SPES exotic beams for science

Electrical-thermal-structural coupled-field finite element modeling and experimental testing of high-temperature plasma ion sources for the production of radioactive ion beams

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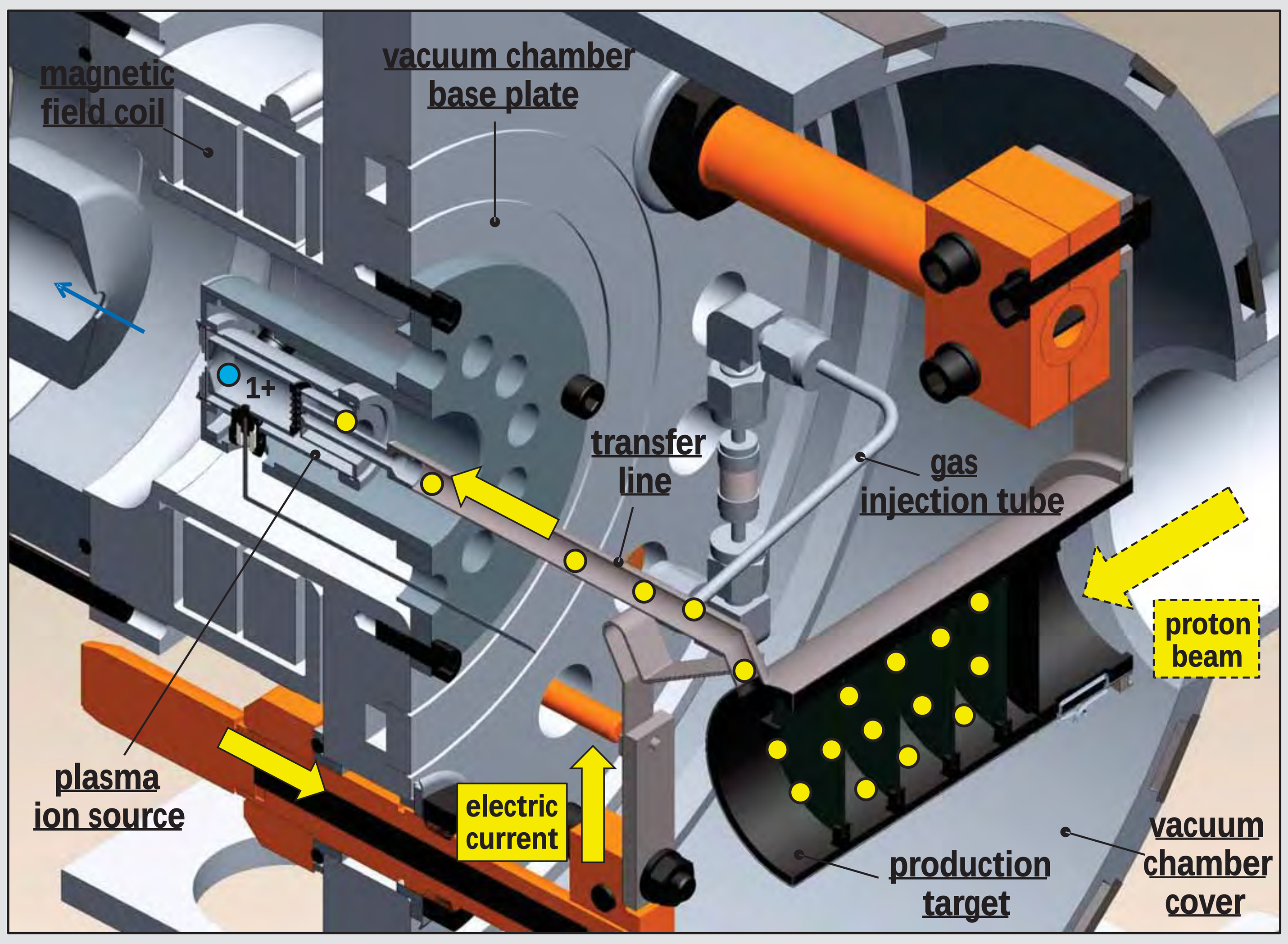
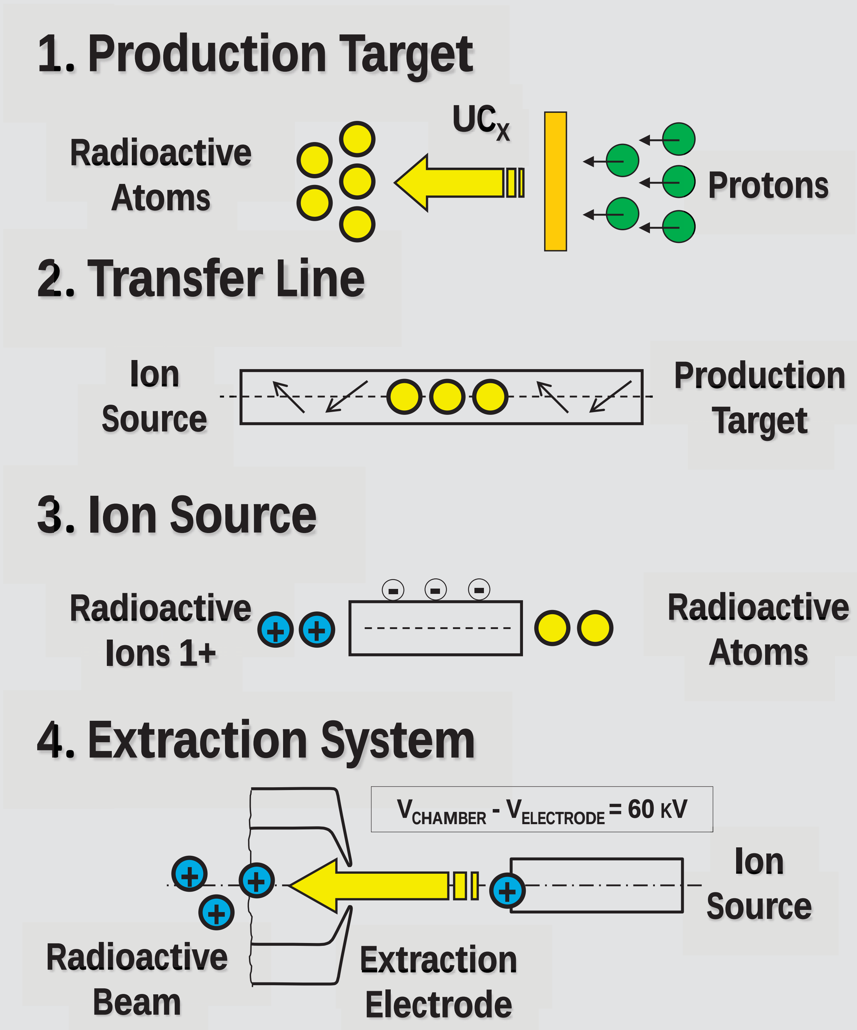
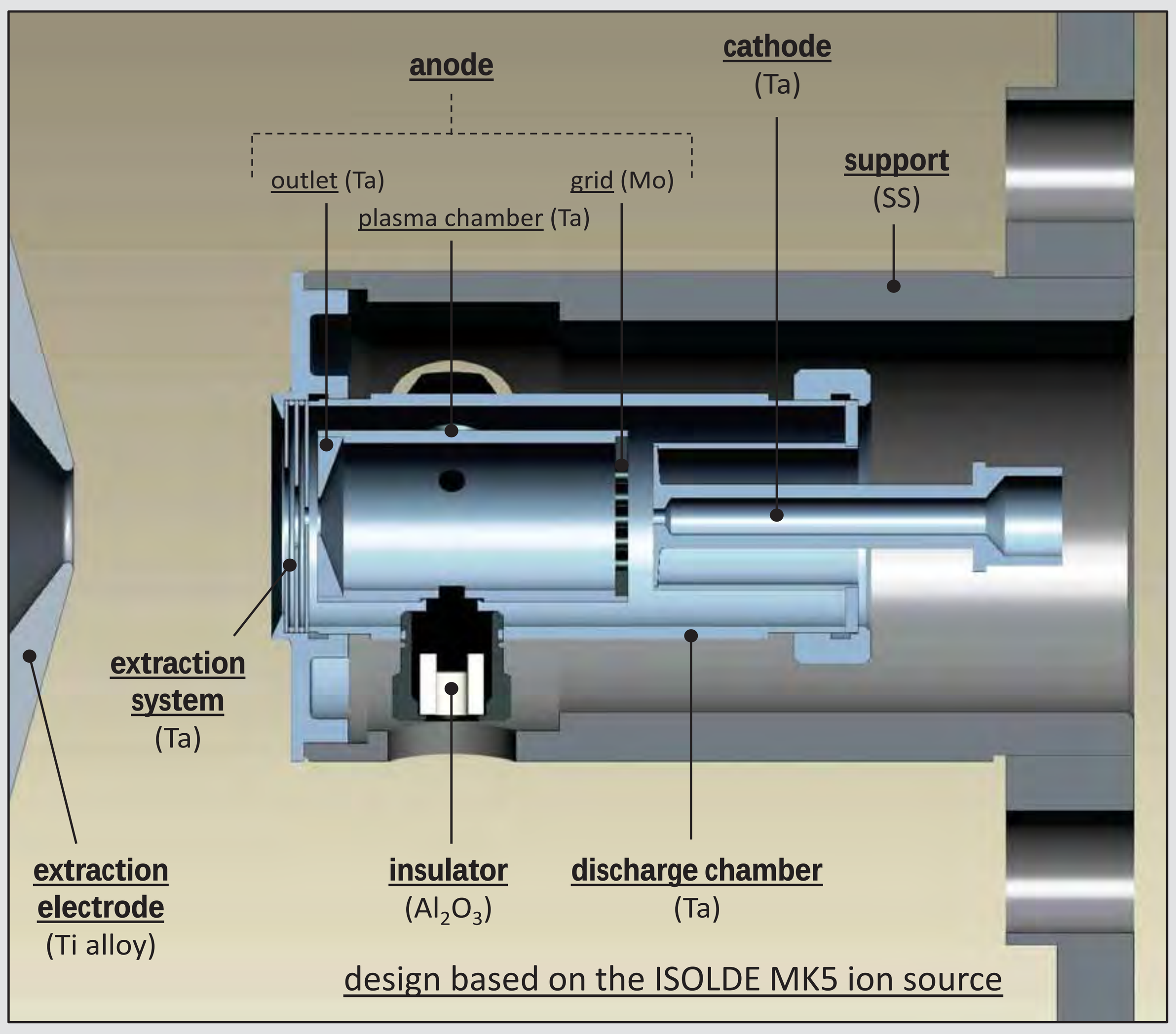
ABSTRACT AND TARGET OF THE STUDY: In the field of isotope separation on line (ISOL) facilities, the plasma ion source[1] (that is a forced electron beam induced arc discharge ion source) is used to ionize a wide range of elements. The aim of this work was to develop a virtual model of the ion source, with the purpose of improving the quality of the design phase. The main components of the ion source are a cathode and an anode, that require a *high temperature field* to allow the ionization with acceptable efficiency: the electron beam that causes the ionization is produced by thermionic effect from the metallic cathode[2]. In this work the *electrical-thermal behaviour* of plasma ion sources is studied in detail by means of coupled field finite element models[3]. Moreover, the thermal behaviour can affect significantly the functioning of the ion source because it modifies the cathode-anode interface distance. Therefore a detailed thermal-structural study is also presented: the temperature data obtained from electrical-thermal model were used as a new thermal load in the *structural model*. After that, numerical results were compared with electric potential difference, temperature, and displacement measurements to validate the electrical-thermal as well as the thermal-structural models. Finally, by considering the plasma ion source the thermionic effect parameter, called ionizing electron current, was measured, and then compared with the analytical values estimated combining calculated temperatures with the well-known Richardson formula and Child-Langmuir relation. The approach presented in this work defines a reference procedure for the electrical-thermal-structural design of plasma ion sources, characterized by improved ionization efficiency.

