Thermal and plasma modeling of a hot cavity ion source for radioactive ion beam production at ISOL@MYRRHA

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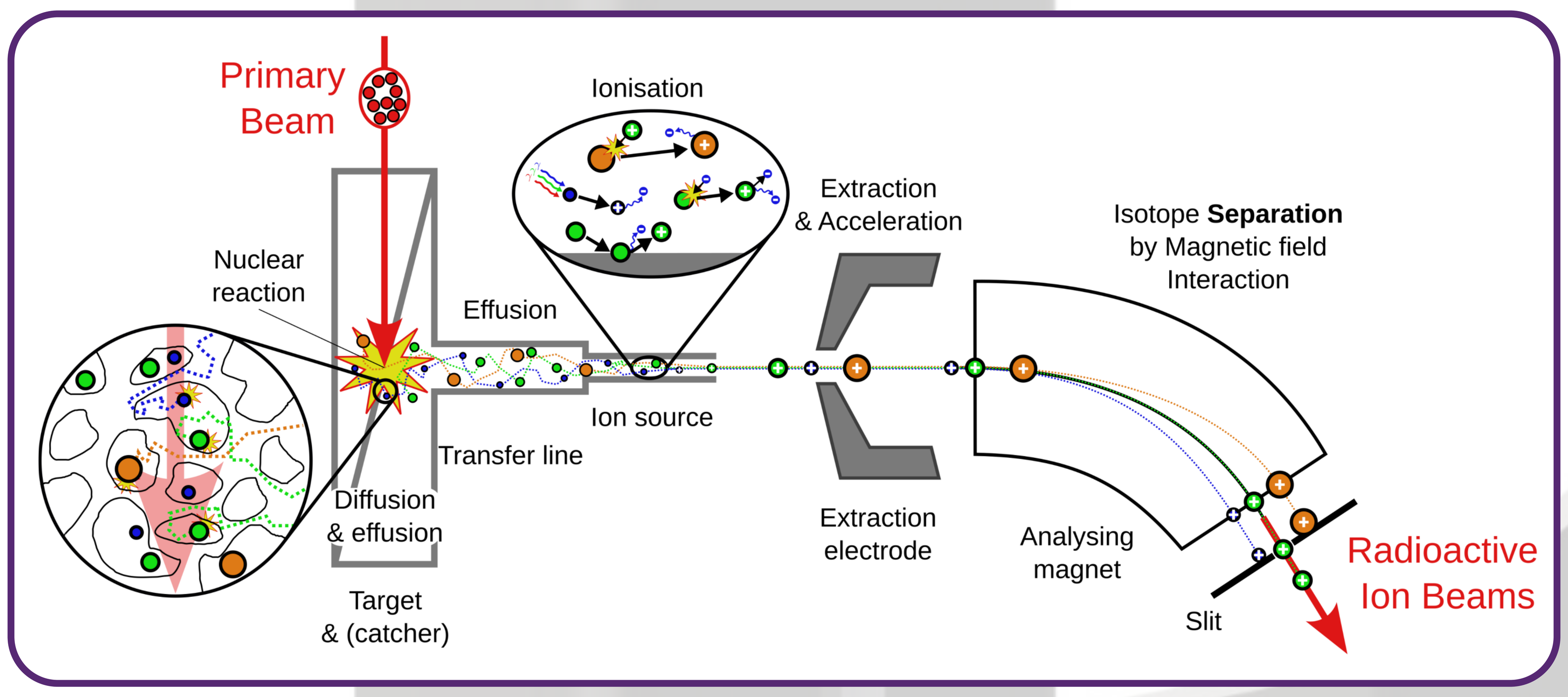
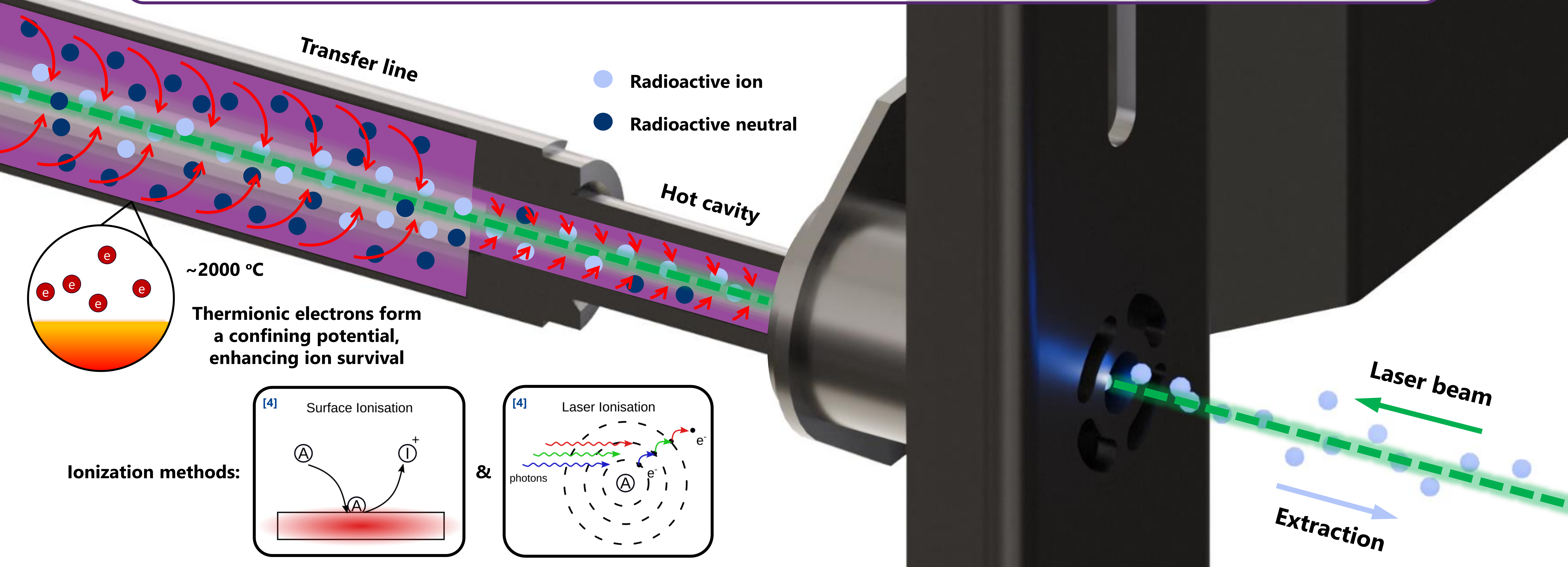
ISOL@MYRRHA & the ion source

