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FEATURE

Sixty years of spectroscopic research: a tribute to Professor Edward B. M. Steers

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Abstract
It was a very sad day when the unbelievable news reached us that Prof. Edward Steers of London Metropolitan University had passed away. He was a major figure in Glow Discharge Spectroscopy (GDS). This text is intended as a brief overview of Edward's career in science, his activities in organizing meetings and research networks focused on GDS and the many-sided promotion of the field, including lecturing, his work with graduate students and post-docs, and the various research projects on which he collaborated with many colleagues throughout Europe. He was widely respected and admired for his keen scientific insight and encyclopedic knowledge and he was universally loved as a genuine and wonderful person.

Keywords Edward Steers · Glow Discharge Spectroscopy · Atomic spectra · Excitation · Molecular gases · GLADNET

Career summary

Prof. Edward Steers was a member of academic staff at London Metropolitan University (formerly Northern Polytechnic) for almost 60 years, starting in 1959. He retired in 1987 and became an Honorary Professor, being awarded a DSc, the highest honour of the University in 2010. His research ranged from the first measurements of atomic emission spectra in the 1–2.6 μm region, to spectroscopy tackling problems of interest to industrial analysts and instrumentation manufacturers, and spectroscopy of Glow Discharge Sources. Here, Prof. Steers' work obtained fundamental understanding of phenomena occurring during analytical applications, often in industrial settings, for which corrections were being made on an empirical basis for analytical purposes. Prof. Steers' research is internationally respected, and his energy and leadership in establishing international networks of collaborative partners across universities, research institutes and industrial laboratories across Europe and beyond have had immense impact on the field of Glow Discharge Spectroscopy.

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Scientific work of Prof. Steers

After obtaining his PhD in spectroscopy (1957) at the Physics Department of Imperial College, part of London University at that time, Edward started his career by joining the Spectroscopy Group of the Chemistry Division at the then Atomic Energy Research Establishment (AERE) at Harwell, UK. The work Edward became involved in while at AERE was the first measurements of infrared atomic emission spectra in the 1–2.6 μm wavelength region, in connection with spectral term analysis for some actinide elements and also the rare earth element lutetium, Lu. This was a highly specialized and then very topical field. Edward developed a carbon tube vacuum furnace with an auxiliary discharge as a spectral source for Lu and the term analysis studies he did with a scanning monochromator with PbS detector (Bovey et al. 1956). For radioactive elements, however, such sources were not suitable. However, microwave-excited discharges had just been developed at that time at the Argonne National Laboratory, USA, in which a small sealed tube containing low pressure inert gas and a volatile compound of the element under study was excited by 2450 MHz microwave radiation. Using this technique, Edward studied the uranium, plutonium (Bovey and Steers 1960, Bovey et al. 1961) and americium spectra and was also responsible for processing much of the data. In 1959, Edward joined the then Northern Polytechnic, London, as a lecturer in the Physics Department. He extended his previous work on infrared atomic spectra in short return visits to AERE, by recording and analyzing the spectrum of thorium (Steers 1967).

At the Northern Polytechnic, Edward set up a 1 m focal length scanning spectrometer for the infrared region and also facilities for the production of sealed electrode-less tubes for non-radioactive elements. He also improved the microwave cavities used for excitation of the sealed tubes. The first PhD students working under Edward's guidance recorded the infrared spectra of cerium, hafnium and manganese and that data were used for the term analysis of these elements. Studies of infrared atomic spectra drew to a close shortly after 1970, when it became clear that a newly developed Fourier transform spectrometer could yield much more accurate wavelength data than that obtainable from scanning grating spectrometers.

Following on the previous work, Edward and his colleague Dr. Mike Outred prepared sealed discharge tubes for many elements and used these sources for studies on the ionized spectral lines of xenon. Subsequently, the microwave slab line cavity was developed in their group as a more flexible type of source for microwave excitation of spectra (Outred et al. 1994; Rümmeli et al. 1996).

Also, developments related to analytical atomic absorption spectroscopy were carried out in Edward's group, in collaboration with instrument manufacturers. A pressure scanning Fabry–Perot interferometer system was set up to measure spectral line widths in sealed hollow cathode lamps and the width and shifts of flame absorption lines (together with Pye Unicam, Cambridge). This was followed by studies on the excitation processes in hollow cathode lamps (Howard et al. 1983; Light and Steers 1985) and on other forms of discharge in collaboration with Cathodeon, Ltd., Cambridge).