The SPES target-ion source system

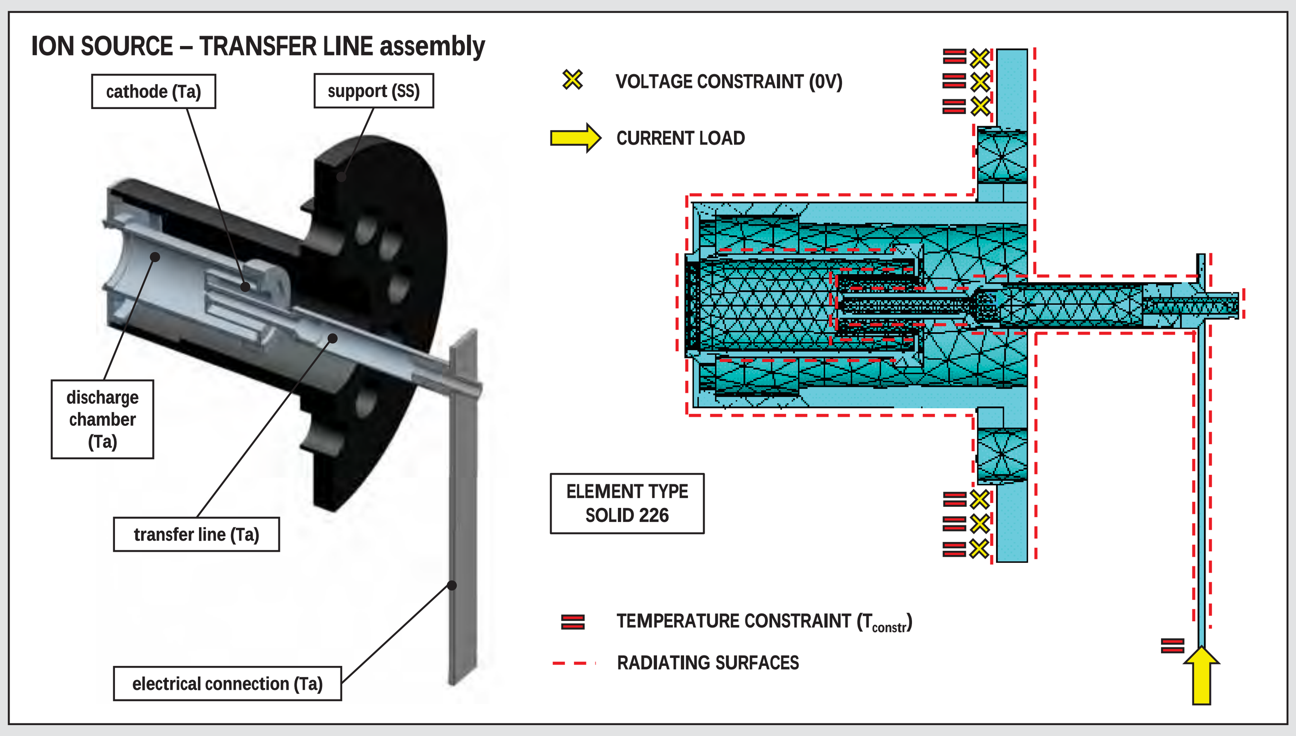


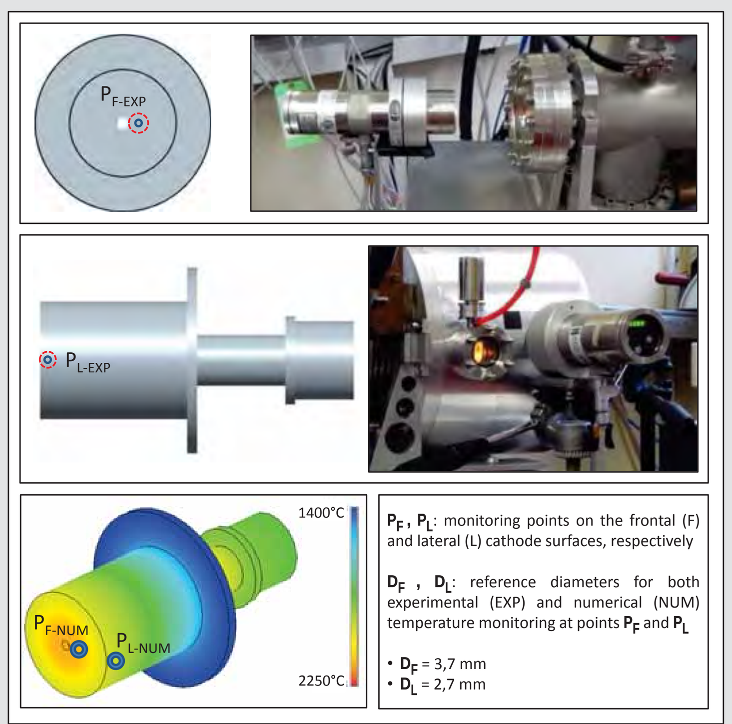


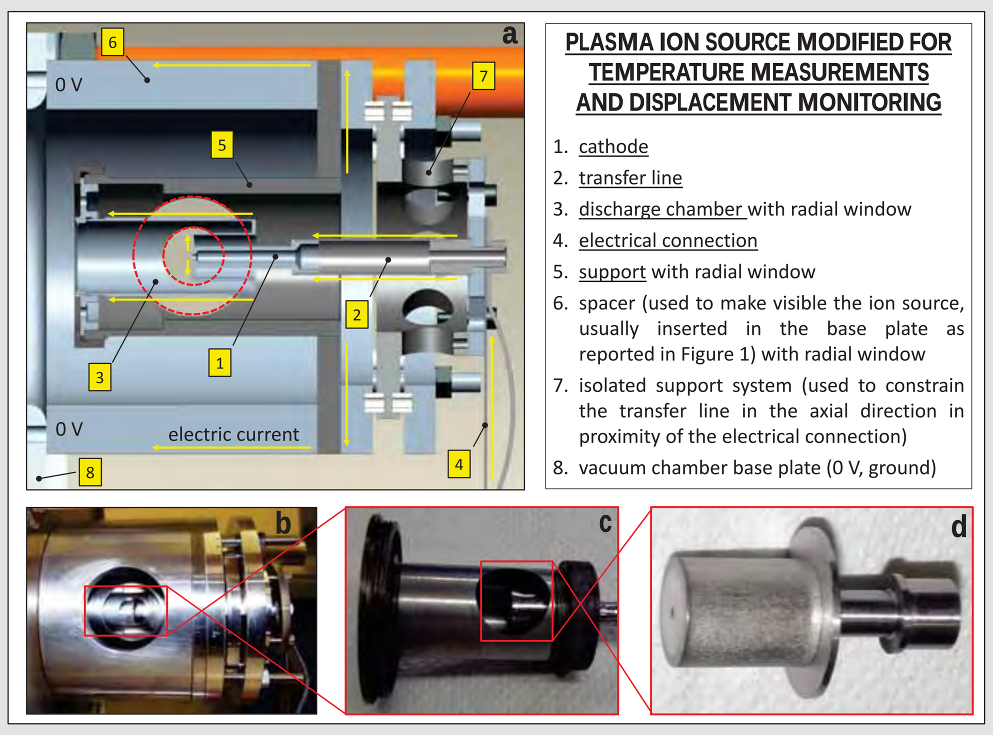
