PUTCHA VENKATESWARLU
(25 October 1921 – 8 April 1997)

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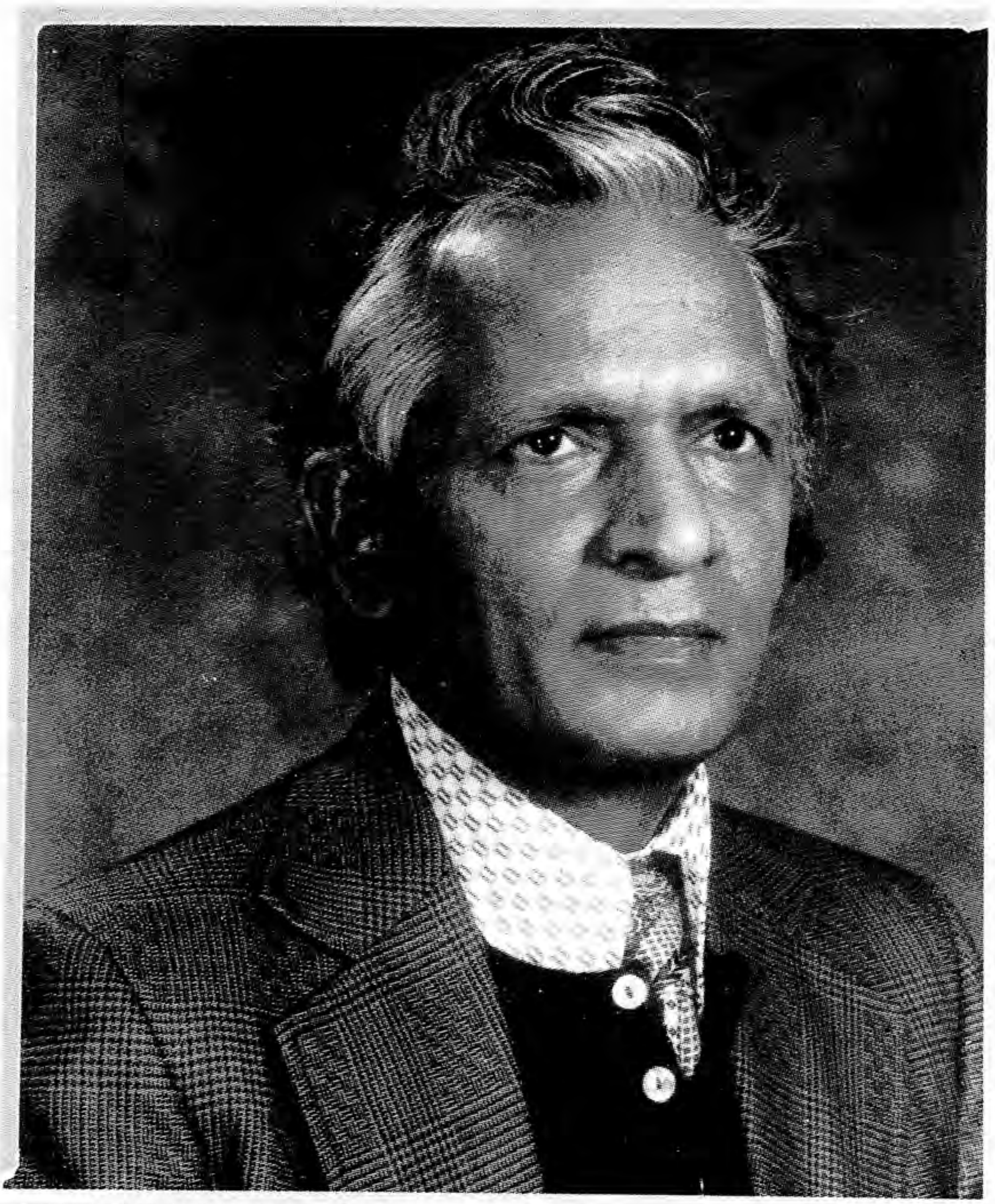

Putcha Venkateswarlu

PUTCHA VENKATESWARLU

(1921-1997)

Elected Fellow 1970

FAMILY BACKGROUND AND EARLY EDUCATION

PUTCHA VENKATESWARLU was born on 25th October 1921 to Putcha Chandramouli Sastri and Kambhampati Bala Tripura Sundari in the village of Dantalur in Guntur District, Andhra Pradesh. He was the youngest of five children and the only son. Many of Venkateswarlu's forefathers were Vedic scholars and this was a source of great pride to him. His mother passed away when he was only ten years old. At a very early age, Venkateswarlu was married to Evani Saraswati. They had one daughter and four sons. Two of the sons are Professors in USA and the other three children head consulting firms in USA. Venkateswarlu's education until B.Sc. was in Guntur. He then joined Banaras Hindu University, and obtained M.Sc. in 1944 and D.Sc. in 1947.

CONTRIBUTIONS TO SCIENCE AND EDUCATION

Professor P Venkateswarlu started his research with (Late) RK Asundi in Banaras Hindu University and obtained the D.Sc. degree in 1947. He published 11 refereed papers including one in *Nature* from his graduate work on the electronic spectra of the halogens, 9 of which are single-author papers. This pattern of him as the single author in publications (nearly half) continued in later years when he worked as post-doctoral associate in several leading laboratories in Europe, USA and Canada. From his early years he was very bold, and took pride that he could take up novel and challenging tasks. An example was his decision to go to Niels Bohr's Laboratory to work in nuclear physics immediately after his graduation from Banaras where he had done traditional molecular spectroscopy using only low resolution prism spectrographs. The two areas had nothing in common, and they were quite different from each other in experimental technique as well as theoretical understanding. Later, he chose wisely the very best schools for his post-doctoral work: the laboratories of Gerhard Herzberg at NRC, Canada and Robert Mulliken at the University of Chicago for optical spectroscopy, Walter Gordy at Duke University for microwave spectroscopy, and Richard Lord at MIT for infrared spectroscopy. The inspiration that he derived from working in these famous laboratories (three of which were headed by Nobel Laureates) may have been the driving force in the relentless and aggressive research that he pursued throughout his life.

