Holistic approach to investigate burn-up depended thermal conductivity in dispersed fuel plates

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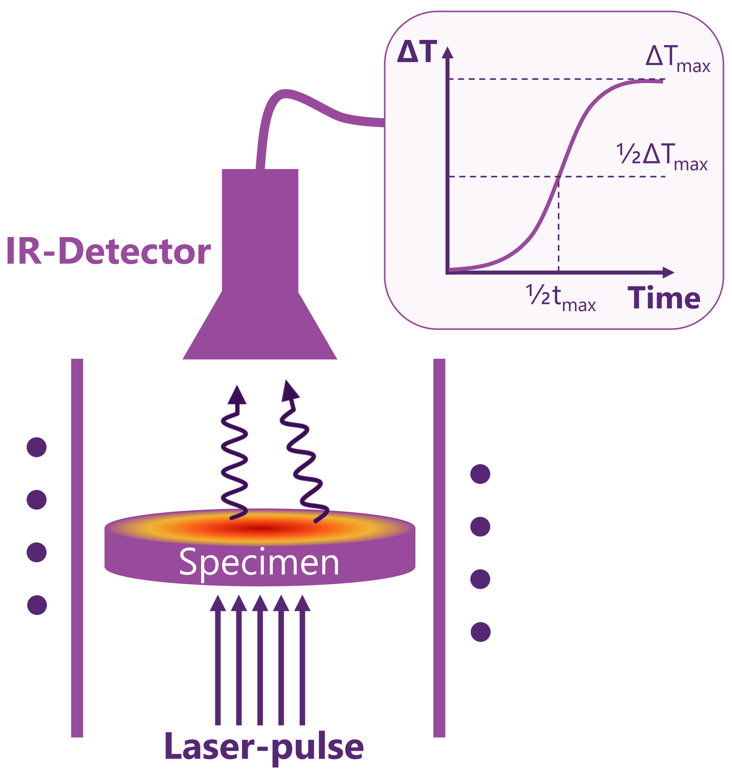
Introduction

The HEU to LEU conversion of high performance research reactors based on dispersed UMo and U_3Si_2 fuel systems represents a major challenge in context of thermal properties. Significant decrement of the thermal conductivity with accumulative burn-up leads to the demand of a detailed investigation into the root causes and impacting factors. These include microstructural changes in the fuel and its matrix material, such as interaction layer formation. In order to deduce a thermal conductivity / burn-up relation a holistic investigation and modeling approach based on macro- and micro-thermal analysis is being conducted.

HEU ... high-enriched uranium   LEU ... low-enriched uranium

Laser-flash-analysis

- Standard measurement tool for thermal diffusivity (α)
- Thermal conductivity (κ) determination via: $\boxed{\kappa = \alpha \cdot \rho \cdot c_p}$



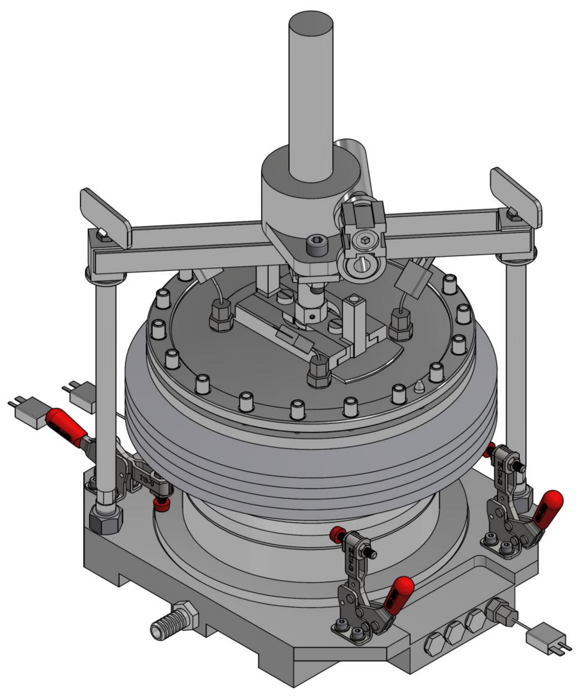
- Secondary measurements: Pycnometry (ρ) and Differential Scanning Calorimetry (c_p)
- Carbon coated specimen
- Intensive sample preparation
- High multi-factor uncertainty