A new phase of Edward's research work opened in 1984, when he spent an 8-month period of sabbatical leave at the Institute for Spectrochemistry and Applied Spectroscopy (ISAS), Dortmund, Germany, in the group of Prof. Kurt Laqua. He started studying the spectral properties of Grimm-type glow discharge (GD) sources, introduced 16 years before (Grimm 1968), in particular the difference between sources with plane and hollow cathodes, wrongly attributed to fundamental differences in excitation mechanisms (Ferreira et al. 1984). By investigating the effect of the noble gas used as the plasma gas on the spectra emitted, Edward opened a new view on glow discharge excitation, having successfully explained the excitation of the 224.7 nm Cu II line, one of the strongest Cu lines emitted by a glow discharge in argon with a copper cathode, by the asymmetric charge transfer (ACT) reaction between argon metastable ions (Ar II, $3s^23p^5\ {}^2P°_{1/2}$) and neutral copper atoms (Steers and Fielding 1987). In a further, 4-month-long stay at ISAS, in 1986, funded by the Max Planck Society, Edward worked on the microwave (MW) boosted glow discharge source. This modification of the Grimm source had been introduced by Laqua, Leis and Broekaert (Leis et al. 1987) to improve the limit of detection obtainable with GDS. While working on some analytical applications, Edward found that the differences in the relative intensities of spectral lines in the boosted and the conventional glow discharge give information on the mechanisms by which the upper levels of the emitting energy transition are excited (Steers and Leis 1989a, b; Steers and Thorne 1989; Leis et al. 1991, Leis and Steers 1994).

At ISAS, all spectral measurements were made using a scanning monochromator, where the observation of a wide spectral range at high resolving power takes a long time and is only possible with very stable sources. An alternative is Fourier Transform Spectroscopy (FTS). It had been used in the infrared region since the 1950s, and in the near infrared since the 1970s, but the difficulties greatly increase at shorter wavelengths. However, in the late 1980s, Anne Thorne et al. (Thorne et al. 1987) built FTS instruments for the visible and the first in the vacuum ultraviolet region (140–900 nm) in the Spectroscopy Group of the Physics Department, Imperial College London. These allowed the complete spectrum to be recorded over a wide wavelength region with very high resolving power in several minutes, although the subsequent Fourier transform and the extraction of the parameters of individual lines required additional time and effort. Edward had maintained close links with Imperial College ever since studying for his PhD there, and was able to use the FT instruments to record spectra from GD sources during the last 25 years until the end of his life (Steers and Thorne 1989, 1993, 1996; Smid et al. 2003, 2008b; Weinstein et al. 2010; Mushtaq et al. 2011, 2012a, 2014a, b; Pickering et al. 2015; Weiss et al. 2009, 2014a, b, c, 2015, 2016, 2018; Mushtaq et al. 2012a, b, 2016). Glow discharges are not very noisy and can produce a stable emission, constant over several minutes at least, making them suitable for their investigation by FT spectroscopy. With high-resolution FT spectra, systematic studies involving large numbers of lines are possible, virtually without line interferences (overlaps). Also real line shapes can be investigated. Thereby, a wealth of information about excitation processes taking place can be collected. An early application involved evaluation of the spectral data by a method of plotting the ratio of the intensities of individual spectral lines at two different glow discharge operating conditions against the total energy of the upper level involved. Thereby it is possible to compare, e.g., the MW-boosted and the conventional Grimm-type discharge (Leis and Steers 1996; Steers and Leis 1997), or MW-powered glow discharge or glow discharges running in different discharge gases (Steers and Leis 1991; Steers and Thorne 1993; Steers 1993, 1997). From the resulting plots, it is possible to identify levels that are excited by ACT reactions. Subsequently, Edward's work focused on the effects of trace molecular gases in GD sources.

