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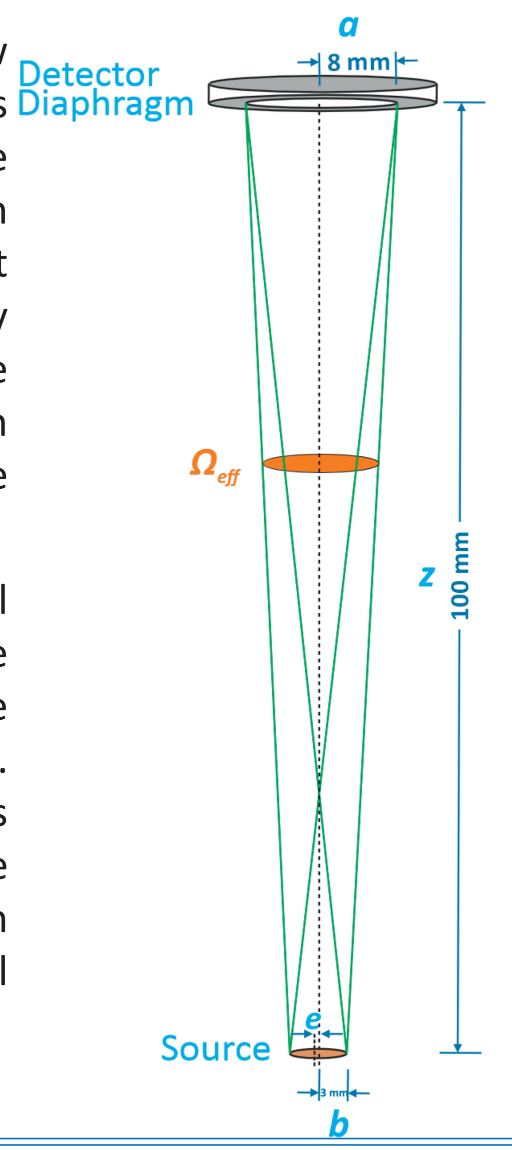
Defined Solid Angle (DSA) alpha spectrometry for absolute Radon-222 activity determination: Thermal modelling of the cryogenic source

Introduction

Defined solid-angle (DSA) alpha spectrometry is an accurate primary method for the absolute activity determination of Radon-222 [1–6].
In our previous study, the sensitivity of the geometry factor (G) in this method to geometrical parameters was investigated [7]. It was demonstrated that the source-to-diaphragm distance (z) is the dominant contributor to the uncertainty budget, whereas the source radius (b) has only a minor influence under typical NMI operating conditions.

To reduce the uncertainty of G below 0.1%, Finite Element (FE) simulations using COMSOL Multiphysics® were applied to optimize the system geometry. The results indicated that optimization of z is accompanied by an increased contribution of b to the measurement uncertainty, since both parameters exhibit temperature dependence.

In the present work, the thermal distribution within the source assembly and its dependence on the system geometry are investigated. Furthermore, an uncertainty analysis was performed to evaluate the effects of the geometry optimization and its impact on the total measurement uncertainty.



DSA alpha spectrometry

Primary method:

Cryogenic radon deposition on a cold surface under ultra-high vacuum (UHV) conditions (T < 100 K)

Activity determination:

$$A = \frac{\text{Counting rate}}{G}$$

Geometry factor:

$$G = \frac{\Omega_{eff}}{4\pi},$$

where Ω_{eff} is the effective solid angle.

