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Laser Induced Breakdown Spectroscopy - Summary of recent publications that include the author Christian Parigger

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ABSTRACT: This communication summarizes research on the subject of laser-induced transient micro-plasma diagnoses and selected publications during the years 2018 to 2023. Time-resolved spectroscopy elucidates plasma dynamics and species distributions that are generally of value in analytical chemistry. Aspects of electron density, atomic and molecular distributions are contents of the summarized work. Applications extend from analyses of laboratory to stellar plasma. Of particular interest is the spectroscopy of the hydrogen Balmer series and several diatomic molecules. In most of the publications, nominal nanosecond radiation from table-top laser devices is employed for generation of the micro-plasma, and spatio-temporal experimental methods capture phenomena that occur at well-above hypersonic, supersonic, and subsonic plasma and gas expansion speeds.

Key words: laser induced breakdown spectroscopy, atomic and molecular spectroscopy; laser-plasma; data analysis; combustion diagnosis; time-resolved spectroscopy; spectra fitting program; analytical chemistry, astrophysics

1. INTRODUCTION

The research-summary addresses recent 2018 to 2023 investigations that were primarily conducted at the Center for Laser Applications at The University of Tennessee Space Institute. However, a few selected publications with international collaborators are also included. The author, Dr. Christian Parigger, has been engaged in laser-plasma research at The University of Tennessee from 1987 to 2023. Recent publications in Multidisciplinary Digital Publishing Institute (MDPI) journals Atoms, Molecules, Foundations and Symmetry encompass various research aspects. During the 2018-2023 period of time, twenty-one MDPI articles referenced in this summary reflect scientific open-access peer-reviewed engagements. Various conference contributions including in the Journal of Physics: Conference Series further portray recent research associated with the biannual and well-established International Conferences on Spectral Line Shapes (ICSLS). The transition from previous archived journals such as Applied Optics, Optics Letters, Spectrochimica Acta Part A and/or Part B and Journal of Quantitative Spectroscopy and Radiative Transfer to peer reviewed open access journals is in accord with world-wide transition to open-access viz. access-for-everyone. In addition, the moderated Cornell University https://arxiv.org and MDPI https://www.preprints.org preprint servers convey aspects of research as well. And, of course, the Auburn University electronic the International Review of Atomic and Molecular Physics (IRAMP) journal https://www.auburn.edu/cosam/departments/phyiscs/iramp/index.htm communicates peer reviewed research activities.

2. SUMMARY

A. Laser-plasma atomic and molecular spectroscopy

Hydrogen and selected diatomic emission spectroscopy includes analysis of laboratory and stellar astrophysical plasma, e.g., from white dwarfs [1-6]. These works include self-absorption assessments. Expansion dynamics at hypersonic, supersonic, and subsonic are usually measured with spatio-temporal spectroscopy [7-15]. Fundamental aspects of diatomic molecular spectroscopy [16] lead to consistent data analyses without invoking the concept of reversed angular momentum - programs Nelder-Mead temperature (NMT) and Boltzmann Equilibrum Spectra Program (BESP) are freely available [17] as clear-text scripts with data files. Plasma diagnosis is elaborated with selected diatomic molecules including comparisons of the published data base with other readily available data bases for OH, CN, C_2, AlO [17-23]. In addition, the collaboration with University of Prayagraj (formerly Allahabad), India, on meteroite and gypsum laser-induced breakdown spectroscopy (LIBS) [24, 25] and on medical applications that include gallstone and pointed gourd leaves analyses [26, 27]. Collaborations with The University of Cairo include research on plasma involving silver nano-particles [28-30]. Recent collaborations with the Chemical Research Center in Hungary focus on microwave plasma methylidyne (CH) cavity ring-down spectroscopy [31].

B. Molecular Spectroscopy Chapter and E-Book

Two fundamental works in 2020 comprise a book chapter [32] on molecular laser-induced breakdown spectroscopy and an e-book on Diatomic Spectroscopy [33]. The former communicates molecular spectroscopy and applications to plasma-, combustion-, astro-physics- analyses. Primary interests include plasma in gases; however, the book chapter [32] includes laser ablation, including co-authors' work on laser-ablation molecular isotopic spectrometry (LAMIS). Diatomic molecules include cyanide (CN), aluminum monoxide (AlO), titanium monoxide (TiO), Swan bands of C_2, and the hydroxyl radical (OH). Aspects of spherical aberrations from focusing with a single lens are elaborated, and Abel inversion techniques are discussed for determination of spatial molecular distribution. The latter derives diatomic spectroscopy transition strengths [33] employing the Wigner-Witmer diatomic eigenfunction. The diatomic line strength is composed of electronic-, vibrational-, and rotational- transition terms including Franck-Condon, Hönl-London and r-centroid factors.

3. DISCUSSION

Both atomic and molecular species can be readily discerned from comparisons of measured and computed atomic line shapes and molecular band appearances. Several of the investigations elucidate experimental spatially- and temporally- resolved LIBS records' analysis details.The molecular emission spectroscopy comparisons require accurate data bases. The established and well-tested data bases for selected electronic, vibrational and rotational diatomic transitions and the associated analysis programs are now published for applications in LIBS research [17]. The 2018 to 2023 summary shows a research focus in 2022 to 2023 on molecular diagnosis by comparing accurate line strengths predictions [17-22] with those from readily available other corresponding data bases [34, 35], including ExoMol [35]. Future applications are envisioned to include laser-induced hydrogen based combustion - analysis of hydrogen emission lines and OH molecular bands are expected to benet from the research publications communicated in this summary.

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