lee
Output Characteristics of TEA CO_2 Laser with UV-Preionization by Trigger Wire Discharge

New Physics (Korean Physical Society), 1981, Vol. 21, p226-31, In Won Lee
Output Characteristics of the Triple Discharge TEA CO_2 Laser Oscillator

New Physics (Korean Physical Society), 1982, Vol. 22, p6-11, Hee-Sarm Lee
Performance of Nd:YAG Laser and Dye Q-Switching

New Physics (Korean Physical Society), 1982, Vol. 22, p12-17, Yong Lee
Performance of Double Discharge TEA CO_2 Laser with Modified Electrode System and Its V-I Characteristics

New Physics (Korean Physical Society), 1982, Vol. 22, p97-101, Chang-Ho Cho
Second Harmonic Generation in KDP Crystal with Nd:YAG Laser

New Physics (Korean Physical Society), 1982, Vol. 22, p223-9, Myong-gwon Park
A 10-Hz Positive Branch Confocal Unstable Resonator Nd:YAG Laser

New Physics (Korean Physical Society), 1982, Vol. 22, p330-4,

Chul-Han Oh
Dye Laser Pumped by Segmented Coaxial Discharge

Transactions of the Korean Institute of Electrcial Engineers, 1983, Vol. 32, p157-63, Chul-Han Oh
Experimental Study of DC Coronas in Point-to-Plane Short Gap

Transactions of the Korean Institute of Electrical Engineers, 1983, Vol. 32, p164-9, Chul-Han Oh
Investigation of Changeable Discharge Colour Controlled by Electronic Circuit

New Physics (Korean Physical Society), 1983, Vol. 23, p386-91, Jong Dae Park
The Characteristics of Nd:YAG Laser Amplifier System

New Physics (Korean Physical Society), 1984, Vol. 24, p168-72, Jeong In Hyun
Coherent Light Generation from Temperature Tuned Optical Parametric Oscillation in $LiNbO_3$

New Physics (Korean Physical Society), 1984, Vol. 24, p293-9, Jae Woong Lee
Active Q-Switching og Nd:YAG Laser by an Electrooptic Modulator

New Physics (Korean Physical Society), 1984, Vol. 24, p305-11, Y.D. Lee
The Characteristics of a Crossed Porro-Prism Nd:YAG Laser Resonator

Journal of the Korean Institute of Electrical Engineers, 1984, Vol. 33, p371-6, Chul-Han Oh
New Laser Pumping Source, HCP (hypocycloidal pinch)

Transactions of the Korean Institute of Electrical Engineers, 1985, Vol. 34, p56-62, Chul-Han Oh
Development of Homemade Dye Laser (Korean Dye Laser)

New Physics (Korean Physical Society), 1985, Vol. 25, p69-77, Ho Young Kim
Ultra Short Pulse Generation by a Passively Mode-Locked, Pulsed Nd:YAG Laser

New Physics (Korean Physical Society), 1985, Vol. 25, p283-8, Jae Yong Jeong
A PTM Q-Switching of Nd:YAG Laser

Applied Optics, 1985, Vol. 24, p935-7, Chil-Min Kim
Effect of Photolysis on Seeding Gases in a TEA CO_2 Laser

New Physics (Korean Physical Society), 1985, Vol. 25, p186-92, Keun-Young Yang
The Characteristics of Cofocal Unstable Resonator in a TEA CO_2 Laser

New Physics (Korean Physical Society), 1985, Vol. 25, p264-9, In Hon Hwang
Argon Flash Pumped Dye Laser

Journal of the Korean Physical Society, 1985, Vol. 18, p206-13, Tae-Soo Kim
Experimental Investigation of a Small-Bore CW Argon Ion Laser

IEEE Journal of Quantum Electronics, 1985, Vol. QE-21, p1747-8, K. Im
Transverse-Discharge Copper-Vapor Laser

New Physics (Korean Physical Society), 1986, Vol. 26, p1-5, Yun-Woo Lee
Performance Assessment of a Laboratory Made Laser Wavemeter

New Physics (Korean Physical Society), 1986, Vo. 26, p101-6, Chil-Min Kim
Hot Band Effect of the Vibrational Transitions Lines in a Tunable TEA CO_2 Laser

New Physics (Korean Physical Society), 1986, Vol. 26, p107-13, B.H. Cha
Development of a Copper Vapor Laser