The SPES plasma ion source

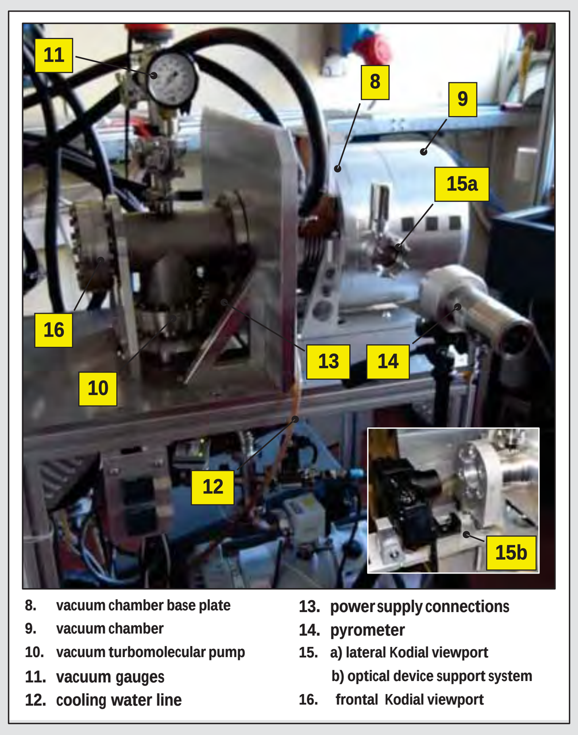


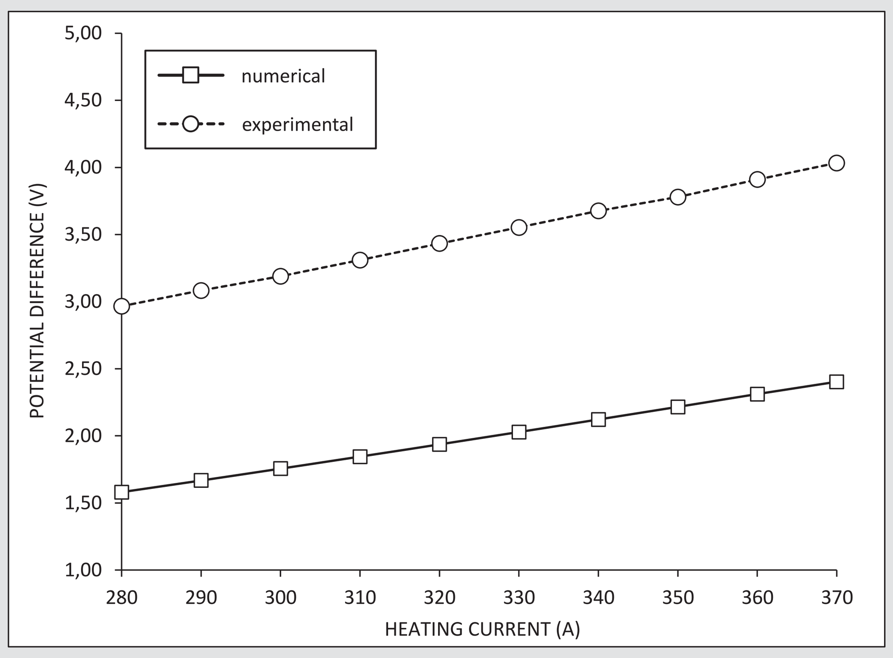
The SPES plasma ion source electrical-thermal model