TEACHING AND RESEARCH CONTRIBUTIONS

His greatest contribution to the scientific community is the establishment of three excellent schools, one at Aligarh Muslim University, another at Indian Institute of Technology, Kanpur and finally at Alabama Agriculture and Mechanical University, Huntsville. During 1954-1997, he trained well over 50 Ph D students. He continued his passion to engage in new scientific ventures all through his career; not only did he continue in areas of research of his earlier years (optical, infrared, and microwave spectroscopy) but he also initiated studies in totally new areas like nuclear magnetic resonance, electron paramagnetic resonance, solid state spectroscopy, lasers, laser-induced fluorescence spectroscopy, upconversion studies, interferometry, optical phase conjugation, holographic gratings, nonlinear and fibre optics, microspherical lasers, powder lasers and planar wave guides. He published over 200 papers, covering almost all major scientific journals. His pioneering contributions at the three institutions are given below in brief.

He was elected Fellow of the Indian Academy of Sciences and also of the Indian National Science Academy. He was a recipient of the Raman Centenary Award. He was a member of the American Physical Society and Optical Society of America.

(a) Aligarh Muslim University (AMU)

His first academic assignment in India was in Aligarh Muslim University as Reader in 1954. At one time, AMU was a centre of spectroscopic research under Professors R Samuel and RK Asundi. During World War II when Samuel left for Germany and Asundi to Banaras, the laboratory was almost closed and most of the equipment was locked up for 20 years. Soon after joining, Venkateswarlu rejuvenated the field of electronic spectra of diatomic molecules at AMU. Using the old low resolution spectrographs used by Professors Samuel and Asundi in the thirties, he started guiding students on electronic spectra of halogens. It is noteworthy that electronic spectra of halogens, his pet project since his graduate work at Banaras, continued to be of his interest throughout his career extending into the last few years of his life. It is also interesting to note that a major equipment grant of large magnitude was awarded to Venkateswarlu for the first time in the field of spectroscopy by the Council of Scientific and Industrial Research. His first major purchase of equipment was an NMR spectrometer, an area in which he had not done research earlier. He assembled the first microwave spectrometer in India and three Ph D candidates were trained using that set up. Also, vacuum ultra violet spectroscopy was started for the first time in India by Venkateswarlu. A total of 9 graduate students were trained by him at AMU of which 7 became Professors in India, USA or Canada.

(b) Indian Institute of Technology, Kanpur (IITK)
Arawind Parasnis, Formerly Professor of Physics (IITK)

Fortunate for IITK, its first director, (Late) PK Kelkar began taking several non-traditional administrative and academic initiatives to bring a different Indian institution into reality. To achieve this, finding right kind of Faculty was ever his priority. Venkateswarlu, one of the first four to be appointed as Faculty members, assisted Kelkar by taking initiatives and making significant contributions to recruit high caliber Faculty in IITK.

Whereas in 1960 Venkateswarlu was already a leading young researcher, with much achievement abroad and in India, and a bright future ahead, what Kelkar saw in him, in particular, was a willingness to learn and try out new ways for establishing that different academic institution. He also noted in Venkateswarlu an intense commitment to not only research activity but also to taking an institutional approach as a whole. Subsequently, Kelkar found many others, yet Venkateswarlu epitomized the archetype of a leader as well as follower for collective benefit of the institute.

Among the various activities in which an academic person is expected to be involved, research was Venkateswarlu's forte. Within just a few months of his joining IITK, he ordered equipment for his group and encouraged younger colleagues to do the same without waiting for space and laboratory staff. More important, he began scouting for talent in not only physics but also other areas, notably chemistry. He used to participate in the major scientific conferences of India to spot motivated young people who would fit into IITK's philosophy and scheme of things.

Following Kelkar's lead, Venkateswarlu took up the responsibility of arranging colloquia of competent scientists from elsewhere in India, to enable all to see a person in flesh and blood for assessing if he/she would be a good addition to IITK Faculty. It has been an IITK's policy all along that "Interview committees are for endorsing local effort in getting the right people, not for finding them". If one person were to be mentioned who devotedly and consistently made efforts quickly to create research atmosphere in IITK it would be Venkateswarlu. He seemed to be a man in a hurry.

Venkateswarlu's *karma-bhoomi*, of course, was the Department of Physics. During the six years (1961-67) that he was the (first) Head of the Department he did many things, among which the most important was recognizing the potential of lasers. He did not just start research in spectroscopy using lasers; he also motivated colleagues from physics, chemical engineering and electrical engineering to get into laser technology. As part of a total picture, he arranged for a colleague – RR Dasari – to spend two years in MIT laser laboratory. Another colleague – KR Sarma from EE –

spent a year in MIT and, on return, became an asset for teaching and research in optical signal processing.