ISOL@MYRRHA [1], currently under construction, will be an isotope separation facility designed to produce radioactive ion beams (RIBs) using 100-MeV protons at beam intensities of up to 500 µA. These RIBs support applications in fundamental research, medical research and material science.

A key component of the system is the 'hot cavity' ion source, which relies on surface and/or resonant laser ionization to ionize radioactive isotopes. Temperature and geometry are crucial [2,3], influencing both surface ionization efficiency and ion survival. This work aims to optimize the current ion source prototype by integrating experimental studies with computational modeling to achieve higher efficiencies at higher ion loads.



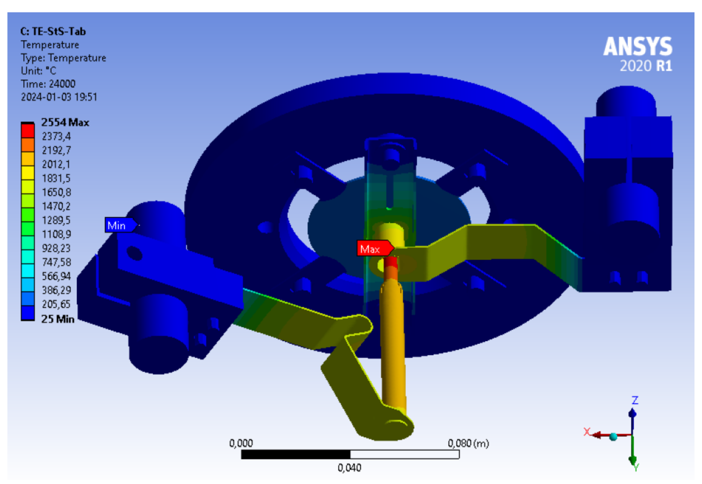
ISOL technique diagram which combines target bombardment, release, ionization, extraction and acceleration [4].



Thermal-electric simulations

A finite element model of the prototype is created in Ansys [5]. Boundary conditions corresponding to the water-cooling mechanism, contact surfaces, and radiative cooling/heating are applied.

The thermal-electric simulation determines the temperature distribution and voltage drop to be used for the plasma simulations.



Example of a typical Ansys thermal-electric simulation [4].

