NINTH ALL-UNION SYMPOSIUM ON HIGH-AND ULTRAHIGH-RESOLUTION SPECTROSCOPY

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The 9th All-Union symposium on high-ultrahigh-resolution spectroscopy was held in Yakutsk from June 28 to July 3, 1989. The symposium was organized by the Scientific Council of the Academy of Sciences of the USSR on the problem of coherent and nonlinear optics, the Scientific Council of the Siberian Branch of the Academy of Sciences of the USSR on Spectroscopy, and the Institute of Atmospheric Optics of the Siberian Branch of the Academy of Sciences of the USSR. One hundred eighty scientists, representing Moscow, Leningrad, Tomsk, Novosibirsk, Gor'kii, Minsk, Saratov, and a number of other scientific centers where work on high- and ultrahigh-resolution molecular spectrometry of gaseous media is being conducted, participated in the symposium.

One hundred one reports, including 14 plenary, 35 oral, and 52 poster reports, were presented at the symposium. During the symposium a regular session of the working group on atmospheric spectroscopy under the All-Union Commission on Radiation and a round-table discussion of quantum phenomena in optics and their experimental observation were held.

The symposium consisted of five sections:

1. Theory of the spectra of molecules and radicals;
2. Experimental high-resolution study of the spectra of molecules in the gas phase;
3. Spectroscopy of intermolecular interactions in a gaseous medium;
4. Spectroscopy of intensity fluctuations, and,
5. Techniques of high-resolution spectroscopy.

Three plenary reports were made on the opening day of the symposium. In his review report "Laser ecological monitoring based on spectroscopic effects" the director of the Institute of Atmospheric Optics, Academician V.E. Zuev, reported on work at the Institute on the development of a new generation of apparatus for studying the gas composition of the atmosphere, including monitoring of anthropogenic pollutants. The development of this apparatus is based on the results of complex high-resolution studies of the absorption and Raman scattering spectra of molecules and the development of new methods for synthesizing laser frequencies in the visible and IR ranges of the spectrum using nonlinear crystals. The results of tests of the technique of remote and local gas analysis under laboratory and natural conditions were presented.

Studies in which the methods of diode laser spectroscopy are most useful were analyzed in a plenary report by Doctor of Physical and Mathematical Sciences, A.I. Nadezhdinskii (Institute of General Physics of the Academy of Sciences of the USSR (IGP)), "Diode laser spectroscopy. Current trends". The main directions in these studies are: high-precision measurements of the parameters of spectral lines, diagnostics of fast processes, and high-sensitivity spectral analysis. The fundamental methodical achievements were pointed out: recording of line shape parameters with an accuracy of better than 1%, achievement of a limiting sensitivity of 10^{-9}% of the volume concentration in detecting trace impurities, and high degree of automation of the measurements.

In the third plenary report Doctor of Physical and Mathematical Sciences S.D. Tvorogov (Institute of Atmospheric Optics of the Siberian Branch of the Academy of Sciences of the USSR (IAO)) and A.V. En'shin (Tomsk State University (TSU)) presented interesting theoretical and experimental results on the excitation of high rotational states of molecules by a biharmonic light field, resulting in the appearance of scattered pencil radiation with a large number of frequencies in the spectrum. In the section "Theory of the spectra of molecules and radicals" three plenary reports (B.I. Zhilinskii, Moscow State University (MSU); V.G. Tyuterev (IAO); and, A.V. Burenin, Institute of Applied Physics of the Academy of Sciences of the USSR (IAP)), eight oral and fifteen poster reports were presented. Analysis of their content shows that since the last symposium (1987) significant progress has been made in the following directions:

– development of new methods, including methods in the theory of symmetry, for describing critical phenomena of the phase-transitions type in the structure of the vibrational-rotational states of polyatomic molecules (MSU, Institute of Spectroscopy of the Academy of Sciences of the USSR (IS), IAO); these methods have been used successfully to analyze the qualitative features of the rotational structure of doubly and triply degenerate vibrations;