In the next decade or less, IITK had designed and fabricated laboratory versions of HeNe, Ar^+, N_2, CO_2, and Cu-vapour lasers, some of which were then used to carry out original research. With the involvement of Faculty from the Department of Electrical Engineering, a working system for the transmission of speech over a HeNe beam was demonstrated. He also encouraged research in holography in the Department of Physics, and plans for research in laser materials processing in collaboration with mechanical engineering Faculty. During 1980-81 he was Acting Director of IITK. Actually the seeds of the Centre for Laser Technology were laid then, with MHRD allotting funds for the acquisition of equipment related to research and development in lasers. By the time he retired in 1981 the stage was set for the formation of the Centre. It was established in 1983. It is interesting to note that the younger colleague who had been selected at the same time as he in 1960 was the first Head of the Centre. Over the last two decades the Centre has done much work of research, teaching and training in all fields cognate to lasers: design and fabrication of lasers, spectroscopy, holography, nonlinear optics, plasma diagnostics, fibre optics, metrology, materials making and processing, etc.

An institution in India that caters to both science and engineering has *per force* to face the "dichotomy problem", which was not too serious in IITK, thanks to Kelkar's commitment to both. Venkateswarlu's commitment to science never wavered. At the same time he had the ability to take the engineering colleagues along, at least most of the time, that came handy when he chaired important Senate committees. No individual is free of controversies, nor was Venkateswarlu. Nevertheless they weigh far less than his achievements in IIT Kanpur. Being strong willed he was, a fighter for what he thought was right, and remained a phenomenon to reckon with.

In summary, Venkateswarlu's significant contributions in IITK are development of strong research base in science and engineering, and fostering collaborations among science and engineering Faculty. He supervised 33 Ph D students in the areas of lasers, spectroscopy and optics, and always stood solidly behind the interests of students. In recognition of his contribution, IITK named the library of the Department of Physics as "Putcha Venkateswarlu Physics Library" in May, 2000. One must commend the efforts of Dr KK Sharma, the then head of the department to make this happen.

(c) Alabama Agricultural and Mechanical University

(Ravindra B Lal, University Eminent Scholar and Professor of Physics)

Professor Putcha Venkateswarlu joined Alabama Agricultural and Mechanical University (AAMU) in 1982 as a Professor of Physics. Unfortunately he passed away on August 8, 1997 at the age of 76 after a sudden illness. True to his constant dedication to the department and in general to AAMU, he worked until the last breath of his life. Actually he worked in the department till 6 pm on that day and passed away in the night.

He was instrumental in initiating the experimental optics/laser research at AAMU and obtained his first research grant from US Army Missile Command for Optics/Laser research work. That was the start of Optics/Laser research at AAMU. He was also instrumental in obtaining a grant of $10 Million covering a ten year period from the National Science Foundation for research in Nonlinear Optics and Optical Materials. He was responsible for obtaining a total of 12 research grants from several federal agencies including NSF, DOE, NASA, Air Force and Army Research office. Now AAMU is regarded as one of the leading institutions among Historically Black Colleges and Universities (HBCU) and also one of the few universities offering Ph D in Optics/Lasers in USA. He hired most of the present Faculty members in the Department of Physics at AAMU as postdoctoral associates in his research grants.

He supervised the very first PhD-student of AAMU, Hossein Abdeldayem who was awarded the doctorate degree in 1991. He is now working at NASA/ Goddard Space Flight Centre in Maryland. He supervised many more Ph D and MS students in subsequent years. Between 1991 and 1997, he had supervised 10 Ph D students. Following his tradition, the department has produced a total of 47 doctorates to this date. It is indeed a proud achievement for the AAMU physics department. Several of Venkateswarlu's associates in USA in association with AAMU faculty made preparations for a symposium to honour his achievements for October 1997. In view of his unfortunate sudden death in August of that year, the symposium was held as planned except that it turned out to be in his memory.

In recognition of his outstanding services to the university, AAMU under the leadership of its President Dr John T Gibson approved a permanent grant for an annual memorial lecture series in his memory. The First Memorial Lecture was given in October 1998 by Nobel Laureate Robert Curl of Rice University, subsequent lectures were given by Nobel Laureate William Phillips of National Institute of Standards and Technology (NIST) in 1999, Nobel Laureate Horst Stormer of Columbia University in 2000, Nobel Laureate Nicolaas Bloembergen in 2001, Nobel Laureate Douglas Osheroff in 2002, Nobel Laureate Eric Cornell in 2003, and Nobel Laureate Alan Heeger will give the seventh lecture on October 1, 2004. The University looks forward to continuing this series of lectures by Nobel Laureates in the years to come. Alabama A&M University remembers Dr P Venkateswarlu as the "Father of Experimental Optics Research at AAMU".

RESEARCH CONTRIBUTIONS

(a) Electronic Spectroscopy
(RD Verma)

In the nineteen thirties RS Mulliken proposed a "Molecular Orbital Theory", which later earned him the Nobel Prize. Using this theory one could predict electronic states of molecules. Mulliken extended his theory and predicted ground and excited electronic states of diatomic molecules. The nineteen forties and fifties saw immense growth in the field of molecular spectroscopy. Young Putcha Venkateswarlu belonged to this era of spectroscopy. He started his postgraduate research under the well-known molecular spectroscopist, RK Asundi at Banares Hindu University.

Under the guidance of Asundi, Venkateswarlu began research on complex spectra of halogen molecules. Mulliken had predicted many electronic states of halogen diatomic molecules back in the thirties. It remained to interpret observed halogen spectra in terms of electronic transitions. Venkateswarlu took this challenge and published a series of papers during his graduate research, giving a satisfactory interpretation of the observed fluctuation and continuous bands of halogens as the emission from the excited electronic states to the lower quasi-bound states resulting from the combination of ground atomic states of halogens consistent with the molecular orbital theory. This was a very important breakthrough at a time when the molecular orbital theory was going through the scrutiny of experimental data.