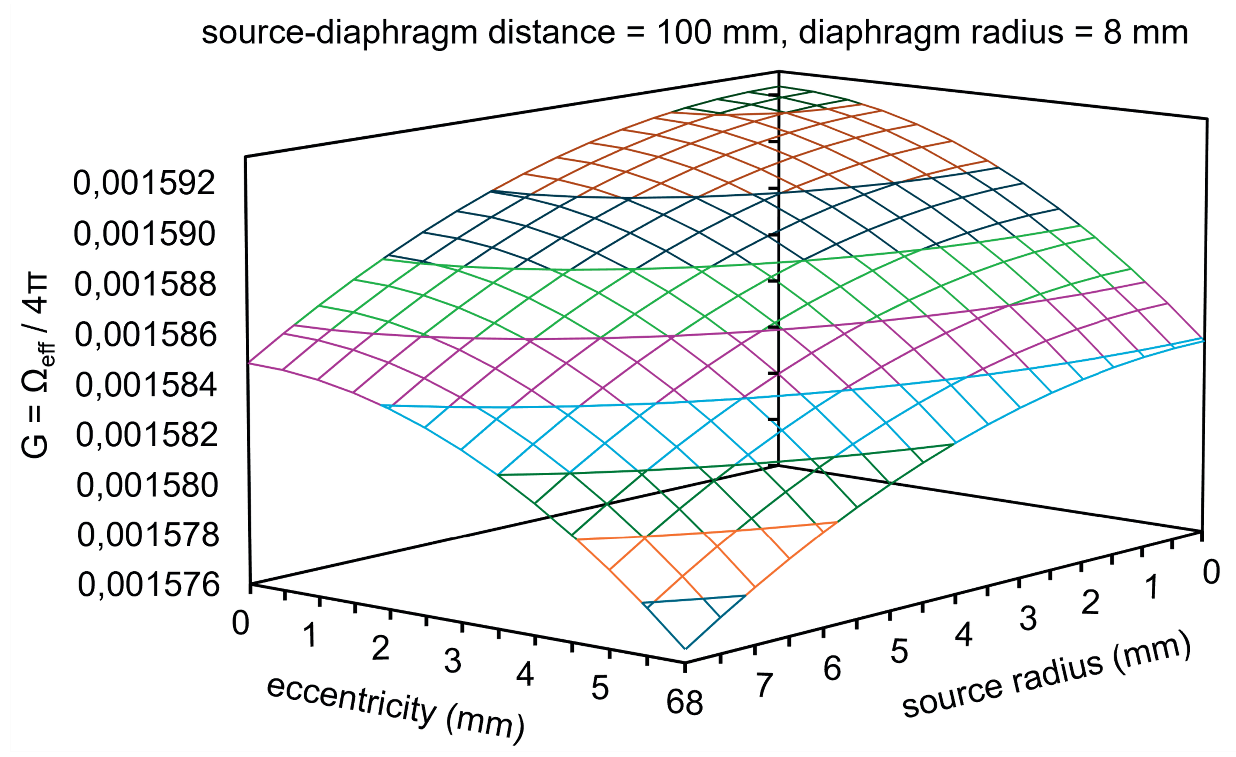
Key point:

