X-RAY SPECTROSCOPY TO DETERMINE LINE COINCIDENCES BETWEEN K- AND L-SHELL TRANSITIONS

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Accurate wavelengths for highly-ionized L-shell spectra were measured in the 10-16Å region. The purpose being to determine lines in coincidence with L-shell transitions from the elements oxygen, fluorine, and neon. L-shell transitions have been proposed for resonant photopumping of K-shell electrons in these elements to generate lasing between upper levels in the 40-150 eV region.(1) The current effort improves on and expands the earlier spectroscopic work performed at KMS Fusion, Inc., where possible line coincidences were identified for photoionizing in the 1-3 and 1-4 levels in fluorine.(2) New experimental techniques have led to a wavelength accuracy now believed to be ± 2 mÅ for cases in which adequate calibration lines are available. Exact spectral line matches were found for Mn with the F H_α line at 12.643Å and for both Mn and Cr with the F He_α line at 14.458Å. The Mn line at 12.643Å has been identified, using ab initio atomic structure calculations, as the $^1D_2 - ^1F_3$ transition in Be-like Mn XXII. The Mn line emissivity was determined to be 30 MW into 2π steradians for a conversion efficiency of 0.04%. Photopumping with Mn coated gas-filled targets is presently being tried in gain measurement experiments at LLNL.(3)

X-ray spectra were collected under controlled illumination and target conditions in order to examine a number of potential L-shell lines. These lines represented cases where near agreement between L-shell transitions and the 1-3 transitions in He- or H-like O, F and Ne had been previously reported. The KMSF CHROMA laser was used to generate a plasma source of soft x-ray emission. The glass laser was operated in the frequency-doubled mode (0.527 μm) for enhanced light absorption at an irradiance of $1.5 \cdot 10^{14}$ W/cm^2.

Several new techniques were used in this experiment to improve the wavelength accuracy. These included (1) the use of a cylindrically-focused lens and end-on viewing of the plasma source, (2) the use of short-laser pulses of 120 psec duration to reduce the extent of x-ray

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emission due to plasma expansion, (3) the targets were viewed at 90° to the laser beam to minimize the Doppler shifts, (4) the use of high-sensitivity x-ray film and active-element intensified spectrographs, and (5) in a few shots, a split target was used to confirm the line coincidences in single laser shots.

Two high-resolution spectrographs viewed the target in the same plane, both at 90° to the laser beam. This arrangement allowed viewing the plasma end-on, resulting in an effective source size of about 100 μm. Another intensified spectrograph viewed from behind the target. Its diffraction crystal was set to record spectral data at wavelengths corresponding to the 1-2 transitions in the ionized gases.

Spectral data were collected directly onto film in the passive spectrograph. the film selected was Kodak direct exposure film SO445 (DEF). This film has a good sensitivity and a low background fog level. The DEF film is about 3 times more sensitive than Kodak No Screen film.[4] Spectral data were recorded in either one or two shots per element with the passive spectrograph, and with intensified spectrographs incorporating microchannel plates.[5]

The data were recorded as spectral pairs on the spectrograms. Target elements for calibration purposes were carefully selected for each of the spectral regions investigated. Fig. 1 shows a typical spectrogram collected with a beryl diffracting crystal directly onto film. The 2p-3d F-like Fe XVIII transitions were used for calibration of the Mn lines. Fig. 2 shows spectrograms collected with one of the intensified spectrographs near 12.6Å. Line calibration for the Mn spectra was provided by Fe, Ca, and Cr lines in this spectral region. These juxapositioned spectral pairs were read on a Grant comparator densitometer which was set up to read both strips alternately with a Decker system. In a few shots, confirmation of the line coincidences was observed in spectrograms from split targets. These targets were formed by coating half the plastic substrate with the candidate element and the other half with CaF_2. By using spatial imaging, the upper spectra in Fig. 2 were collected in a single laser shot.

The results of the wavelength measurements are listed in the Table for the various spectral regions. Exact line coincidences were found in the first two cases with fluorine 1-3 transitions. The wavelengths for the nearest lines are listed for other metal L-spectra that match K-lines in neon and oxygen (in two cases within 4 mÅ). Lines were absent in Mn spectra that coincided with 1-2 transitions in fluorine. These would have spoiled the lasing scheme by filling the lower level.