His interest in halogen spectra continued throughout his research career. He trained several postgraduate students pursuing further research in the electronic spectra of halogens. They extended the knowledge of electronic spectra of diatomic halogen molecules, I_2, Br_2, Cl_2, IBr and ICl and many other diatomic molecules containing a halogen atom. He personally took electronic spectra of iodine and bromine diatomic molecules in the vacuum region in the laboratory of G Herzberg. The complex absorption bands of the first two of these molecules, which were obtained at high resolution for the first time, posed a challenge for interpretation in terms of the electronic states predicted by Mulliken. Venkateswarlu succeeded in classifying all the bands as electronic transitions from excited states to the ground states of I_2 and Br_2 consistent with the molecular orbital theory.

Besides his important contribution to diatomic halogen molecules, Venkateswarlu is credited with discovering the electronic spectra of the triatomic molecule CF_2. Later he guided one of his students to discover the spectrum of similar molecule SiF_2.

(b) **Microwave Spectroscopy**
(KVLN Sastry)

Venkateswarlu started research in microwave spectroscopy at Duke University. He spent two years there (1953-1954). At that time microwave spectroscopy of gases was at the early stage of development. Gordy and his colleagues at Duke University were some of the pioneers in the development of microwave spectroscopy. Venkateswarlu and coworkers studied the microwave spectrum of methyl alcohol. Methyl alcohol is a slightly asymmetric molecule exhibiting hindered internal rotations. One of the fundamental vibrations of methyl alcohol is associated with the torsional motion of the hydroxyl group with respect to the methyl group. This motion, called hindered rotation, complicates the rotational microwave spectrum of the molecule. Early theoretical investigations were carried out by Dennison and his coworkers. Soon after their paper was published in 1953, Venkateswarlu and coworkers investigated the microwave spectrum of methyl alcohol. They published two papers, which are the earliest experimental studies of the rotational spectrum of this molecule. The importance of the microwave and millimeter wave spectrum of this molecule could be recognized when microwave astronomers observed its microwave emission lines in dense molecular clouds. Since then this molecule has been observed in several sources in the Orion Molecular Cloud in significant abundance. The prediction and laboratory observation of its rotational spectrum is very important to microwave astronomers for identifying the molecule. Thus Venkateswarlu and his coworkers were the first to study the microwave spectrum of this astrophysically significant molecule.

At Duke University, Mizushima and Venkateswarlu explored the possible microwave absorption in molecules belonging to the point group V_d and T_d. These molecules have no permanent dipole moment in their ground state and, therefore, no rotational absorption is possible in its ground state. Mizushima and Venkateswarlu showed that the pure rotational absorption is possible if these molecules are in excited degenerate vibrational states. They predicted frequencies of absorption lines for several transitions of allene molecule. Similar forbidden transitions were observed much later in methane by Ozier and coworkers in 1973. These important scientific investigations are testimony to Venkateswarlu's intuition and scientific insight.

Venkateswarlu returned to India in 1954. Soon after, he joined the faculty of Aligarh Muslim University. Within a year he was awarded a grant by the University Grants Commission to establish a Microwave Spectroscopy Laboratory. Those were the early days of technological and industrial development in India. All the necessary electronic components to build a microwave spectrometer had to be imported. Unlike their optical and infra-red counterparts, microwave spectrometers were not available commercially. They had to be assembled from individual components. Under those circumstances Venkateswarlu, along with his graduate students, proceeded to build a Microwave Spectroscopy Laboratory. They got most of the electronics from Duke University. Some of the waveguide components were locally fabricated. Within a year they built the first working Microwave Spectroscopy Laboratory in India. That was a real accomplishment in those days. It was the foresight and perseverance of Venkateswarlu that made it possible. At Aligarh Muslim University Venkateswarlu and his group investigated microwave spectra of several important molecules such as methyl alcohol and methyl amine.

(c) Magnetic Resonance

i. Electron Paramagnetic Resonance
(MD Sastry and PA Narayana)

Early nineteen sixties had witnessed a significant growth in the applications of both nuclear and spectroscopic techniques to condensed matter research. These techniques essentially used hyperfine interactions and the effects of electric field gradients on electronic levels to obtain precise information about the local structure and bonding around the probe ion in solids. These investigations also offered new information on electronic spectra of 3d and 4f ions due to the possibility of overcoming the Laport forbiddenness in condensed matter. Venkateswarlu was very quick to realize the potential and importance of these emerging areas and in 1962 formulated a comprehensive programme on crystal spectra and electron paramagnetic resonance (EPR) studies of 3d and 4f ions in solids down to cryogenic temperatures, at IIT Kanpur.

ii. Areas of Investigation

The work of Venkateswarlu and his colleagues has revealed significant new information on the structure and bonding of a number of paramagnetic species in single crystals over a range of solids: purely ionic crystals like NaCl and KCl, hydrogen-bonded ferroelectrics like KDP, a number of sulphates and selenates with and without hydrogen-bonding networks, molecular solids such as alums, ammonium sulphates and halides and a number of transition metal and alkaline earth perchlorates. Besides obtaining structural information of paramagnetic complexes, Venkateswarlu and his students were among the first to use EPR technique to understand the critical phenomena in solids using paramagnetic probe ions. He and his students investigated structural phase transitions in hydrogen-bonded KDP, molecular dynamics close to lambda transition in ammonium halides, and discovered new transitions in alkali nitrates and perchlorates of transition metals and alkaline earths.