– development of theoretical models for solving inverse spectroscopy problems of the determination of

line centers and line intensities in the presence of degeneracy and random resonances, based on a theory of the reduction of the effective Hamiltonians and dipole moments and the application of these methods to high-precision description of the spectra of spherical and symmetrical top molecules as well as linear molecules (IAO, MSU, Khar'kov State University, IS, IGP);

– improvement of theoretical methods for calculating the collisional half-widths and shifts of the centers of rotational-vibrational lines due to foreign-gas pressure, which take into account systematically the intramolecular interactions of different types (IAO, TSU, Tomsk Polytechnical Institute, IAP, Leningrad State University (LSU);

– development of a theory of nonrigid molecules using methods of nonpolynomial generating functions, Pade approximants, and optimized rational approximants for the effective rotational Hamiltonians and asymptotically correct methods of perturbation theory for diatomic molecules; development of methods for calculating the anomalous behavior of the spectroscopic parameters and reconstruction of the potential functions of molecules with centers of inversion, and reconstruction of the spectroscopy constants for molecules with internal rotation (IAO, IAP, Institute of the Academy of Sciences of the Azerbaidzhan SSR); and,

– improvement of the software and computational methods used in applied studies in the creation of a data base on high-resolution spectroscopy of atmospheric gases and gaseous pollutants in the atmosphere, radiation characteristics of electronic-vibrational transitions in diatomic molecules, and estimates of the spectral behavior of the absorption by high-temperature gases (IAO, MSU, LSU).

The section "Experimental high-resolution studies of the spectra of molecules in the gas phase" included three plenary reports: on the results of complex studies of the shifts and pressure broadening of the absorption lines of H_2O in air (Yu.N. Ponomarev et al., IAO) on the investigation of the absorption spectra of isitopes of H_2O in the photographic IR range (L.N. Sinitsa et al., IAO); and, on the absorption and fluorescence spectra of H_2O vapor in the UV range (V.M. Klimkin et al., IAO). Eleven oral and ten poster reports were also presented.

The main results presented concerned the development of high-resolution laser spectrometers and the performance of high-volume studies of the absorption, Raman scattering, and fluorescence spectra of molecules of atmospheric gases and gaseous pollutants in the atmosphere. Analysis of the reports presented and discussed in this section showed that scientific centers in which experimental studies on high- and ultrahigh- resolution spectroscopy meeting modern standards now exist in the USSR (IAO, IGP, IS, IAP, MSU, Latvian State University). The investigations being conducted at these centers are based on a combination of highly sensitive methods of laser spectroscopy with modern methods for interpreting vibrational-rotational spectra. High-volume high-resolution measurements of spectra have made it possible to develop and improve substantially the theoretical methods for analyzing spectra with an accuracy comparable to the experimental accuracy.

Automated laser spectrometers with a resolution of ~ 10^{-3}–10^{-4} cm^{-1} and laser gas analyzers, making it possible to study and monitor the content of gaseous pollutants in air at the level of the limiting admissible concentration both in local volumes and on atmospheric paths, have been developed in the USSR (IGP, IAO, Institute of Radioelectronics of the Academy of Sciences of the USSR, IAP, and S.I. Vaviliv State Optics Institute (SOI)). A report by V.M. Klimkin on the discovery of a new electronic state of the H_2O molecule, giving rise to a band in the absorption and fluorescence spectra of H_2O in the UV region, elicited considerable discussion.

The question of the necessity of organizing intraunion and international cooperation in developing an All-Union information center on molecular spectroscopy of atmospheric gases and gaseous pollutants in the atmosphere was also discussed in this section.

Questions regarding the spectroscopy of intermolecular interactions in the gas phase were examined in the third section. Plenary reports by M.B. Tonkov and N.N. Filippov (LSU) and S.D. Tvorogov (IAO) concerned the problem of the formation of the contours of spectral lines and bands in the region of the wings. A.K. Popov et al. (Institute of Physics of the Siberian Branch of the Academy of Sciences of the USSR) examined interference phenomena in the region of collision-induced nonlinear resonances. Seven oral and 13 poster reports were presented.

