Preselection of emission lines for future CF LIBS analysis of the suitable fusion devices first wall material

Introduction

CF-LIBS is a proven effective method for elemental analysis of metal alloys. EUROFER97's development began more than 25 years ago as a replacement for radiologically undesired elements like Mo, Nb, Ni and Co with their lower-activation counterparts like Ta, W, Mn, and V. The addition of about 0.2 wt% of V improves creep strength and impact behavior, whereas about 1 wt% of W is added as solution strengthening element [1].

The nominal composition is approximately 0.11% C, 9.0% Cr, 1.1% W, 0.4% Mn, 0.2% V, 0.1% Ta, with the balance being iron (Fe).

EUROFER is the European structural candidate material for future fusion devices wall material. Its development included several boundary conditions such as lifetime at operational conditions at elevated temperatures and neutron irradiation, environmental and economic issues.

The current EUROFER material development tries to find an optimum temperature by thermodynamically guided alloying, thermal treatment, and microstructural optimization.

Goal

This work involved a preliminary evaluation of the emission lines of the elements in the EUROFER. This preliminary evaluation consisted of determining the optimal emission lines for studying the concentrations of the elements using the LIBS technique. Their selection was based on the following properties:

The lines have to be isolated from other emission lines (interference free) and should not be self-absorbed, which could contribute to an error. The preselection of the good lines of all elements and degree of ionization for future CF-LIBS analysis is crucially important.

Lines recognition

For this preselection we used the **NIST LIBS** application [2], which provides a plot with the spectra of the emission lines of the elements in the alloy, considering their respective concentrations. The parameters selected were: spectra range: 200 nm-600 nm; Te(eV): 1; Ne(cm-3): 1e17.

Experimental Setup

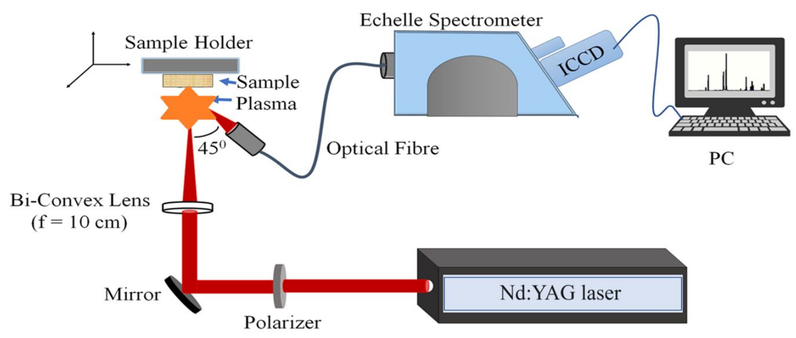

Fig. 1. Possible LIBS experimental setup.

Results

C I: 247.8 nm overlaps with Fe. C I at 165.6 nm is the strongest of all C lines yet not sufficiently intense comparing to the spectral lines of other elements. The other lines and the lines from CII and CIII are too weak.

V II: Spectral line at 291.9 nm is strong but is interfered with another line, while 309.3 nm, 310.2 nm and 311 nm are isolated (310.2 has another line bellow), 327.2 nm is fairly intense and isolated. While all V I and III lines are weak.

Cr I: The most intense line was found at 359.4 nm, 426.2 nm is fairly intense and isolated. Cr II: The line at 283.7 nm the most intense (but Fe II has a weak line there interferes this line). Lines 205.62 nm and 206.25 nm the intense enough and isolated, and lines at 286.76 nm and 267.78 nm are among the weaker lines in Cr but intenser than peaks of other elements and are isolated.

Mn I: 279.46 nm overlaps with Fe II line, Mn II: 257.6 nm is and isolated, 294.7 nm is the second strongest.

W II: 204.94 nm, 207.97 nm, 225 nm second stronger and is isolated. While all W I and III lines are weak.

Fe I: 248.8 nm is the most intense among the Fe I lines and isolated, 374.4 nm second stronger. Fe II: 239.1 nm is the strongest.