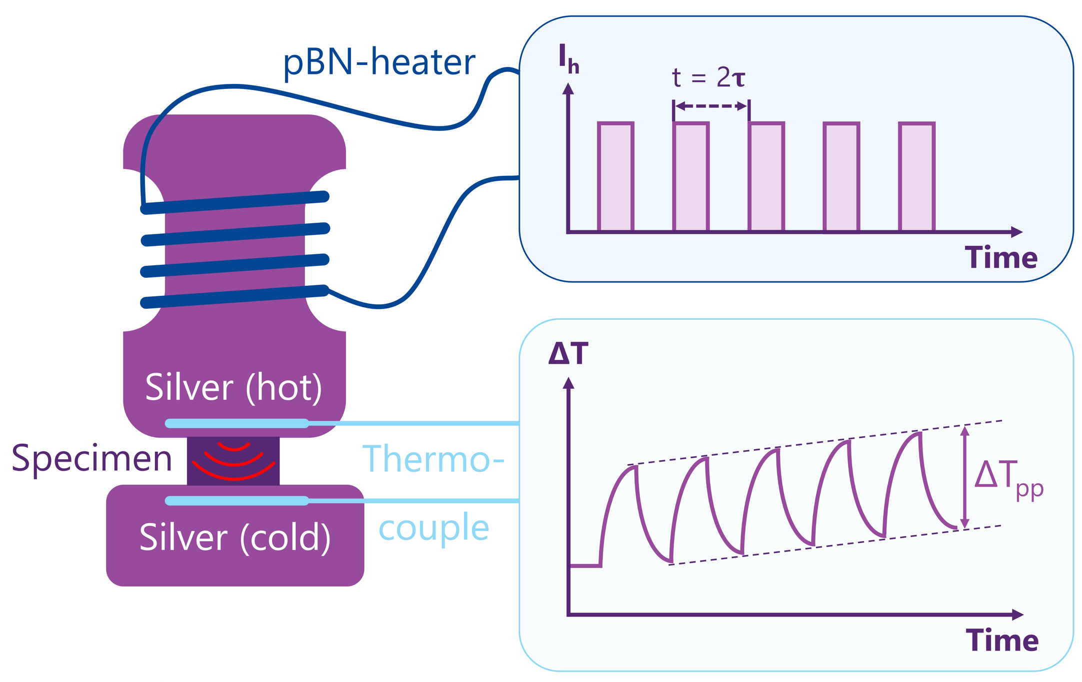
MALDONADO-method

- Pulsed power method utilizing transient heat diffusion
- Numeric solved conductivity (κ) via: $\boxed{\kappa = \frac{RI_h^2}{\Delta T_{pp}} \tanh\left(\frac{\kappa\tau}{2C_s}\right)}$

RI_h^2 ... Electric resistance and pulsed heater current
C_s ... Heat capacity of heat source

- Simple sample preparation, fast measurement
- Direct thermal conductivity access, reduced uncertainty