Applied Physics Letters, 1986, Vol. 49, p131-2, K. Im
Self-Mode Locking in a Transverse-Discharge Copper-Vapor Laser

Journal of Applied Physics, 1986, Vol. 60, p2717-20, Chil-Min Kim
Tunable Multiline and Single-Line Operations on a Pulsed Transversely Excited Atmospheric Pressure CO_2 Laser by Means of an Inracavity CO_2 Gas Absorber

Applied Optics, 1986, Vol. 25, p2926-8, Chil-Min Kim
Two-Line Operation of a TEA CO_2 Laser with Three Cavity Mirrors

Journal of Applied Physics, 1986, Vol. 59, p3930-2, K. Im
Transversely Excited Atmospheric-Pressure Copper-Vapor Laser

Transactions of the Korean Institute of Electrical Engineers, 1986, Vol. 35, p3-7, Chul-Han Oh
Development of HCP Device for Dye Laser Pumping Source

New Physics (Korean Physical Society), 1987, Vol. 27, p220-6, Byung Heon Cha
On the Development of Copper Vapor Laser

New Physics (Korean Physical Society), 1987, Vol. 27, p227-31, Kyoung-Hwan Oh
Passive Mode-Locking with a CO_2 Saturable Absorber in a Pulsed TEA CO_2 Laser

Review of Scientific Instruments, 1987, Vol. 58, p1185-7, In Heon Hwang
Externally Heated Copper Vapor Laser Using a Carbon Heater

Optics Letters, 1987, Vol. 12, p885-7, N. Sung
Stimulated Emission in Optically Pumped Atomic-Copper Vapor

New Physics (Korean Physical Society), 1988, Vol. 28, p79-84, Joon-Mook Yang
Studies onConstruction and Operational Characteristics of the Nitrogen Laser with Rapid High-Voltage Spark-Gap and a Multiple Parallel Capacitor-Type Blumlein Transmission Line Circuit

New Physics (Korean Physical Society), 1988, Vol. 28, p432-7, Chul-Han Oh
Enhancement of Blue-Green Dye Laser Pumped by Xe-Flashlamp by Means of the Dye Laser Mixture Method

Journal of the Optical Society of America B, 1988, Vol. 5, p1596-99, T.S. Kim
Relation Between Photon Statistics and Pumping Fluctuations in a Dye Laser

New Physics (Korean Physical Society), 1989, Vol. 29, p30-3, Chil-Min Kim
Self-Mode Locking of a Pulsed Mode TEA CO_2 Laser

New Physics (Korean Physical Society), 1989, Vol. 29, p694-700, Doseok Shim
Characteristics of Output Energy from Blumlein N_2 Laser

Transactions of the Korean Institute of Electrical Engineers, 1989, Vol. 38, p765-71, Chul-Han Oh
Enhancement of Blue-Green Dye Laser Energy by an Energy Converter Dye

Korean Applied Physics, 1990, Vol. 3, p50-4, Cha Hwan Oh
Output Characteristics of Surface Corona Discharge Transversely Excited Atmospheric Pressure CO_2 Laser

New Physics (Korean Physical Society), 1990, Vol. 30, p136-44, Seung Ho Kim
Output Characteristics of the Transverese -Discharge Copper-Vapor Laser
New Physics (Korean Physical Society), 1990, Vol. 30, p149-53, Si-Pho Rho
Studies on the Characteristics of a 12.81 mu m Ammonia Laser

New Physics (Korean Physical Society), 1990, Vol. 30, p537-43, Tai Hyun Yoon
Development of a CW Standing-Wave Ti:Al_2O_3 Laser Pumped by Ar+ Laser

IEEE Journal of Quantum Electronics, 1990, Vol. 26, p818-19, J.J. Kim
Transverse-Discharge Copper Vapor Laser at 5 kHz

New Physics (Korean Physical Society), 1990, Vol. 30, p653-6, Sung Mo Nam
Copper Laser-Pumped Rhodamine 590 Dye Laser

Journal of the Korean Physical Society, 1991, Vol. 24, p19-26, Kiegon Im
Metal Vapor Laser Research. I. Kinetic Simulation of High Repetition Rate Copper Vapor Lasers

Journal of the Korean Physical Society, 1991, Vol. 24, p27-33, Jick Hyun Kim
Thermal Effect in a Dye Laser Caused by a Hypocycloidal Pinch (HCP) Plasma Light Source