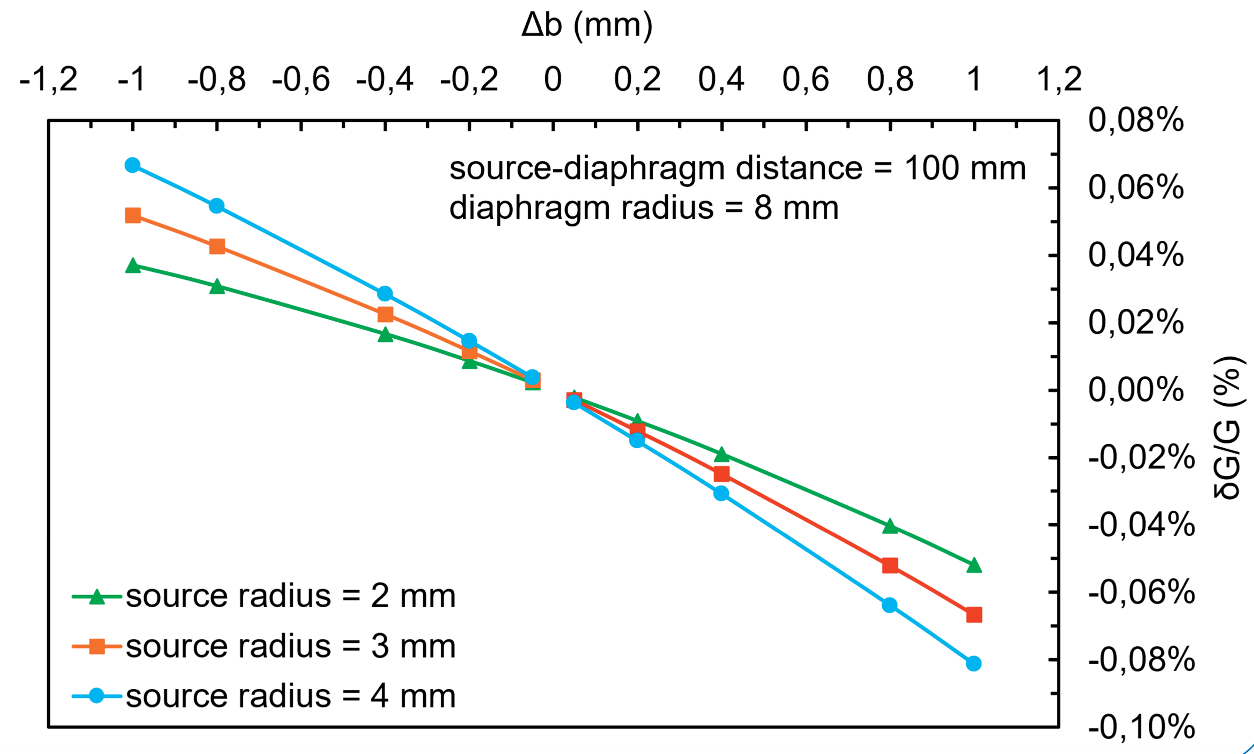
The geometry factor G depends on several geometrical parameters. Therefore, accurate knowledge of the measurement geometry is essential for achieving low-uncertainty activity determinations.

Geometrical parameters:

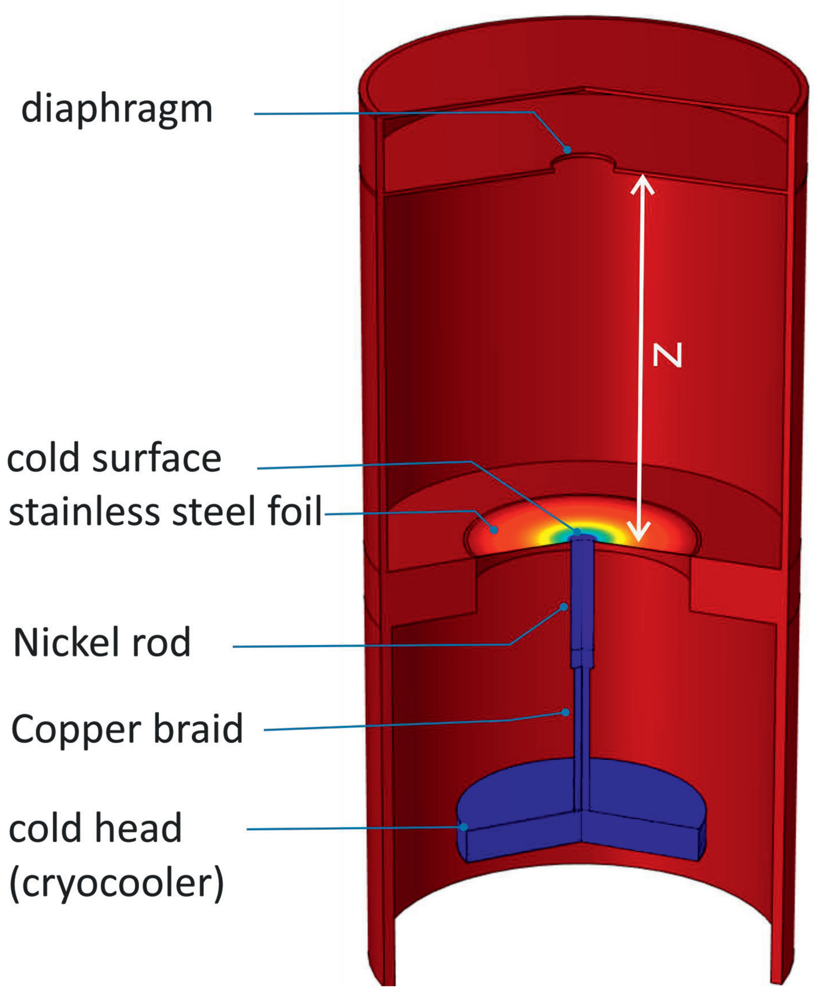
- *a: diaphragm radius,*
- *b: source radius,*
- *z*: source-diaphragm distance,
- *e*: eccentricity between the source and diaphragm axes.