iii. New Methodologies

A significant part of the EPR investigations of ions with spin equal to or greater than unity deals with obtaining quantitative information about the zero field splitting and crystal field parameter. With a view to obtaining this information directly, Venkateswarlu and colleagues designed and built a zero-field EPR spectrometer, which was essentially a microwave spectrometer for measuring the absorption of solid samples in GHz range. The spectrometer was the first of its type in India, and could be operated in both X and K bands. Using this spectrometer Venkateswarlu and his colleagues obtained information about the zero field splitting of divalent Mn and trivalent Fe in ammonium chloride. It was an important contribution as that information was not easily obtainable by EPR due to large zero-field splitting.

iv. EPR of NLO Materials

Venkateswarlu gainfully used the insight he obtained in the structural properties of point defects in solids even after shifting his main activity to non-linear optics and holography. He established an EPR laboratory with facilities for photo-EPR studies at Alabama A & M University, and integrated EPR research into the mechanistic investigations of holography in photo refractive systems like $BaTiO_3$, $LiNbO_3$ and Bismuth Silicon Oxide. Using photo-EPR, he and his colleagues obtained direct experimental evidence to show that photo-induced charge transfer from Fe^{3+} impurities played a major role in the grating formation in crystals like $BaTiO_3$. Based on this work, they proposed a new model for grating formation in photorefractive $BaTiO_3$ and other piezoelectric crystals.

v. Nuclear Magnetic Resonance (NMR)

Venkateswarlu established a state-of-the-art research facility in NMR at Aligarh Muslim University, the first such facility in an Indian university. Later on he also established similar facilities at IIT Kanpur.

He and his students published several papers on a range of topics, obtaining nuclear magnetic resonances (NMR) of H^1, F^{19}, Cl^{35} and C^{13} in molecules of interest. Specifically, NMR spectra of four-spin systems were studied extensively. These include the H^1 and F^{19} resonance spectra of l-fluoro, 2, 4-dinitrobenzene, para-disubstituted benzenes, and α, β, and γ picolines. H^1 and F^{19} NMR spectra were also studied in fluorobenzenes and para-substituted fluoreobenzenes. Other studies include observations of Cl^{35} resonances in alkali chlorides.

In collaboration with CNR Rao's group, they investigated the hydrogen bonding phenomena in several molecules including thiobenzoid acid, phenol, aniline thiophenol, ethanol and 2, 2, 2-trifluoroethanol.

(c) Solid State Spectroscopy
(UV Kumar and BR Reddy)

To tread the beaten track was never the attitude of Venkateswarlu. He was never satisfied with continuing to do the same thing. So when he started the experimental research programme in IIT Kanpur in 1964, he did not limit himself to the molecular spectroscopy he had worked for so long in. He laid plans for major studies in solid state spectroscopy as well, and included a state-of-the-art Varian EPR machine and a Cary 14 Optical spectrometer in the plans for the department. The work done in EPR of transitional metal ions in single crystals is discussed elsewhere in this article. Optical spectroscopy of these ions in the solid state was a natural extension of his interest and much work was done in that field.

The electronic absorption work done on $RbMnF_3$ has led to a determination of the spin-orbit coupling in the excited state of Mn^{2+} for the first time, besides giving a complete analysis of the spectrum in terms of crystal field and Racah parameters. This was published in Physical Review Letters. Venkateswarlu and his students also investigated the electronic absorption spectra of divalent Co and Ni in ammonium chloride single crystals in both ordered and disordered phases of the crystal to elucidate the effects of lambda transition on the electronic sites of the dopant ions.

The period from 1973 saw yet another shift in his interests to study rare earth ions in hosts like lanthanum fluoride, calcium fluoride and other crystals. A substantial amount of work was done in this field with increasing sophistication over a period of about twelve years. The ions studied included Nd^{3+}, Dy^{3+}, Eu^{3+} and Pr^{3+}. It was a period of great activity and excitement with several graduate students working on related projects and uncovering interesting aspects of these spectra. The ions were studied initially by photographing their absorption spectra, and the fluorescence excited by a home-made nitrogen laser. A spectrograph was later converted in the laboratory into a recording spectrophotometer and was used to record the fluorescence excited by a commercial CW argon ion laser. The fluorescence was recorded by exciting the crystals using polarized light along several axes, and over a wide range of sample temperatures 77K and above.

The steady state spectra were used principally to understand the energy level structures and site symmetry identification. They also revealed the presence of several active sites in calcium fluoride. Many interesting phenomena like self-absorption, anti-Stokes fluorescence subsequent to sequential two photon absorption, and ion pair exchange were identified from the spectra of these materials.

Time dependence studies were made initially using the home-made nitrogen laser and photographing the decay curves from a storage oscilloscope. Crude as this technique was, the accuracy of lifetime measurement was adequate to identify the excitation and fluorescence pathways in many cases.

The next phase of the study used a commercial tunable pulsed dye laser as the excitation source. This enabled elegant site selective excitation rather than 'brute force' excitation with the nitrogen laser. By then a box car averager built by the ACES activity of IITK also became available. This superb averager allowed recording the decay profiles with exquisite detail and accuracy; the results obtained were more accurate than those obtained with a CRO earlier. This work provided a wealth of data on radiative transition rates, ion pair relaxation processes, and upconversion phenomena. These results were also useful in site-selective spectroscopy investigations.