Applied Optics, 1991, Vol. 30, p629-34, Jong Hoon Yi
Efficient, Spectrally Narrow Pulsed Dye Laser Using a Volume Holographic Transmission Grating

Optical and Quantum Electronics, 1991, Vol. 23, p5469-76, J.J. Kim
Metal Vapor Lasers: A Review of Recent Progress

Journal of the Korean Physical Society, 1992, Vol. 25, p218-21, Hyo Soon Eom
A Study of Energy Transfer Processes for Laser Dye Molecules in Solution Using a Time-Correlated Single Photon Counting System

New Physics (Korean Physical Society), 1992, Vol. 32, p768-74, Goo Dong Park
Intensity Fluctuations in the Output of a Single Mode Dye Laser

Journal of Applied Physics, 1992, Vol. 72, p2556-61, In Heon Hwang
An Analytical Model for Longitudinally Pumped Continuous-Wave Laser

Korean Applied Physics, 1993, Vol. 6, p7-14, Yong-Pyung Kim
Construction of Discharge-Pumped XeCl Laser with Automatic Preionization and its Construction

Journal of the Korean Physical Society, 1993, Vol. 26, p60-3, Jae-Bong Lee
Parametric Behavior of a Trigger-Pulse-Generated TEA CO_2 Laser Output with a Very Small Amount of Ferrocene in the Laser Gas Mixture

Optical Engineering, 1993, Vol. 32, p2837-40, Yun Woo Lee
Half-Aperture Shearing Interferometer for Collimation Testing

Journal of the Optical Society of Korea, 1994, Vol. 5, p80-3, Do-

Kyeong Ko
Construction of the Single Longitudinal Mode Dye Laser Inserted a Wedge Prism

Review of Scientific Instruments, 1994, Vol. 65, p3634-8, Dong Hwan Kim
Controllable Pulse Duration of a XeCl Laser

Japanese Journal of Applied Physics, Part 1, 1994, Vol. 33, p4617-21, Hong Chu
Injection Locking of a Modified-Unstable-Resonator XeCl Laser by using a Line-Narrowed Hemiconfocal Oscillator

Applied Optics, 1995, Vol. 34, p983-7, Do-Kyeong Ko
Accurate Frequency-Tuning Mechanism From a Wedge Prism in a Single-Mode Tunable Laser

Sae Mulli, 1995, Vol. 35, p626-30, Jung Hwan Lee
Generation of Picosecond Laser Pulses by Active Mode-Locking of a Ti:Sapphire Laser

Optics Letters, 1995, Vol. 20, p710-2, Do-Kyeong Ko
Self-Seeding in a Dual-Cavity-Type Ti-Sapphire Laser Oscillator

Note: J.J. Kim is with the Institute for Modern Optics, University of New Mexico. Most of the coathors on his papers are associated with Korean universities or industry.

Area II: Spectroscopic Studies

Journal of the Korean Physical Society, 1989, Vol. 22, p129-35, Jean Bae
Survey of Shape Resonances for Photoionizing Transitions

Korean Applied Physics, 1990, Vol. 3, p60-6, Jang-Soo Shin
Molecular Selective Photodissociation of $^{32}SF_6$ by Pulsed TEA CO_2 Laser

Journal of the Korean Physical Society, 1990, Vol. 23, p191-8, Dalwoo Kim
Laser Intensity and Polarization Effects on the Multiphoton Ionization of Magnesium Atoms

Journal of the Korean Physical Society, 1990, Vol. 23, p532-4, Jung-bog Kim
Effect of Atom Density in Resonant Multiphoton Ionization

Journal of the Korean Physical Society, 1990, Vol. 23, p532-4, Jung-bog Kim
Effects of Atomic Density in Resonant Multiphoton Ionization

Journal of Modern Optics, 1991, Vol. 38, p919-24, Kisik Kim
Operator Analysis of a Two-Level Atom in a Radiation Field

Journal of Modern Optics, 1991, Vol. 38, p1919-26, Changwan Lim
Spectrum of Scattered Light by an Ionized Two-Level Atom

Journal of the Korean Physical Society, 1992, Vol. 25, p196-205, Changhwan Lim
Population Dynamics and Effective Ionization Rate in an Ionized Two-Level Atom Model