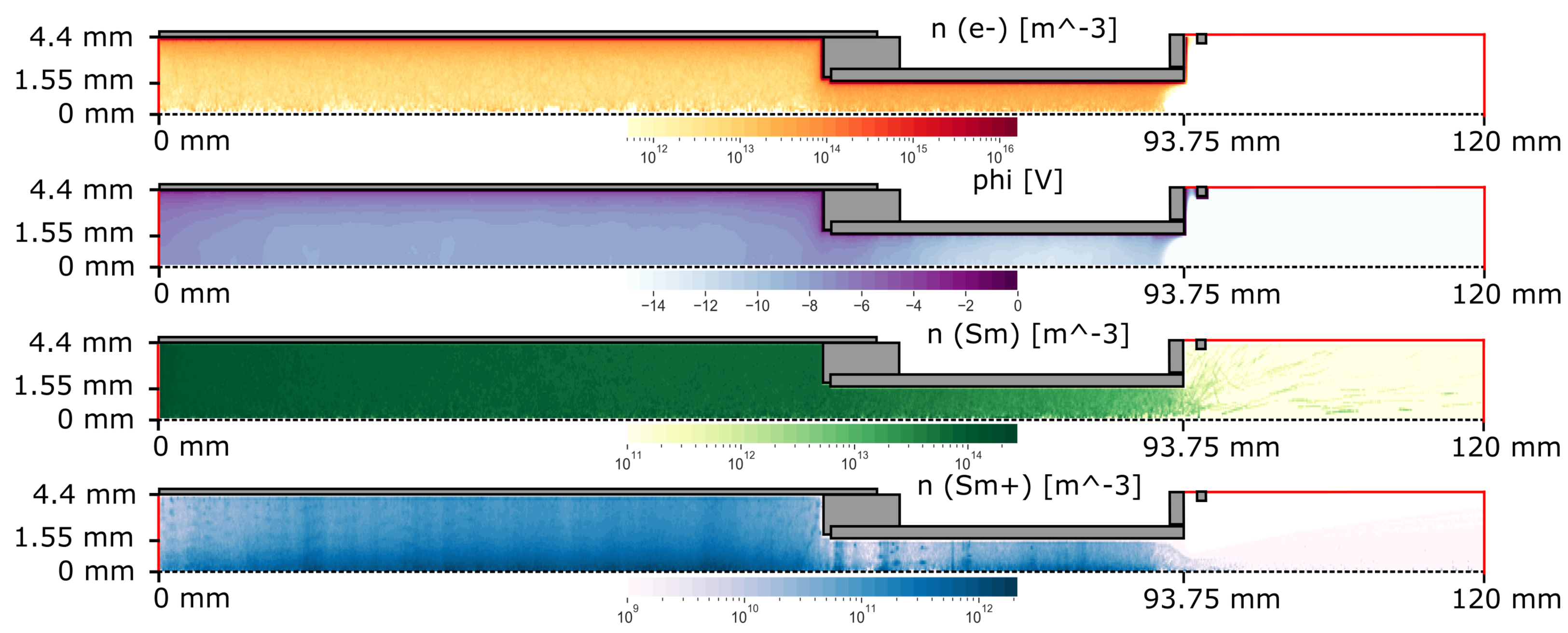
Conclusions

- The thermal-electric model performs well overall, but struggles with the linker region, where a cold spot was not observed in measurements.
- The plasma model demonstrates expected behavior and captures key time-structure features, though further benchmarking is required.

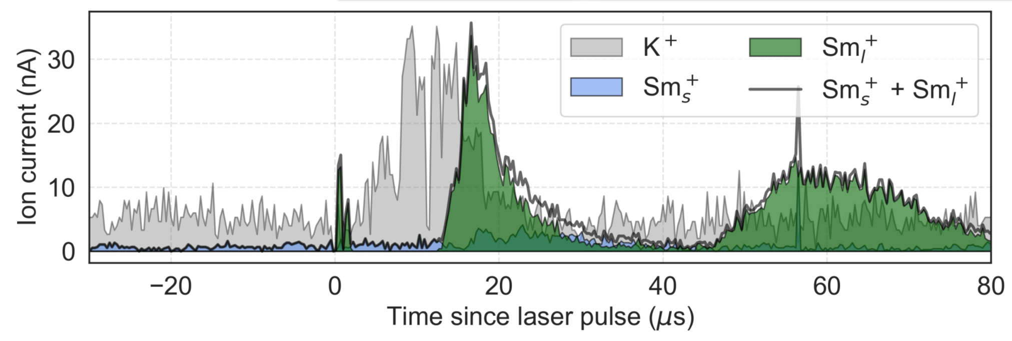
Particle-in-cell plasma simulations

In the particle-in-cell plasma code Starfish [6], a 2D cross-section of the ion source is generated, incorporating surface and laser ionization of samarium, thermionic electron emission, and external electric drift and extraction fields.

The plasma potential from thermionic electrons confines ions along the centerline. The confinement in the linker region is reduced due to a cold spot in the temperature profile.



Simulated n_{e-}, n_{Sm}, n_{Sm+} and ϕ profiles in a hot cavity ion source.



A simulated time-structure profile with a 40 ns laser pulse at time stamp 0 µs.

The simulated time-structure profile exhibits a small pre-peak at 0 µs from laser-generated Sm ions in the extraction region, followed by peaks from ions originating in the hot cavity and transfer line.

References

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[5] ANSYS®, Academic Research Mechanical, Release 20.1
[6] STARFISH®, Particle In Cell Consulting LLC, Release 0.24