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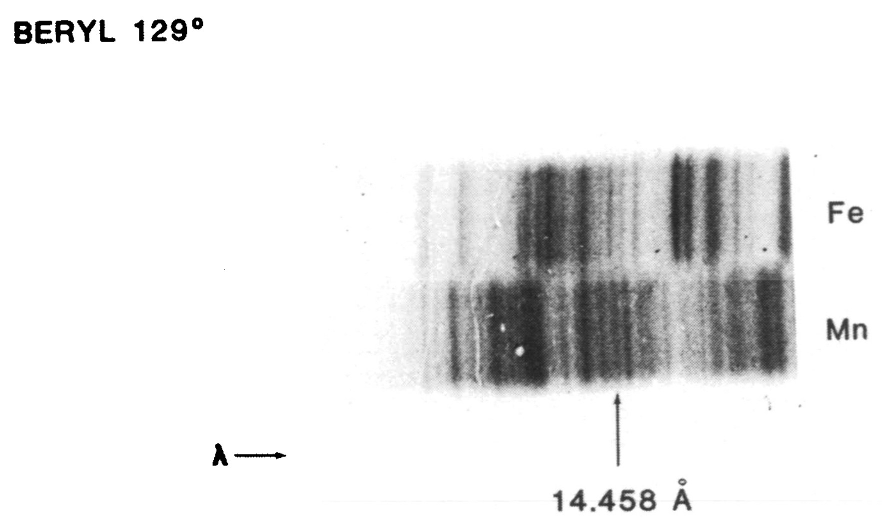

Figure 1. Spectral lines for Fe and Mn collected with passive spectrograph

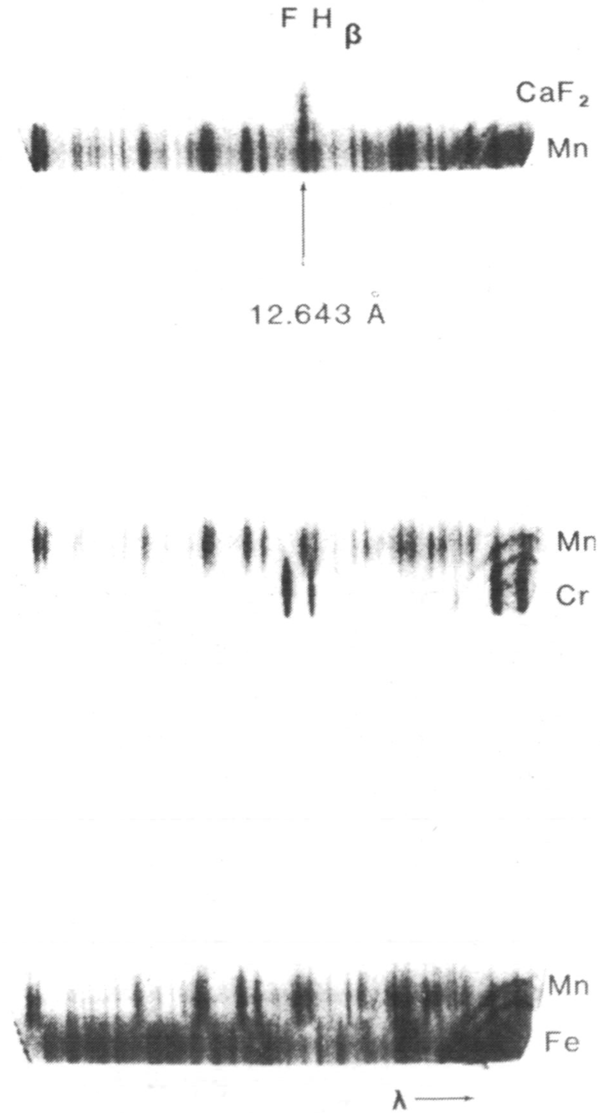

Figure 2. Spectrograms from an intensified detector system. Upper set shows line coincidence for F and Mn lines at 12.643 Å.

L-SERIES X-RAY WAVELENGTH MEASUREMENTS

LINE TO BE PUMPED		PUMP WAVELENGTH	TARGET PAIRS	MEASURED WAVELENGTH	ELEMENT
FLUORINE	He_β	14.458Å	Mn,Cr/Fe Mn,Cr/CaF_2 Mn/Cr	14.458 ± 2 mÅ	Mn/Cr
	H_β	12.643	Mn/Fe,Cr Mn,Cr,Fe/CaF_2	12.643 ± 2	Mn
NEON	He_β	11.547	Ni/Fe Ni/Mn	11.551 ± 3 11.556	Fe Ni
	H_β	10.239	Zn/Co Zn/V	10.242^5 ± 3 10.244	Zn Co
OXYGEN	H_β	16.006	V/Fe V/FORMVAR	15.998 ± 3 16.003	V Fe

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