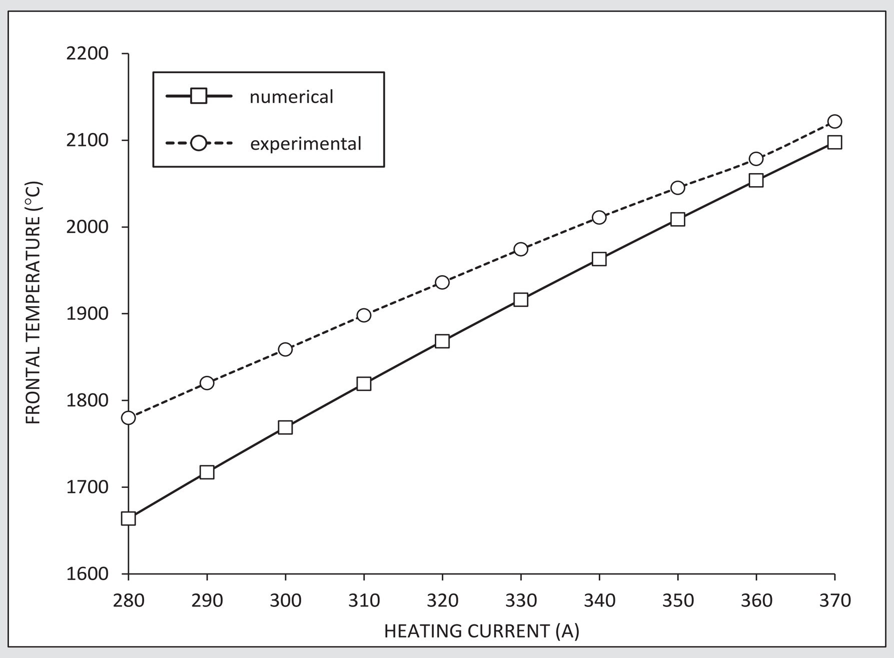


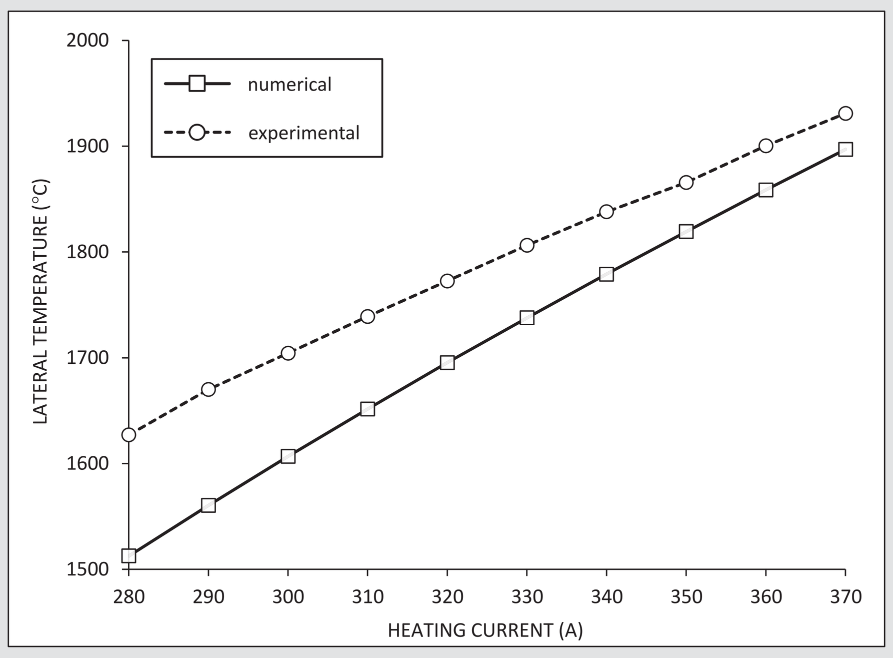


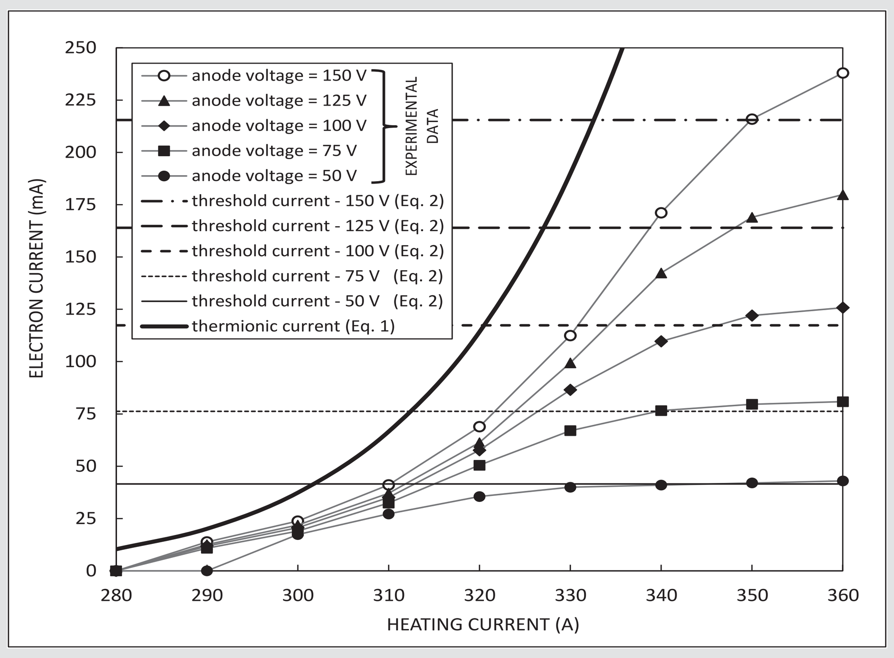




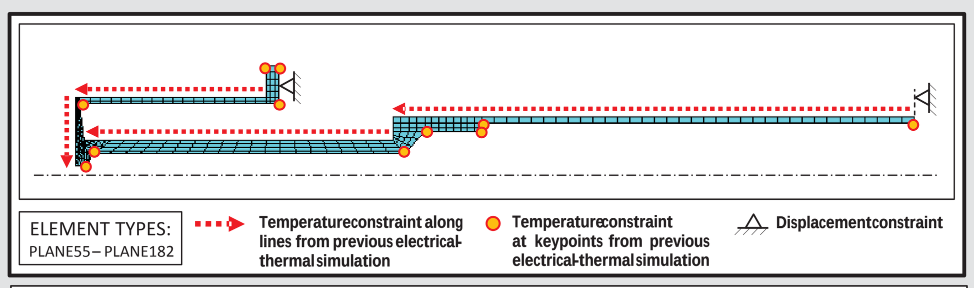


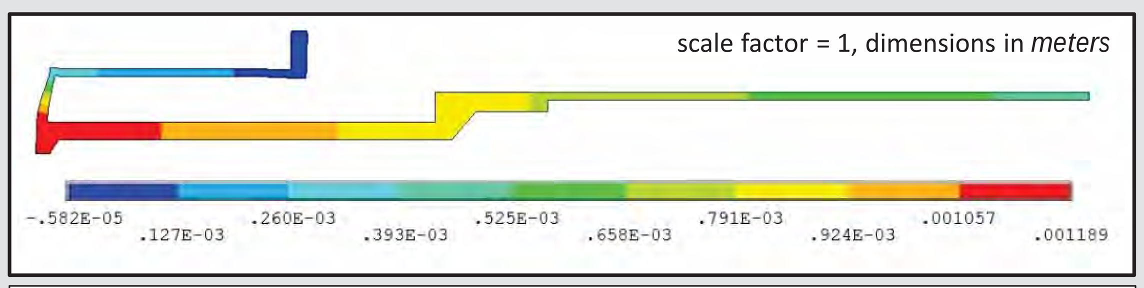


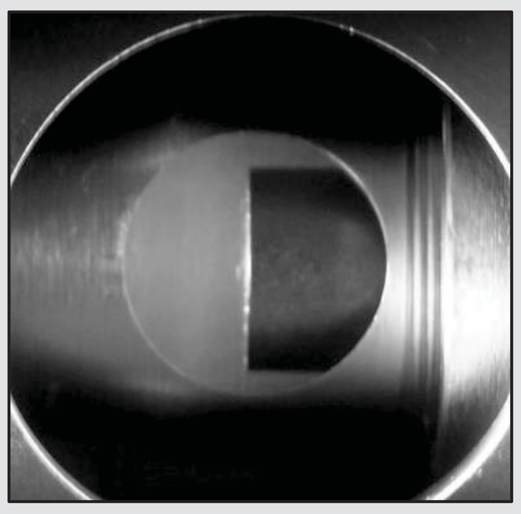


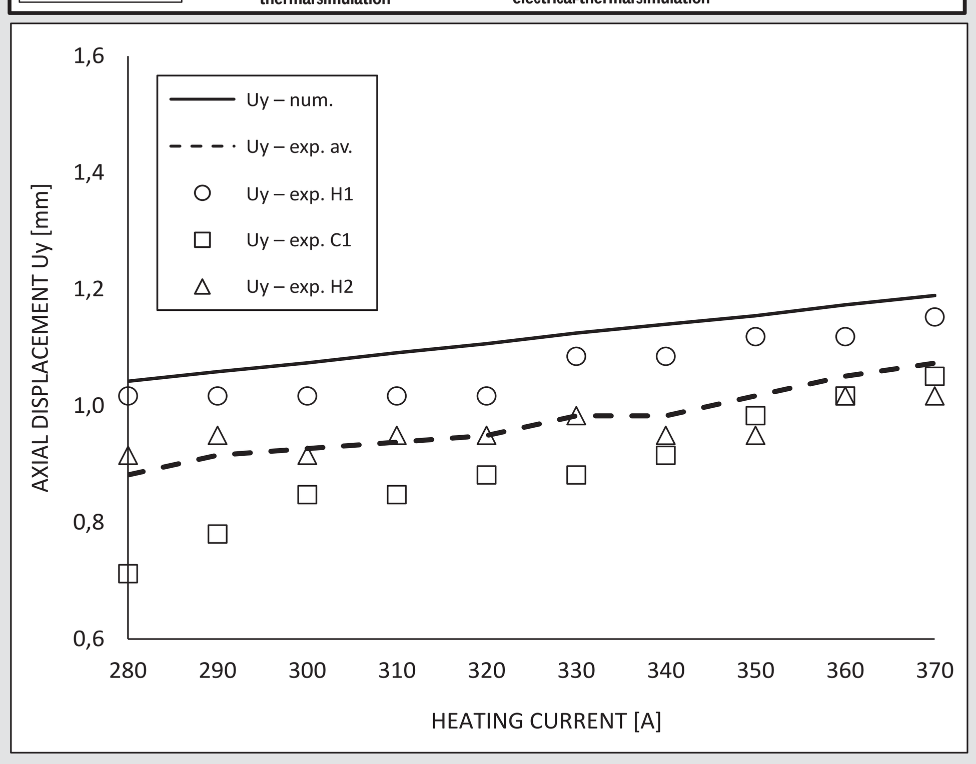


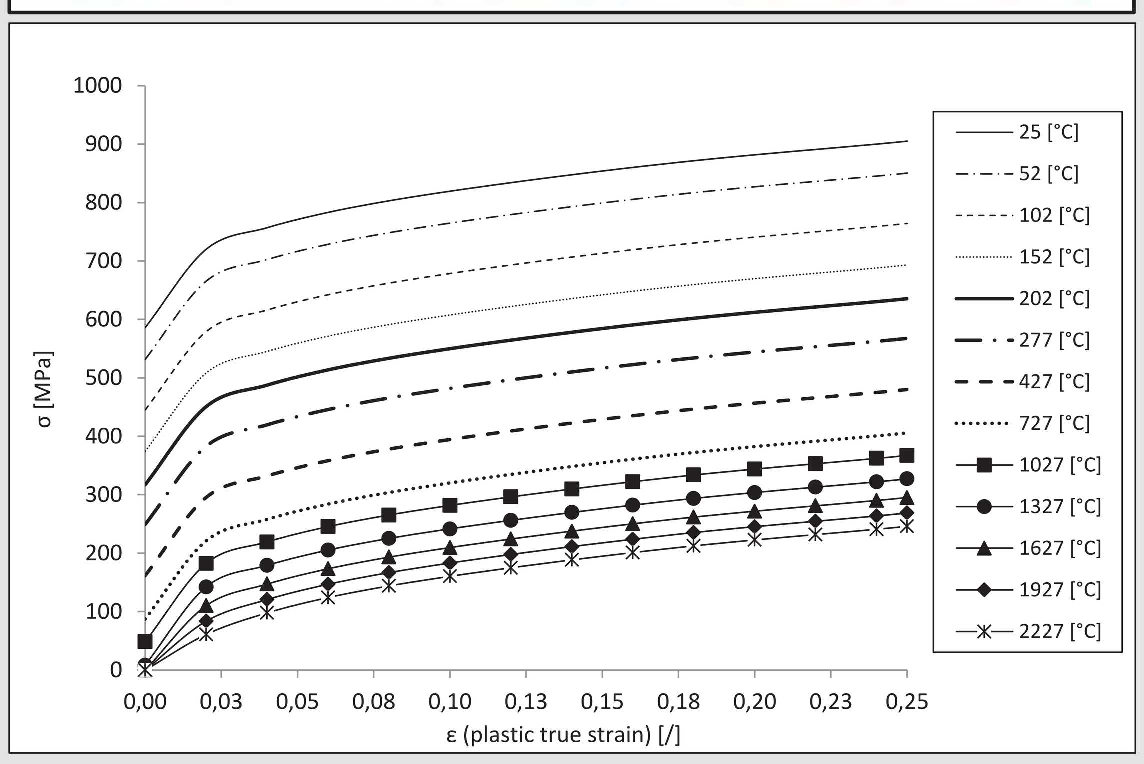