Geometry Factor sensitivity to source radius [7]

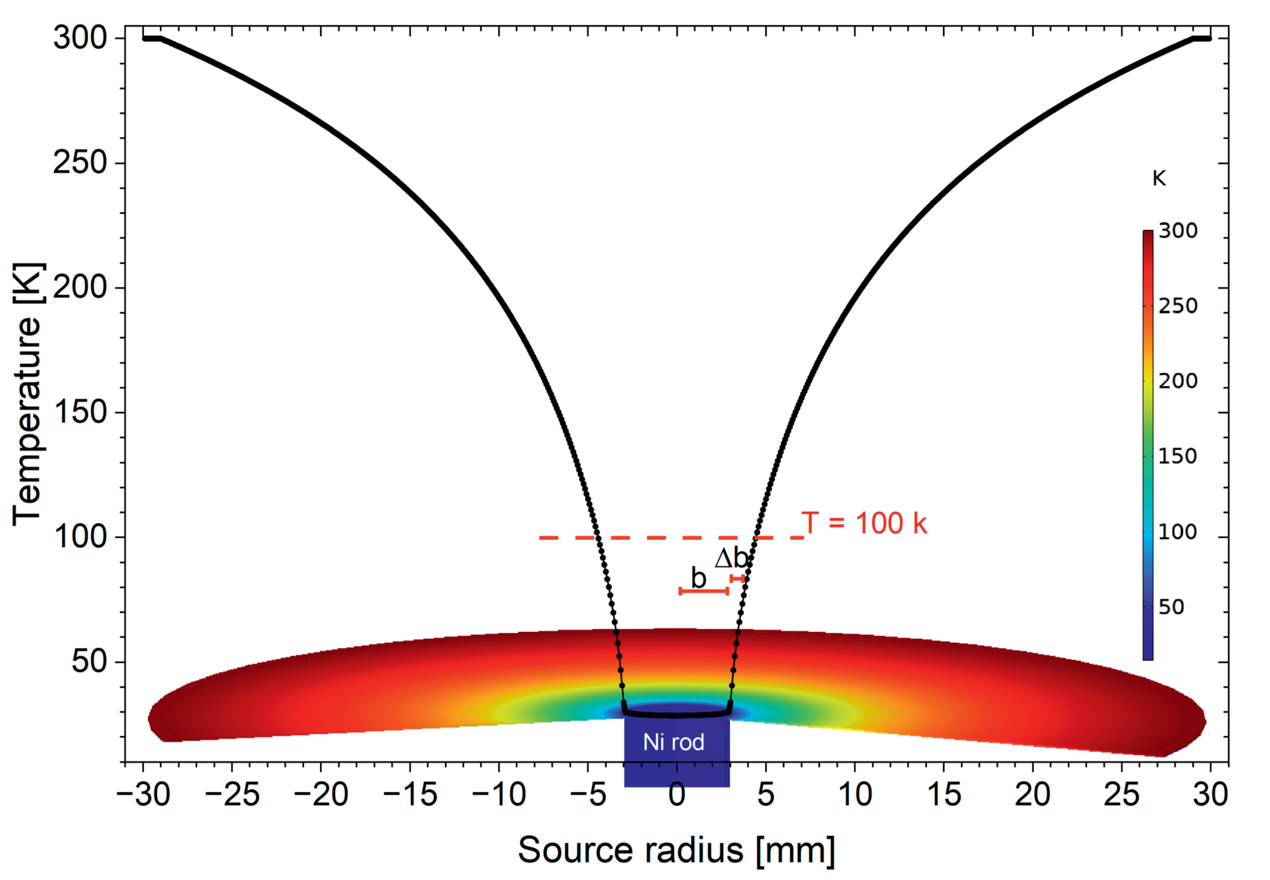




Geometry of the simulated system

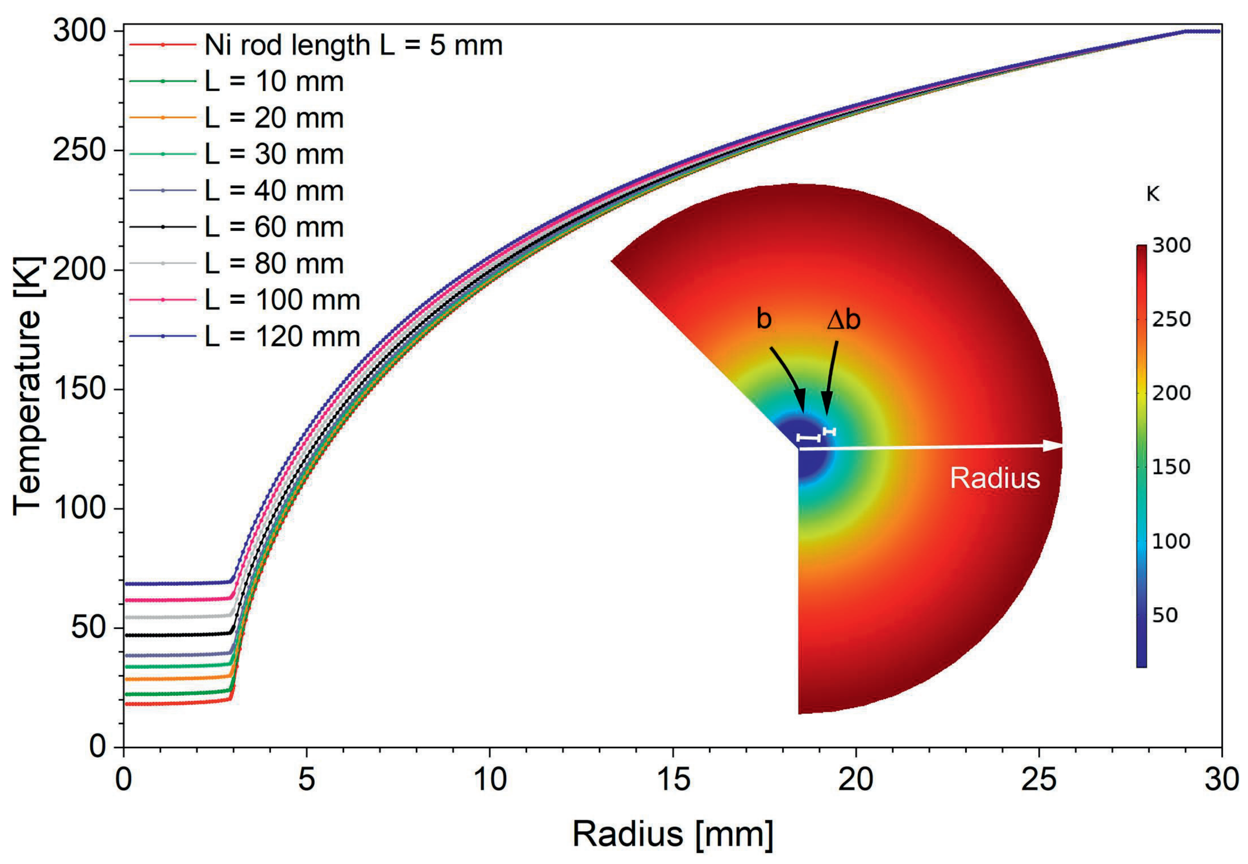


Temperature distribution of the source assembly

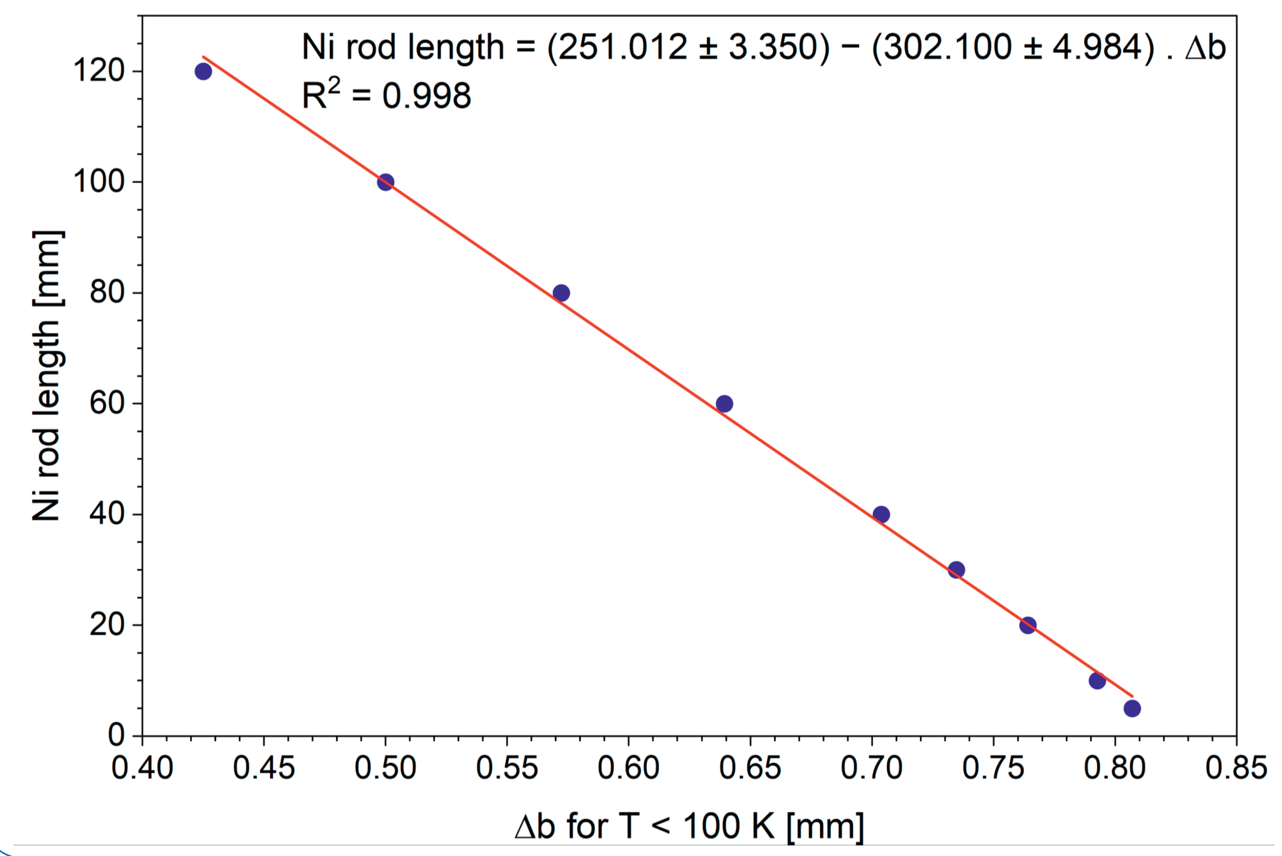


- Thermal simulations enable estimation of source radius variation (Δb).

Influence of system geometry on source radius



- Shorter Ni rod → higher cold-surface temperature → larger effective source radius.



Conclusion

- Finite Element (FE) method simulations can be used to estimate the effective Radon-222 source radius in Defined Solid Angle (DSA) alpha spectrometry.
- COMSOL Multiphysics® simulations show that the source radius depends on the cold-surface temperature. Lower temperatures lead to a wider spread of deposited radon and consequently a larger effective source radius.
- Although shortening the Ni rod increases source spreading by lowering the cold-surface temperature, the total measurement uncertainty is reduced because the Geometry Factor G is considerably more sensitive to the source-to-diaphragm distance (z) than to the source radius (b).
- FE simulations provide a reliable tool for source-radius estimation and can complement preliminary autoradiography measurements in the DSA method.

References

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