New Physics (Korean Physical Society), 1992, Vol. 32, p472-7, A.S. Choe
The Calculation of the Photoionization Cross Sections for the $^1/S(6s/_2)$ and $_{1,3}/P(6s6p)$ States of Yb Using the Local Spin Density Functional Theory

New Physics (Korean Physical Society), 1993, Vol. 33, p24-30, Wang Young Oh
Effect of AC-Stark Shifts on the Selective Resonant Ionizations

New Physics (Korean Physical Society), 1993, Vol. 33, p31-6, Wang Young Oh
Numerical Solutions of Density Matrices for Selective Two-Photon Resonant Thre-Photon Ionization of Atoms

Journal of the Korean Physical Society, 1994, Vol. 27, p396-401, A. S. Choe
Autler-Townes Splitting in an Ionization Scheme Including Two Bound Levels Coherently Coupled by Both Linearly and Circularly Polarized Lasers

New Physics (Korean Physical Society), 1994, Vol. 34, p396-400, Do-Kyeong Ko
Theoretical Analysis of a Noble Frequency Tuning Mechanism by a Wedge Prism in the Littman Type Single Mode Tunable Laser

Journal of the Korean Physical Society, 1994, Vol. 27, p506-12, A.S. Choe
Modulation Effect of a Spatial Beam Profile on Single-Colour Resonant Two-Step Three-Photon Ionization

New Physics (Korean Physical Society), 1994, Vol. 34, p644-52, Jong-Hoon Yi
Effect of the Optical Characteristics of Pumping Laser on the Selective Photoionization of Ytterbium Atoms

New Physics (Korean Physical Society), 1994, Vol. 34, p661-8, Gyu Ug Kim
Multiphoton Ionization Effect on High-Order Harmonic Generation with Subpicosecond Dye Laser Pulses

Laser Physics, 1994, Vol. 4, p1132-8, Jongmin Lee
Selectivity of Photoion Extraction for Isotopes of Rare-Earth Elements

Physical Review A, 1995, Vol. 51, p5-83, A.S. Choe

Laser-Light Propagation in a Medium Consisting of Four-Level Yb Isotopes and Selective Photoionization of ^{168}Yb

Journal of the Korean Physical Society, 1995, Vol. 28, p89-95, A.S. Choe
Population Dynamics for Yb Isotopes in a Thin Medium Interacting with Laser Radiation Resonant with Transitions Lines of ^{168}Yb

Sae Mulli, 1995, p164-74, A.S. Choe
Maxwell-Bloch Equation of Four-Level Atomic Media

Sae Mulli, 1995, p175-83, A.S. Choe
Laser-Light Propagation in a Medium Consisting of Four-Level Yb Isotopes and Selective Photoionization of ^{168}Yb

Chemical Physics Letters, 1995, Vol. 244, p183-7, Wee Kyung Kang
Two-Dimensional Photoelectron Imaging of State-Selected Iodine Atoms by (2+1) Resonance Enhanced Multiphoton Ionization

Journal of the Korean Physical Society, 1995, Vol. 28, p282-8, A.S. Choe
Effect of Laser Pulse-Shape, Bandwidth, and Atomic Doppler-Broadening on Efficient Selective Excitation

Sae Mulli, 1995, Vol. 35, p473-9, A.S. Choe
Effects of Laser Pulse Shape and Bandwidth on Ionization and Population Dynamics Through Double Optical Resonance

Journal of the Korean Physical Society, 1995, Vol. 28, p468-71, A.S. Choe
Dynamic Shift and Population Inversion in Single-Color, Two-Step, Three-Photon Ionization by a Gaussian-Pulse Laser

Physical Review A, 1995, Vol. 51, p3053-7, Jong-Hoon Yi
Autoionization States of the Ytterbium Atom by Three-Photon Polarization Spectrosocpy

Journal of Physics B, 1995, Vol. 28, p3805-20, A.S. Choe
Selective Photoionization of ^{168}Yb in a Three-Level Atomic Medium by the Collinear Propagation of Laser Pulses

Journal of Physics B, 1995, Vol. 28, p3821-9, A.S. Choe
Effects of a Laser Pulse Photoionizing an Effectively Excited Three-Level Atom on the Ion Yield

Physical Review A, 1995, Vol. 52, p382-6, A.S. Choe
Effective Excitation Method of a Three-Level Medium in a Selective Photoionization