The SPES plasma ion source thermal-structural model

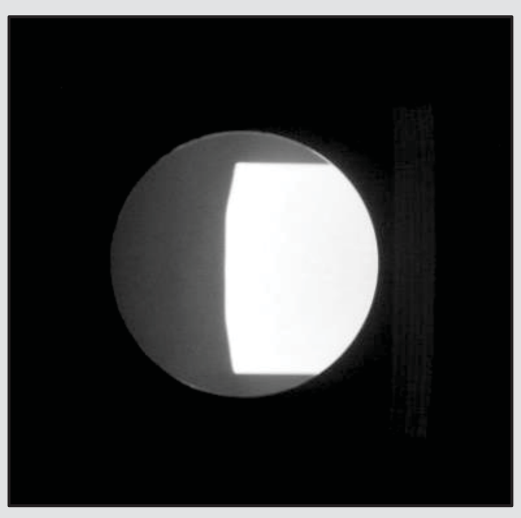












Theoretical Frame

1. Thermionic effect (Richardson formula[2]):

$$J_{em} = A * b * T^2 * exp\left(\frac{-e\phi}{kT}\right) \ [A/_{cm^2}]$$

2. Threshold effect (Child-Langmuir relation):

$$J_{tr} = \chi * V^{\frac{3}{2}}/a^2 \ [A/_{cm^2}]$$

REFERENCES

[1] M. Manzolaro et al., Rev. Sci. Instrum. 85, 02B918 (2014).
[2] B. Wolf, Handbook of Ion Sources (GSI Center for Heavy Ion Research, Darmstadt, Germany, 1995).
[3] G. Meneghetti, M. Manzolaro, A. Andrighetto, Fin. Elem. Anal. Des. 47, 559 (2011).

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