In summary, the optical spectroscopy work at IIT Kanpur was aimed at characterizing the rare-earth ion doped fluoride crystals for luminescence studies. The work included absorption, laser induced fluorescence and lifetime measurements. Venkateswarlu had a long range vision also; for example, the upconversion spectroscopy work done at IIT Kanpur was of current interest at that time. Based on the energy upconversion spectroscopy work done at IIT Kanpur, IBM scientists later developed a violet upconversion laser using LaF_3:Nd^{3+}. Afterwards there was a surge in upconversion spectroscopy/laser work for the next fifteen years.

So he continued the upconversion spectroscopy work at Alabama A&M University. Experimental research in optical physics there was started by him. He was instrumental in attracting significant research funding from several government agencies. He carried out experimental work in optogalvanic spectroscopy, photoacoustic spectroscopy, interferometry, nonlinear spectroscopy of organic media, nonlinear optics of solids, fiber optics and optical spectra of crystals. In Alabama the rare-earth spectroscopy work was centered on Er^{3+}, Ho^{3+}, Nd^{3+} etc, doped fluorides, garnets and glasses. For a long time, oxide glasses were not popular candidates for upconversion work because of their large phonon frequencies. So the higher radiating levels were quenched by multiphonon relaxation. However, Er^{3+}-doped multielement oxide glass (containing tellurium oxide) made at AAMU exhibited bright green upconversion under near-infrared excitation. At the same time similar work was done in many other laboratories. Nowadays rare earth ion doped telluride fibres are available in the market (made in Japan). That shows the importance of the work done at AAMU; these publications were cited often in the literature. Further activity at AAMU was centered around near-infrared to visible upconversion phenomena. Site-selective upconversion spectroscopy of Ho^{3+}-doped CaF_2 gave interesting results.

(e) NonLinear Optics
(A Sharma)

Venkateswarlu joined the Physics Department at Alabama A&M University (AAMU) in 1982. During his tenure of fifteen years till his death in 1997, he made important contributions to several areas in optics. These contributions are summarized here under the following five areas: (1) Spectroscopy and Upconversion Studies, (2) Interferometry, (3) Optical Phase Conjugation and Holographic Gratings, (4) Nonlinear and Fibre Optics, and (5) Microspherical Lasers, Powder Lasers and Planar Waveguides.

i. Interferometry

This area of research was initiated under Venkateswarlu with initial funding from NASA's Marshall Space Flight Centre in Huntsville. Several interferometric techniques were developed to test the surface quality of optical components like lenses and mirror flats. A Twyman-Green interferometer was developed for testing spherical surfaces and lenses and for measuring refractive indices of liquid and solid media. A wedged plate interferometer was used to measure birefringence of optical materials and for determining the refractive index of lenses. A non-contact profilometer was developed for measuring surface roughness and for correction of tilts in optical samples. Laser beam collimation techniques were developed using a phase-conjugate Twyman-Green interferometer and a Talbot interferometer.

ii. Optical Phase Conjugation and Holographic Gratings

This research was started early and continued till the very end of Venkateswalu's tenure at AAMU. Several of the early studies involved volume holographic gratings and optical phase conjugation in $BaTiO_3$ crystal. Beam couplings and phase conjugate effects in reflection and transmission; beam fanning in counter propagating beams, optical bistability, self-pulsations as well as energy-transfer and phase-shift measurement were demonstrated in this crystal. External seeding in double phase-conjugate mirror was investigated as well as phase-conjugate studies and image-processing by holographic gratings in organic dyes doped in boric-acid glasses. Reflection holographic gratings in $Bi_{12}TiO_{20}$ were investigated for real time interferometry while $Y_3Sc_2Ga_3O_{12}$ laser crystal was investigated for excitation diffusion using transient light-induced grating. Light-induced grating was studied for energy migration in Er, Tm, and Ho doped YSGG laser crystals. Extensive use of EPR spectrometer was made in the investigation of grating formation in photorefractive materials. An example of this is photoinduced charge transfer from Fe^{3+} in BSO under helium-neon laser illumination. Optical phase-conjugate studies were also performed in dye doped boric acid and polycarbonate hosts. Third order susceptibility measurements were performed.

iii. Nonlinear and Fiber-Optics

Research in these areas started with funding of a National Science Foundation Centre for Nonlinear Optics and Materials. Over the ten-year duration of the Centre during 1988-1998, AAMU Optics Laboratories acquired state-of-the-art laser systems and related instrumentation for optics and materials science research. Venkateswarlu was the director of this Centre for a part of its duration. Nonlinear effects were investigated in several systems including dye-doped glasses and in liquid media. Transient multiple diffraction rings due to third order nonlinear susceptibility were investigated in Chinese tea using an ultrafast laser. Four-wave mixing and stimulated Raman scattering were investigated in single-mode and few-mode optical fibres. Organic materials are particularly interesting as nonlinear materials since they can be molecularly engineered to give very large nonlinearities. A dark-line spectroscopic technique was developed to characterise nonlinear optical properties of thin organic films. Picosecond lasers were used to investigate organic films for transient nonlinear effects. Nonlinear properties of phthalocyanine doped polymeric films were investigated using degenerate four wave mixing. A Z-scan technique was developed for investigating third-order nonlinear effects in thin films. Venkateswarlu guided three PhD students whose research focused on nonlinear optics.

iv. Microspherical Lasers, Powder Lasers and Planar Waveguides

These areas of research concerned Venkateswarlu during the last few years of life. In research funded by NASA, polystyrene microspheres doped with various laser dyes showed morphology-dependent resonance (MDR) in fluorescence spectra, which is characteristic of stimulated emission or lasing. These resonances can be used to characterise the morphology of the microspheres fabricated under microgravity conditions in space. Short pulse stimulated emission in powders of several laser crystals including $NdAl_3(BO_3)_4$, $NdSc_3(BO_3)_4$, and $NdSr_5(PO_4)_3F$ was observed. Several planar waveguides were fabricated out of inorganic crystals like $LiNbO_3$ and organic materials including polymeric films doped with phthalocyanines for their nonlinear characteristics. Among other studies these waveguides were used for chemical sensing.

