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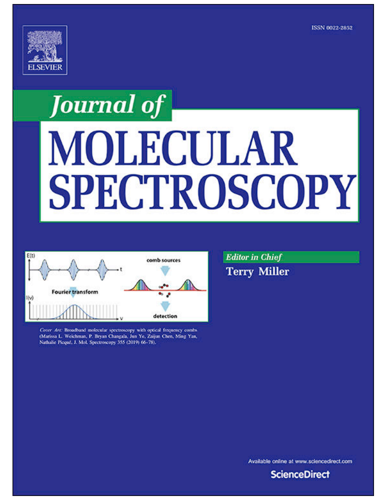

A Uranium Atlas, from 365 to 505 nm

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A Uranium Atlas, from 365 to 505 nm

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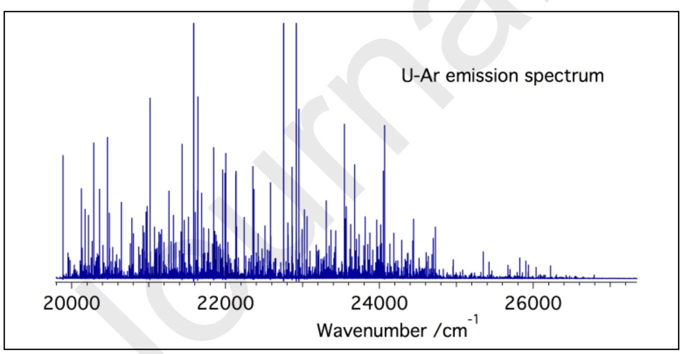
Abstract

A Fourier-transform spectrum of the emission from a commercial Uranium hollow-cathode lamp 19800 – 27400 $cm^{-1}$is proposed, in ascii format, as a possible aid to calibration of laser excitation spectra.

Graphical Abstract



Introduction

It can sometimes be convenient to compare spectral reference signals with an original reference spectrum, rather than matching peaks with a list of peak positions from an atlas. This work was motivated by difficulties encountered in calibrating laser excitation spectra taken in short (1 cm^{-1}) scans with a ring dye laser around 438 nm, using optogalvanic lines from a Uranium-Argon hollow cathode lamp as reference. Uranium has a rich spectrum in this region; a modest selection of transitions between 15870 and 25900 cm^{-1} was published from spectra recorded at Laboratoire Aimé Cotton in France in 1977 [1], followed by a much more extensive catalogue of lines 11000 – 25900 cm^{-1} recorded at Los Alamos in 1980 [2] presented as a spectral atlas, and recommended for optogalvanic calibration[3]. Because the peaks of the weaker features are not quoted in these sources, short pieces of excitation spectra sometimes fall between secure calibration lines. To remedy this, we have recorded the spectrum from a U+Ar hollow cathode lamp 19800 – 27400 cm^{-1}, covering shorter wavelengths than the (much richer) digital I_2 atlas [4] recorded for much the same purpose. This U+Ar spectrum is available in ascii format (supplementary material). It is a convenient extension to the recent work of Sarmiento and coworkers [5], who advocate the use of uranium (in preference to thorium) hollow cathode lamps for calibration of high-resolution astronomical spectrographs operating in the near IR and visible. Ref. [5] covered the spectral bandwidth of the CARMENES instrument (500–1700 nm), and the 25 vacuum wavenumbers for peaks in the region common to both match to within quoted uncertainties, and with average difference 0.0004 cm^{-1}. Redman and co-workers have examined uranium hollow-cathode lamp emission still further to the infrared [6, 7], also in the context of calibration of astronomical instruments where frequency comb standards are not available.

Experiment

We recorded emission from a commercial (Cathodeon) Uranium + argon hollow cathode lamp running at 135 V, 50 mA. The spectrum was recorded in two pieces on a Fourier transform spectrometer (Bomem DA3) using a quartz beamsplitter optimised for the visible spectrum, and a trialkali photomultiplier (EMI 9558QB) as detector. The longer wavelength section, 19800 – 23000 cm^{-1} was recorded on through two optical filters, one blue-green band pass (CS 4-76 from Corning Glass), the other $\lambda < 500$ nm (Corion Inc). The second part was recorded though a $\lambda <$ 450 nm sharp cut filter (Corion Inc) using higher photomultiplier sensitivity to compensate lower signals in this region. The optical path difference for the FT spectrometer was chosen to give an apodised resolution of 0.04 cm^{-1}. Interferograms were re-processed (correcting for phase errors and zero-padding to interpolate between data points) with in-house software [8] to improve on line shapes.

The wavenumber scales were also processed to match a selection of some 150 peaks tabulated in the existing atlases of refs [1] and [2]. The spectrum recorded at Laboratoire Aimé Cotton [1] came from a liquid nitrogen-cooled hollow cathode, with full-width half-maximum linewidths less than 0.02 cm^{-1}. The peaks were on average 0.002 cm^{-1} lower than those from the Los Alamos work (in which the authors gave an estimated accuracy of 0.003 cm^{-1}), taken with a water-cooled commercial lamp. After making small corrections to our raw wavenumber scale, (-0.003 cm^{-1} at 20000 cm^{-1}, increasing to 0.014 cm^{-1} at 27000 cm^{-1}, probably resulting from imperfect setting of the entrance aperture for the instrument), the two pieces were spliced together, merging just below 23200 cm^{-1}. The resulting spectrum is illustrated in Figure 1. The inset highlights the region at shorter wavelength not covered in ref. [2]; in which ref. [1] reports just 7 transitions.