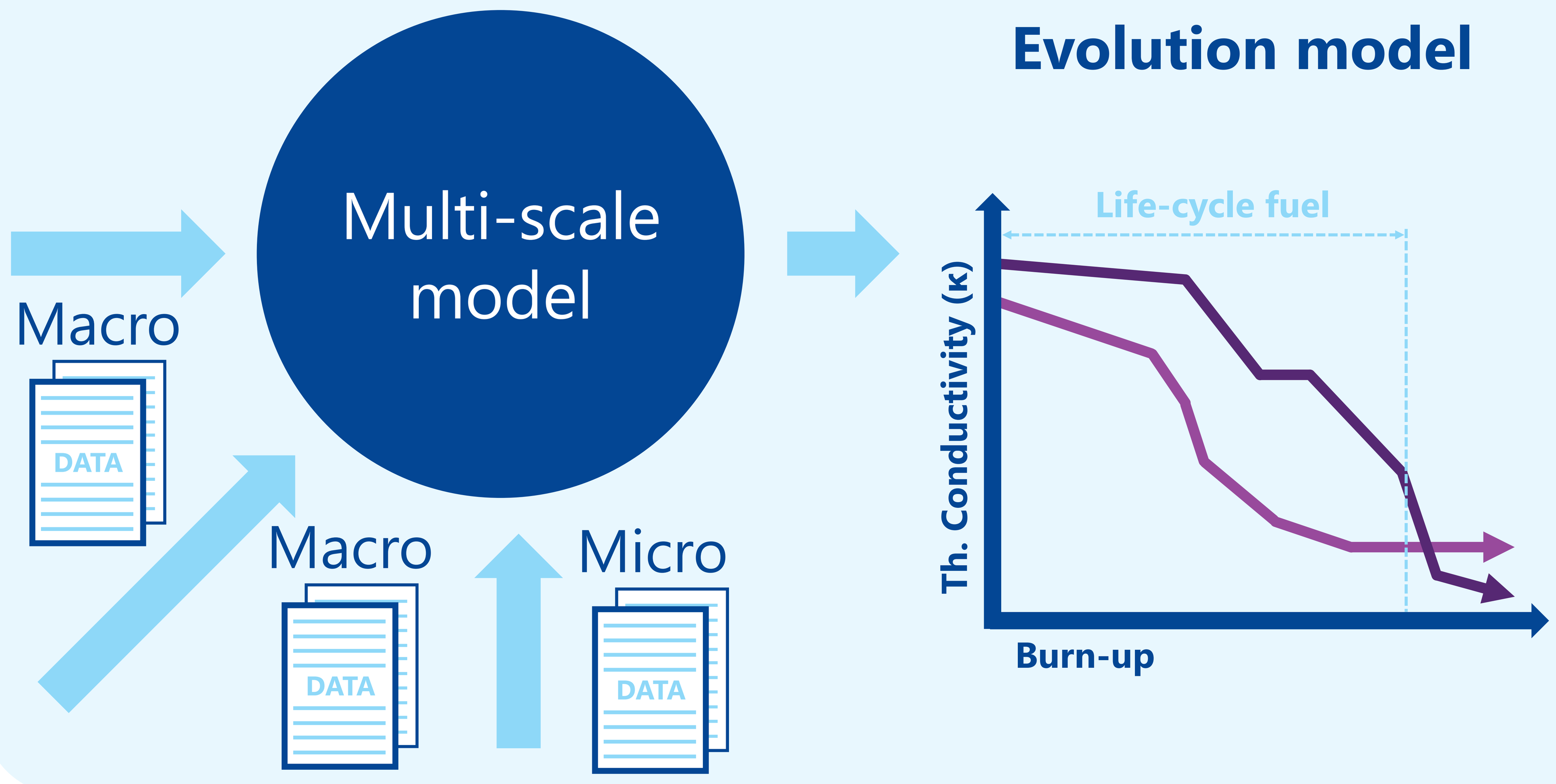
pBN ... Pyrolytic Boron Nitride

Major objectives

- Integration / validation of MALDONADO-method
- Microstructural and thermal analysis with burn-up accumulation, evaluate thermal activated phenomena
- Determine extensive thermal data for dispersed fuels
- Integration of micro-/macro-data in multi-scale model
- Derivation of thermal conductivity evolution model

Multi-scale-modeling

- Micro-specimen composition and burn-up resolved multi-scale model detailing macroscopic results
- Derivation of thermal conductivity / burn-up relation over fuel life-cycle



Micro-device

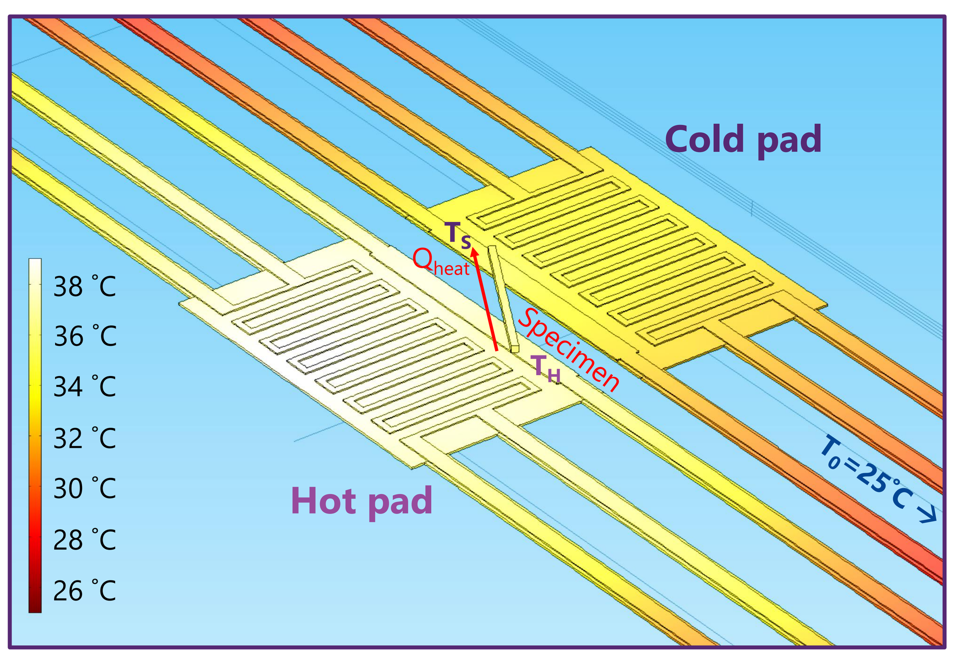
- Micro-device for measurement of micro-specimen based on thermal suspended bridge method
- Measurement based on steady state heat flow

$\boxed{Q_{heat} = G_S(T_H - T_S) = G_L(T_S - T_0)}$

G_S ... Conductance through specimen
G_L ... Conductance towards surrounding

$\boxed{G_S = (L_S/\kappa_S A_S + G_C^{-1})^{-1}}$

L_S ... Micro-specimen length
A_S ... Micro-specimen conductive area
G_C ... Pad/Specimen contact conductance



- Specimen fabrication destructive by focused ion beam
- Determination of local microscale thermal conductivity

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