The link with ISAS convinced Edward that wider collaboration with other European laboratories is desirable, and he developed strong links with the analytical group at IFW Dresden, Germany, under Dr. Volker Hoffmann, and with Dr. Zdenek Weiss, then at LECO Instrumente, Plzen, Czech Republic. The latter resulted in a 3-month-long stay of Z. Weiss with Edward in 1993, funded by the "Go-West" Postdoctoral Fellowship of the EC, with work on MW-boosted and un-boosted GD sources, involving also (but not limited to) FTS. A wide use of GD sources for analytical purposes led to a finding that small amounts of molecular gases present in analytical sources, either as a contamination or coming from the sample, affect the discharge conditions and hence the accuracy of the analysis. Bengtson (Bengtson and Hänström 1999) had first identified the presence of traces of hydrogen as the reason why the two usual Cr analytical lines behaved differently at the start of the discharge. The effects of molecular gases in a GD became a major topic Edward was involved in during the subsequent years. First, when V-D. Hodoroaba, at BAM, Berlin, studied the effect of hydrogen for his PhD project, Edward made a number of visits to Berlin and Dresden to suggest further experiments and to assist in the interpretation of his results (Hodoroaba et al. 2000a, b, 2001, 2003). Subsequently, Edward worked extensively in this area himself. It became clear that one effect of the presence of hydrogen was a reduction in the importance of ACT excitation by argon ions. Also, at certain conditions, strongly selective ACT excitation by hydrogen ions was identified (Steers et al. 2006) and excitation of atomic lines involving hydrogen molecules (Smid et al. 2008a). The effect of small amounts of nitrogen and hydrogen within a discharge was the main research topic of Dr. Petr Smid, then at the University of West Bohemia, Plzen, Czech Republic, when he spent 1 year with Edward (2003–2004), being funded by the NATO/Royal Society postdoctoral fellowship at Imperial College (Smid et al. 2003). After an interruption, close collaboration with P. Smid resumed in 2006–2008, (Smid et al. 2008b; Hoffmann et al. 2008; Steers et al. 2008), when he spent a further 2 years with Edward in a post funded under GLADNET (a European Community Marie Curie Research Training Network project, 2007–2011, see below). One of the topics of that collaboration was collecting emission spectra with a modified Grimm-type source allowing side-on observation to study spatial spectral distributions (Smid et al. 2008b).

The funding under GLADNET provided the means to engage two more graduate students who worked under Edward's guidance on their PhD: Viktoria Weinstein and Sohail Mushtaq. Most of this work took place at Imperial College, in the group of Prof. Juliet Pickering, involving high-resolution FT spectra from a stand-alone Grimm-type source (Spectruma Analytik GmbH., Germany) equipped with a gas-mixing system built earlier by P. Smid (Weinstein et al. 2010; Mushtaq et al. 2011, 2012a, 2014a, b; Pickering et al. 2015; Weiss et al. 2016). Also Z. Weiss used this opportunity and came for two short stays with Edward in 2009, 2010, collecting FT spectra of pure elements and some alloys, originally intended for a catalog of GD spectra, in a project also involving V. Hoffmann (Weiss et al. 2009). The data continue to be analyzed. The spectra of some elements from these campaigns were used for a much more detailed characterization of the excitation mechanisms than before, based on the newly introduced concept of transition rate (TR) diagrams (Weiss et al. 2015). Ionic spectra of manganese, iron, copper and titanium have been analyzed by this method (Weiss et al. 2014a, b, c, 2018). In the years after GLADNET, S. Mushtaq took a postdoctoral position with Edward, after obtaining his PhD from Imperial College (2011) and became the main companion to Edward in his further scientific work. The main research continued to be investigating the effects of minor admixtures of molecular gases on glow discharge excitation (Mushtaq et al. 2011, 2012a, 2014a, b; Pickering et al. 2015; Weiss et al. 2016). Besides Imperial College, Edward measured emission spectra also at IFW Dresden (Germany), together with V. Hoffmann (Mushtaq et al. 2012a, b, 2016). To extend the information resulting from emission spectra, Edward initiated and/or performed, together with S. Mushtaq and other colleagues, mass spectral experiments at EAG (Syracuse, USA), EMPA (Thun, Switzerland) and BAM (Berlin). A significant recent result from this work was the discovery of charge transfer and ionization (CTI), a reaction in which doubly charged titanium ions are created in collisions of Ti atoms with Ne^+ ions (Mushtaq et al. 2017).

Building on extensive experience covering a wide range of topics in optical spectroscopy in the earlier stages of his career, Edward became a prominent figure in the area of analytical glow discharges, glow discharge excitation and ionization. He contributed very significantly to our present knowledge about the processes occurring in glow discharge sources and opened a field that is both important for analytical methodology and interesting as a source of new information about how these spectral sources work.

The activities of Prof. Steers on behalf of the GDS community

After his early retirement, Edward Steers continued his work in the field of analytical glow discharge. When Prof. Laqua of ISAS Dortmund retired at about the similar time, research in GD-OES was reduced at ISAS and the glow discharge work at ISAS of Norbert Jakubowski became focused on mass spectrometry. Going forwards Edward forged additional new links to groups in eastern Europe, where the border had recently opened, and research and development of GD-OES became increasingly popular. Edward gave the first talk at the first common German users meeting on analytical glow discharge, involving participants from both parts of the unified Germany, in April 1990 in Jülich, and since then continued to forge and build on collaborations across Europe, crossing the Channel and driving huge distances in his Fiat Uno from colleague to colleague in Europe. Edward always believed, and his experience has shown, that collaborative experimental work and face to face discussions are absolutely essential for making progress in research.