ON A PERSONAL NOTE

No article on Venkateswarlu would be complete without a mention of his unique personality. He was strong willed, and was a phenomenon to reckon with in getting things done, but was a very kind person and exhibited no animosity to people, even those who differed from him or opposed his point of view. An example of his generosity is that he welcomed all researchers who expressed sincere interest into his group independent of their previous achievements. He worked hard and demanded everyone to do the same. He motivated and built confidence and brought out the best from everyone who worked with him. As testimony to his mentoring, nearly half of his 51 PhD students became professors in universities in India, USA and Canada. Several others became group leaders in national laboratories or in industry. A unique quality of his was treating students as members of an extended family by maintaining strong bonds with their families and constantly enquiring about their welfare. Equally important to him was maintaining close contact with his native village, looking after his agricultural lands in the summer, even taking students to his village and working on their theses there. He continued his association with the village till his final years and his desire was to go back to his roots after retirement from USA, which was one more reason why he retained Indian citizenship.

On a personal level, I am greatly indebted to Venkateswarlu for his continuous guidance and advice all through my career spanning more than two decades of direct association and pursuing collaborative research. During the last two decades, though separated and both working at different places, I had the fortune of his continued advice and friendship. I am also equally indebted to Mrs Saraswati who was always very kind and treated me as one of her family members.

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ANNEXURE I

Names of candidates who have completed their PhD work under the supervision of Putcha Venkateswarlu. The addresses listed here correspond to either their address prior to their retirement or their last known address.

NAME	Title of thesis	Address
1. Ram Din Verma	Molecular spectra of halogens in the presence of Argon	Professor of Physics University of New Brunswick, Fredericton N B Canada
2. BN Khanna	The Emission Spectra of Chlorine, BiCl and BiBr Molecules	Professor, Department of Physics, A M U, Aligarh
3. TS Jaseja	The Microwave Spectra of CH_3CN and IBr molecules	Professor of Physics, M D University, Rohtak
4. KVLN Sastry	The Microwave Spectra of Methylamine and Methylalcohol Molecules	Professor of Physics, University of New Brunswick, Fredericton N B, Canada
5. BD Nageswara Rao	High Resolution Nuclear Magnetic Resonance Spectroscopy	Professor, Department of Physics, IUPUI Indianapolis, Indiana 46205
6. D Ramachandra Rao	Electronic Spectra of SiF and SiF_2 Molecules	Associate Director, Spectro-scopy Lab, MIT, Cambridge, MA
7. YV Rao	Molecular Spectra of Halogens in the Vacuum Ultraviolet	Principal, ANR College, Gudivada Andhra Pradesh
8. PRK Sarma	Electronic Spectra of SiCl, SnCl and SnBr Molecules	Manager, Hindustan Photo Film Co, Ltd Ootacamund, Madras
9. A Sundararajan	Microwave Spectra of Certain Polyatomic Molecules	Professor in Physics, IIT Bombay
10. G Aruldas	Nuclear Magnetic Resonance Spectra of Some Substituted Benzenes	Professor, Physics Department, Kerala University, Trivandrum
11. GC Upreti	Electron Paramagnetic Resonance of Gd^{3+} in Single Crystals of Some Hydrated Rare Earth Salts	Professor in Physics, Physics, IIT, Kanpur (deceased)
12. KN Srivastava	Electron Paramagnetic Resonance of Mn^{2+} in Some Single Crystals	Professor in Phyics, Univ of Hyderabad, Hyderabad, India
13. AK Mehra	Optical Absorption Studies of Mn^{2+} in Crystals	Professor, Physics Department, Univ of Wisconsin, Green Bay, Wisconsin
14. S Mohanty	Nuclear Magnetic Resonance Spectra of Some Fluorobenzenes	Professor in Physics, Utkal University, Bhubaneswar, India
15. GB Singh	EPR of Gd^{3} in Single Crystal of Some Hydrated Rare Earth Nitrates and Chlorides	Professor, Department of Physics, Agricultural University, Ludhiana, Punjab, India