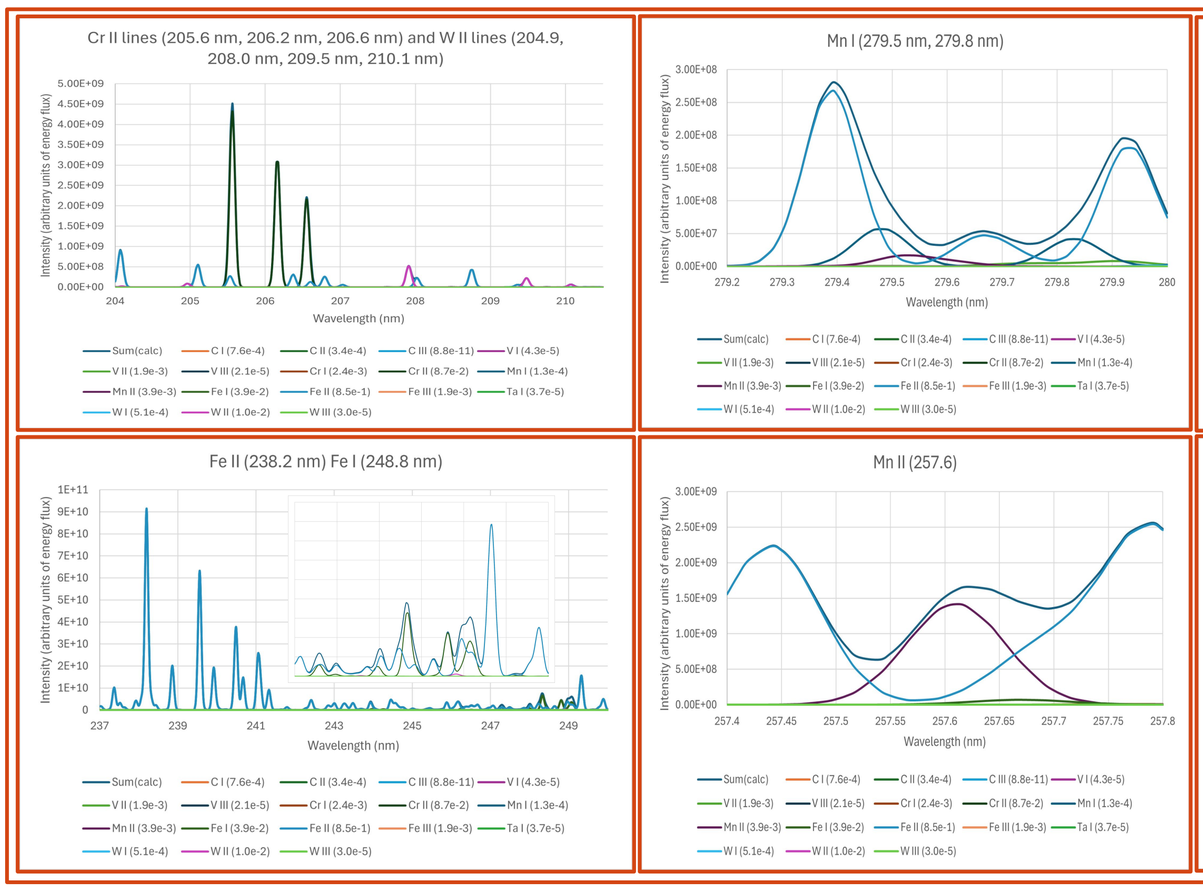

Fig. 2. LIBS spectra provided by NIST LIBS application with the selected lines

Conclusion

The elements in the EUROFERN97 alloy show at least one line that could be measured, which are: C I: 165.6 nm ; V II: 291.9 nm, 309.3 nm, 327.2 nm; Cr I: 426.2 nm; Cr II: 205.62 nm, 206.25 nm, 286.76 nm; Mn II: 257.6 nm, 294.7 nm; W II: 225 nm ; Fe I 374.4 nm; Fe II: 239.1 nm , with the exception of Ta whose concentration is too low to emit a line strong enough to be measured.

Future work

With this preselection of lines, the EUROFERN's spectra will be recorded and measurements will be performed using the proposed experimental setup, analyzing the theoretical lineas (NIST) and the experimental lines obtained through that setup.

Calibration free measurements will also be performed with the same setup to characterize this alloy using LIBS.

Reference

[1] M.Duerrschnabel, U. Jantsch, R.l Gaisin , M. Rieth "Microstructural insights into EUROFER97 batch 3 steels" Nuclear Materials and Energy 35 (2023) 101445.

[2] https://physics.nist.gov/PhysRefData/ASD/LIBS/libs-form.html

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