In vigorous discussion during this section the physics of the formation of the wings of spectral lines and interference of lines was discussed in application to the problem of the "transmission window" of the atmosphere in the region 8–12 μm. This subject dominated the work of the section (IAO, LSU, SOI, and the Scientific-Production Union "Taifun"). Noticeable progress was also demonstrated in the following directions: investigation of the nonlinear resonance interaction of the laser radiation with gaseous media, including analysis of new types of nonlinear resonances; detailed investigation of the polarization dependences in the absorption and fluorescence of simple and complex molecules (IP, Novosibirsk State University, Institute of Physics of the Academy of Sciences of the Belorussian SSR, IAO); and, traditional (for spectroscopy) investigations of collisional broadening and shift of the absorption lines of atmospheric gases. Significant progress has been achieved in the last direction both in experimental studies and in the theory. The development of techniques of diode and multichannel optoacoustic laser spectroscopy and laser spectrophotometry have made it possible to obtain extensive qualitative data on the shifts and pressure

broadening of the lines of H_2O and CO_2 by air and molecular and atomic gases. Improved computational methods make possible not only qualitative explanation of the results but they also give good quantitative agreement between the measured and computed values of the shifts and half-width of the vibrational-rotational lines (IGP, IAO, SOI).

Plenary reports by Yu.M. Golubev (LSU), A.S. Troshin (Leningrad State Pedagogical Institute), and A.S. Chirkin (MSU) were presented at the fourth section "Spectroscopy of intensity fluctuations".

The development and application of laser sources with subpoison photon statistics, (or in "compressed" quantum states) were discussed in all reports presented in the section. The reports adhered to a high theoretical standard and were of interest to all participants of the symposium. At the same time the absence of reports and experimental work indicates that work in this direction is lagging in our country. Since the preceding symposium definite progress has been achieved in the following directions:

– the study of the properties of resonant gaseous media connected with collisional processes and intra-atomic motions, which are is the problem directly addressed to the spectroscopy of intensity fluctuations; special attention was devoted to the problems of probing such media with "quantum" light, since the spectroscopy of intensity fluctuations has direct applications in precisely this case (LSU, Leningrad State Pedagogical Institute,Leningrad Polytechnical Institute, Leningrad Hydrological Institute, IAO);

– the study of the possibilities of producing light in quantum states in different variants of laser and parametric systems; Several approaches to the problem of formation of quantum "noise-free" light proposed (LSU, MSU, Leningrad State Pedagogical Institute, Leningrad Hydrological Institute, IAO).In the fifth section "Techniques of high-resolution spectroscopy" two plenary, five oral, and six poster reports were presented.

The plenary report, by E.A. Sviridenkov et al. (Institute of Physics of the Academy of Sciences of the USSR) was devoted to the study of the effect of nonlinear processes in lasers on the characteristics of intracavity laser spectrometers.

S.M. Chernin (Institute of Chemical Physics of the Academy of Sciences of the USSR) and E.G. Barskaya (SOI) reported on the development unique multipass matrix systems and the prospects for their applications in high-resolution spectroscopy.

The discussion of the material presented in this section showed that the development trends in the development of the techniques of high-resolution laser spectroscopy are connected with the assimilation of new spectral regions, expansion of the functional possibilities of spectrometers, and increase in their sensitivity and resolution. Reports on a spectrometer based on a parametric light generator for nonlinear spectroscopy of molecular gases in the region 1.5–3.8 μm (IAP) and on frequency-stabilized continuous-wave dye laser with precise wavelength tuning (Novosibirsk State University), whose technical characteristics are at least as good as the analogs produced in other countries, were of great interest to the audience.

During the symposium there were several seminars on specific subjects.