With no claim to be complete, Edward's trips included stops at Jobin–Yvon in Paris (Patrick Chapon), University of Antwerp/Belgium (Renaat Gijbels, Annemie Bogaerts), INP Greifswald/Germany (Jürgen Röpke), ISAS Dortmund/Germany (Franz Leis, Alfred Quentmeier, Norbert Jakubowski) and Berlin (Heiner Korte), Degussa in Hanau/Germany (Cornel Venzago), IFW in Dresden/Germany (Volker Liebich, Volker Hoffmann), Spectruma in Hof/Germany (Michael Analytis), University of West Bohemia and LECO in Plzen/Czech Republic (Zdenek Weiss, Petr Smid), KFKI in Budapest/Hungary (Zoltan Donko) and University of Belgrade/Serbia (Nikola Konjevic).

At this time, 1992, the European Working Group on Glow Discharge Spectrometry (EW-GDS) was founded in Paris. The informal group's purpose was to promote the development of GDS technologies for surface analysis. For Edward the European dimension of this work was clear and he organized the next EW-GDS meeting in 1993 at the Post symposium of the XXVIIIth Colloquium Spectroscopicum Internationale about Analytical Applications of Glow Discharges in Optical and Mass Spectrometry in York, UK.

Edward began to seek support for a joint European project on analytical GD spectroscopy to be funded by the European Community. On his many trips to the Continent, he would stop off at the Brussels administration and collect the latest information on possible funding of such a collaborative project. In the mid-1990s, Edward organized several meetings with about ten people at the British EC office in Brussels to find the right partners, scientific content and funding route.

The first successful application was approved in 1999, resulting in the 3-year EC Thematic Network on Glow Discharge Spectroscopy for Spectrochemical Analysis (Steers 2003) (EC no. SMT4-CT98-7517 DG12-HIAS). It started with 19 direct and 12 associated partners from 11 countries with Edward as project manager. Amongst other outcomes, the success of this project pushed the development of new GD instrumentation.

The newly established real collaboration of many groups in Europe led to the wish for continuation of such projects supported by the EC. Again Edward looked for possibilities for new financial support, contacted project officers in Brussels and organized meetings of leading scientists in the field of analytical glow discharges in Europe and overseas. Edward was turning 70 years old, and he decided to stay a little more in the background, and Johannes Michler of EMPA in Thun/Switzerland took over as the official head of a new consortium of 16 partner laboratories from 11 countries. Working with Edward and others, a new project for an "Analytical glow discharge research training network" (acronym GLADNET) was funded 2007 under EC contract MRTN-CT-2006-034559. In this network not only the cooperation of existing staff in Europe was supported, but also importantly the work of ten early stage researchers and five experienced researchers became financed (Gamez 2011). GLADNET was the most important enterprise in the area of analytical glow discharges ever, with seven regular meetings in 2007–2010, typically several days long, involving lectures by leading researchers on relevant topics and reports on the progress in projects carried out in individual member laboratories. Under GLADNET, eight graduate students finished their PhD in the area of analytical glow discharges and contributed significantly to the overall advancement of the field. Edward was involved throughout at the heart of the organization of these meetings, and himself gave key lectures on optical spectroscopy and excitation mechanisms. After the completion of GLADNET, Edward organized a meeting of the GD community in Kingston, UK (2012). Since 2011, the EW-GDS has applied several times for a new EC project, with Edward continuing to help in words and deeds.

In September 2015, Edward Steers was invited to the 42nd Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies SciX in Providence, Rhode Island, USA, where a special honorary session to celebrate his scientific work was organized. Prior to that, Edward had never attempted to visit the USA. Therefore, it was a special opportunity for EW-GDS to arrange both this session and his journey to this scientific meeting. Peter Robinson, Volker Hoffmann and Petr Smid accompanied Edward during the whole journey and together with Prof. Gary Hieftje and John Cantle contributed with their presentations to this honorary session. Edward himself presented one of his last oral presentations there titled: 'One thing leads to another: 60 years of spectroscopy research'. This special session concluded with standing ovations.

During his career, Edward contributed significantly to the field of glow discharge spectroscopy and spectroscopy in general and inspired many researchers. He was brilliant in the experimental work as well as in interpreting spectroscopic data. It is to a large extent by his endeavor and efforts that the present GDS community has developed to its present form. He will be greatly missed.

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