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REVIEW

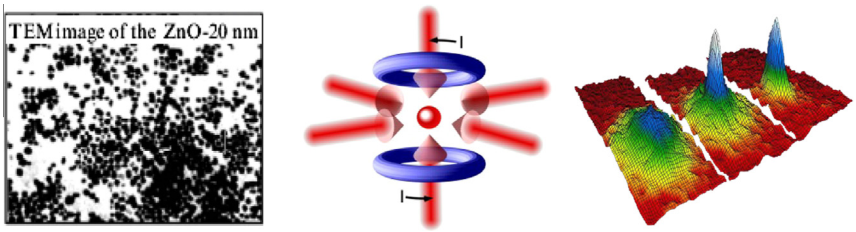
Advances in atomic physics
Four decades of contribution of the Cairo University – Atomic Physics Group

Tharwat M. El-Sherbini *

Physics Department, Faculty of Science, Cairo University, Giza, Egypt

GRAPHICAL ABSTRACT

In this review article, important developments in the field of atomic physics are highlighted and linked to research works the author was involved in himself as a leader of the Cairo University – Atomic Physics Group. Starting from the late 1960s – when the author first engaged in research - an overview is provided of the milestones in the fascinating landscape of atomic physics.



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* Corresponding author. Tel.: +20 1002501511.
E-mail address: thelsherbini@hotmail.com.

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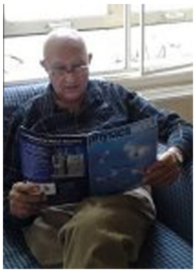

Tharwat El-Sherbini is the leader of the atomic physics group at Cairo University. He acquired a Ph. D. in atomic and molecular physics from Leiden University (The Netherlands) in 1972 and a D. Sc. degree in atomic and laser physics in 1984. He has published more than 160 publications in the field of atomic, molecular and laser physics and has established the research Laboratory of Lasers and New Materials (LLNM) at the physics department of Cairo University. Professor El-Sherbini has received several awards and honors, among which: the "State Award for Scientific Appreciation", the "NILE Award" and the "State Decoration Of The First Order For Sciences and Arts".

Introduction

During the last decades, we witnessed a continuous development in the field of atomic physics that had direct impact on other fields of research such as astrophysics, plasma physics, controlled thermonuclear fusion, laser physics, and condensed matter physics.

The landscape is vast and cannot possibly be covered in one review article, but it would require a complete book. Therefore, I will confine myself to the research works I was involved in and those that have direct connections with the work I have done.

The review is structured around five main topics:

- Electron–atom collisions.
- Ion–atom collisions.
- Atomic structure calculations and X-ray lasers.
- Laser-induced breakdown spectroscopy (LIBS).
- Laser cooling and Bose–Einstein condensation.

Electron–atom collisions

The physics of electron–atom collisions originated in 1930 by the work of Ramsauer and Kollath [1,2] on the total scattering cross-section of low energy electrons against noble gases, which contributed so much to the development of quantum theory. This work was followed by Tate and Smith [3] on inelastic total cross-sections for excitation of noble gases. Several well known physicists, e.g., Bleakney and Smith [4], Hughes and Rojansky [5], and Massey and Smith [6], at this period gave important contributions in the field of electron collision physics. The theory was developed by Stueckelberg [7], Landau [8], and Zener [9]. In 1952, Massey and Burhop's book [10] appeared on "Electronic and Ionic Impact phenomena," which provided the basis for any scientist who wants to start the work on the subject.

Multiple ionization of noble gases by low energy electrons (below 600 eV) has been studied extensively in mass spectrometers [3,11,12]. However, total electron impact cross-sections were determined by Van der Wiel et al. [13] and El-Sherbini et al. [14] for the formation of singly and multiply charged ions of He, Ne, Ar, Kr, and Xe by fast electrons (2–16 keV). The ion selection was performed in a charge analyzer with 100% transmission, and consequently, it was possible to avoid the discrimination effects in the measurement of the relative abundances of the multiply charged ions. Therefore, the data were more reliable than those obtain in low transmission mass spectrometers. The ionization cross-section of large electron impact energies is given by

$$\frac{\sigma_{ni}}{4\pi a_0^2}\frac{E_{el}}{R} = M_{ni}^2 \ln E_{el} + C_{ni} \tag{1}$$

where σ_{ni} is the cross-section for formation of $n+$ ions, E_{el} is the electron energy corrected for relativistic effects, a_0 is the first Bohr radius, R is the Rydberg energy, M_{ni}^2, and C_{ni} are constants.

The constant M_{ni}^2 is given by

$$M_{ni}^2 = \int_{n+} \frac{df^{n+}}{dE}\frac{R}{E}dE \tag{2}$$

where df^{n+}/dE is the differential dipole oscillator strength for an ionization to n^+ continuum at excitation energy E.

In 1970, an experiment was developed by van der Wiel [15], in which fast electrons (10 keV), scattered by He, Ne, and Ar are detected in coincidence with the ions formed (Fig. 1). It was possible from the measurements of the scattering intensity at small angles to calculate optical oscillator strengths. The differential scattering of fast electrons is given by Bethe et al. [16] (in au):

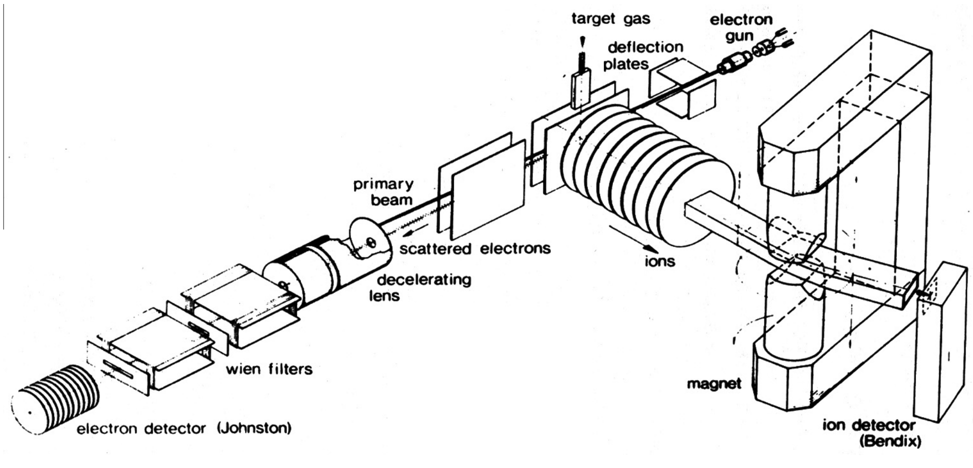

Fig. 1 Schematic view of the scattered electron–ion coincidence apparatus. **The first table-top synchrotron.**