16. MD Sastry	EPR Studies in Some Doped Ammonium Halides	Scientist, Radio Chemistry Division, BARC Bombay, India
17. BVR Chowdari	EPR Studies of $Mn^{2+}$and Fe^{3+} in Certain Single Crystals	Associate Professor in Physics, National University, Singapore
18. PA Narayana	Optical Absorption of Ni^{2+} and Co^{2+} in Single Crystals	Professor of Radiology, Texas Medical Centre, Houston, Texas
19. KV Subba Rao	EPR of VO^{2+} and Mn^{2+} in Single Crystals	Bell Laboratories, Holmdel, NJ
20. AV Jagannadham	Electron Paramagnetic Resonance Mn^{2+} and VO^{2+} in Single Crystals	Vice-Principal, PG Head Physics, MSJ Government College, Bharatpur 321001
21. SD Pandey	Electron Paramagnetic Resonance of Eu^{2+}, Mn^{2+} and VO^{2+} in Single Crystals	Professor of Physics PPN College, Kanpur, India
22. SK Banerjee	Electron Paramagnetic Resonance of Cu^{2+} and VO^{2+} in Single Crystal	Reader in Physics University of Jodhpur Rajasthan, India
23. AL Verma	Vibrational Spectra of Certain Aliphatic Amines and Rotational Isomerism	Professor in Physics, NE Hill University, Shillong Meghalaya, India
24. Kamal Kumar	Vibrational Spectra of Geometry of Certain Aliphatic Molecules	Professor in Physics, NE Hill University, Shillong Meghalaya, India
25. JP Srivastava	Optical Absorption of MN^{2+}, Co^{2+} and Ni^{2+} in Certain Single Crystals	Professor in Physics, Aligarh Muslim University, Aligarh
26. PP Salhotra	Phase Transformation in Rubidium Nitrate and its Solid Solutions with Cesium and Potassium Nitrates	Professor, Physics Dept Government Science College, Datia, MP
27. VK Sharrma	EPR of Gd^{3+} in Single Crystals	Institute for Automatik der ETH, Physikstrasse 3, 8006, Zurich, Switzerland
28. UV Kumar	Spectroscopic Investigations of Eu^{3+} and Nd^{3+} in Certain Single Crystals	President, Rudolph Instruments, Fairfield, NJ
29. VK Kaushik	Centrifugal Distortion in Asymmetric Top Molecules	Professor, Physics Dept Viswabharati, Shantiniketan, West Bengal
30. MS Ansari	Vibrational and Rotational Analysis of Electronic Transitions of Some Diatomic Molecules	Professor in Physics Regional Engrg College Naseem Bagh, Srinagar Kashmir
31. VK Jain	Electronic Paramagnetic Resonance Studies of MN^{2+} and VO^{2+} in Single Crystals	Reader, Physics Dept, M D University Rohtak
32. R Dayal	Electronic Paramagnetic Resonance and Structural Phase Transition Studies of MN^{2+} Doped Single Crystals of Some Metal Perchlorate Hexahydrates	Professor, Physics Dept, Aligarh Muslim University, Aligarh
33. H Jagannath	Relaxation Studies in Nd^{3+} and Dy^{3+} Doped Single Crystals using Nitrogen Laser	Member, Technical Staff, AT&T, Alpharetta, GA
34. AA Ansari	Electronic Paramagnetic Resonance Studies of Mn^{2+}, VO^{2+} and Cr^{3+} in Single Crystals	Professor in Physics Z H College of Engrg, Aligarh Muslim University, Aligarh
35. A Sivaram	Laser Excited Fluorescence and Lifetime Studies of Dy^{3+} and UO^{2+} in Single Crystals	Staff Scientist, G B Tech, Inc, works at NASA Johnson Space Centre, Houston, TX

36. D Narayana Rao	Spectroscopic Investigation of Some Rare Earth Ions in Fluoride Crystals	Professor of Physics University of Hyderabad, Hyderabad
37. VN Sarma	Resonance Series and Absorption of Br_2 in the V U V Region and RKR Potentials and Long Range Analyses of Br_2, Cl_2 and I_2	Sun Micro Systems, San Jose, CA
38. B Rami Reddy	Laser Induced Fluorescence and Energy Transfer in Certain Rare Earth Ions Doped in LaF_3 Single Crystals	Prof Department of Physics Alabama A&M University Normal (Huntsville), AL
39. S K Basu	High Resolution Studies of N_2 Second Positive System under Lasing and Non-Lasing Conditions of Cl_2 in Vacuum Violet	Scientific Officer Physical Research Lab Ahmedabad, India
40. T Pramila	Vibrational and Rotational Analysis of Emission Systems in the Region (3460-3015A) and (4320-4000A), and Ar^+ Laser Excited Fluorescence Studies of I_2	Scientist Dept of Physics IIT Kanpur, India
41. D Kanjilal	Vibrational, Rotational and Laser Induced Fluorescence Studies of Br_2	Scientist Department of Physics J N University New Delhi, India
42. H Abdeldayem	Nonlinear Optics in Organic Materials	NASA Goddard, VA
43. M Dokhanian	Applications of Phase Conjugation in $BaTiO_3$ to Beam Couplings, Resonators, Bistability and Interferometer	Asst Professor Dept of Physics Alabama A & M University Normal, AL 35762
44. M Curley	Novel lasing materials and novel lasing configurations	Research Associate Dept of Physics Alabama A & M University Normal, AL 35762
45. M Moghbel	Optical Phase Conjugation Beam Couplings and EPR Investigations of Photorefractive Crystals with Color Centres	Works in Iran
46. SK Nash Stevenson	Energy Upconversion Processes in Rare Earth Ion Doped LaF_3 and CaF_2 Crystals	Staff Scientist NASA Marshall Space Flight Centre, Huntsville, AL
47. MC Henry	Nonlinear Wave Mixing in Organic Dyes	St Croix, U S Virgin Islands
48. WG Bryant	Studies of the Nonlinear Optical Properties of Organic Materials Used in Guest-Host and Thin Film Media	Birmingham, AL
49. BS Chen	Dynamic Photorefractive Interferometry in Optical Signal Processing	Industry, Chicago
50. M Madhi	Study of energy transfer and upconversion processes in laser crystals	Entrepreneur, Huntsville, AL
51. A Wilkoz	Studies of nonlinear optical properties of organic thin films and waveguides	Northorp Grumman, Chicago