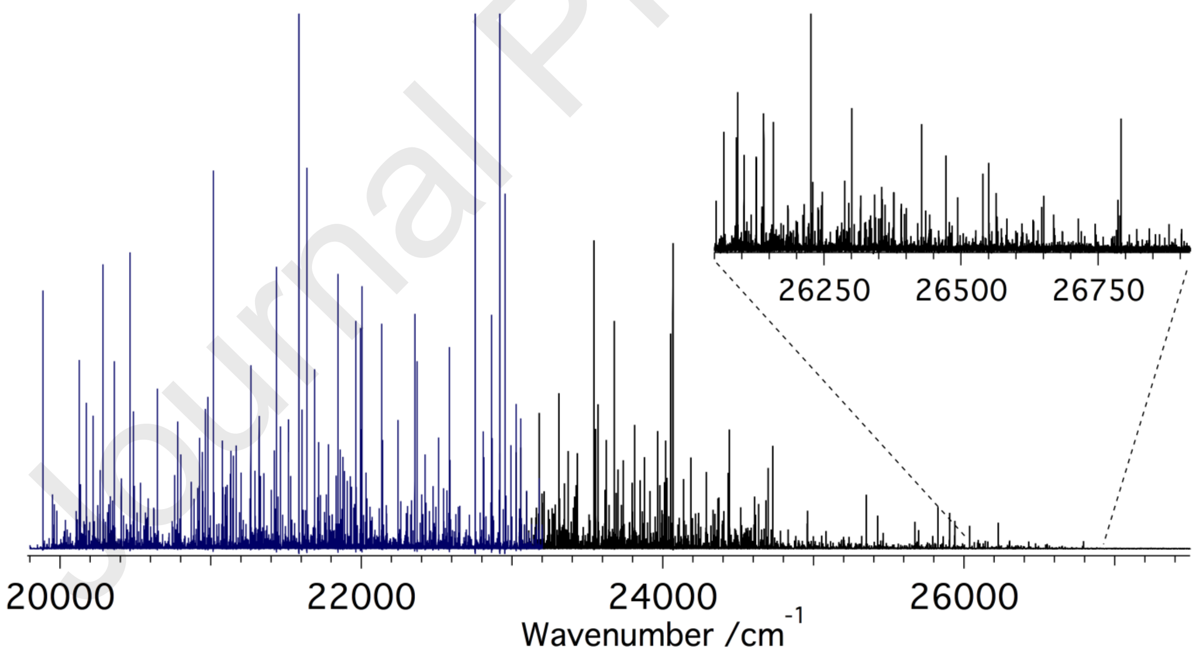


Figure 1 (colour online). Emission from a Uranium+argon hollow cathode lamp, with no correction for instrumental intensity response. Different optical filters were used below and above 23200 cm^{-1} (see text). The inset shows the region beyond the spectrum of ref . [2].

Measured linewidths are between 0.05 and 0.075 cm^{-1}, comparable with the effective resolution at the short wavelength region in ref. [2]; peak positions should be determined to better than 0.005 cm^{-1}. To illustrate consistency with the earlier works, Figure 2 depicts the deviations of peak positions determined from this composite spectrum with respect to our selection of transitions listed in the literature.

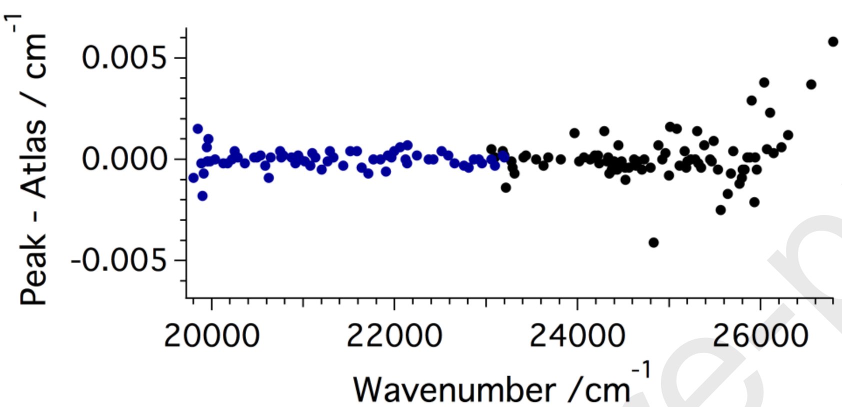


Figure 2 (colour online). Scatter plot showing differences in cm^{-1} between peak positions taken from this spectrum and a selection of peak positions listed in existing atlases, mostly from ref. [2], *but including peaks from ref.* [5] *below 19900 cm^{-1}* and *from ref.* [1] *above 25000 cm^{-1}.*

The complete composite spectrum of the Uranium+argon lamp is available to download in Ascii format (supplementary data), or may be obtained on request to the authors. We believe it matches the estimated accuracy of the Los Alamos atlas (0.003 cm^{-1}) at least up to 26000 cm^{-1}. At shorter wavelengths, performance may be degraded, but differences with other sources remain within 0.005 cm^{-1}.

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Highlights

FT spectrum of blue – near UV emission from a Uranium-argon hollow-cathode lamp.

Reference spectrum for calibration 500 – 365 nm.

Line list, and spectrum given in ascii format.

Declaration of interests

☒ The authors A. Ross, P. Crozet, A. Adam and D. Tokaryk declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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