Why cryogenic composite detectors?

- High target mass (ton scale)
- Large scale production of the detector modules
- Detectors with very similar properties
- Reproducibility of production
- Possibility to employ multi-material targets
- Introduction of a detector design that allows the use of different absorber materials
- Detailed understanding of the detector response
- Thermal model for the chosen detector design

Composite detector design (CDD)

- Use small Al2O3 substrates (3 × 3 × 1 mm³)
- Fabrication of the TES on a separate substrate
- Choice of the target material and thus avoid decoupling the W-TES production from the absorber
- Absorption in the TES is filled with non-thermal phonons
- Suppression of γ and β background by phonon-light-technique

Example: Composite detector with sapphire absorber

Sapphire substrate (5 × 3 × 1 mm³) with deposited W-TES (2–2 nm) is glued on absorber substrate (sapphire, 10–20 mm³). / Direct deposition of the W-TES (2–2 nm) on the surface of the absorber crystal by gluing.

TES working principle

→ Composite Detector Design

Composite detector design (CDD)

- Use small Al2O3 substrates (3 × 3 × 1 mm³) for fabrication of the TES on a separate substrate
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Example: Composite detector with sapphire absorber

Sapphire substrate (5 × 3 × 1 mm³) with deposited W-TES (2–2 nm) is glued on absorber substrate (sapphire, 10–20 mm³).
- Direct deposition of the W-TES on the surface of the absorber crystal
- Fabrication of the TES on a separate substrate
- Use small Al2O3 substrates (3 × 3 × 1 mm³) for the deposition of the W-TES
- Production of several TESs in one step with similar properties

→ Allows testing of the TESs
→ Avoids heating cycles of the absorber (no oxygen loss of the crystal)
→ Enables large-scale production

Thermal detector model for cryogenic composite detectors

Basic thermal detector model

Model of the detector response (pulse shape) dependent on basic detector components [F. Probst et al., J. Low Temp. Phys. 100, 69 (1995)]

- Modelling of the detector response (pulse shape) dependent on basic detector components
- Include glue and TES-substrate into the model: a: as thermal contribution to the thermal detector model (see left)
- Influence of these components on the pulse shape (evolution and propagation of phonons)?
- Identification of dominant contributions to the signal in the TES

- Thermal detector model for cryogenic composite detectors
- Include glue and TES-substrate into the model: b: as thermal and non-thermal phonon propagation possibilities
- Most important propagation possibilities for the non-thermal and thermal phonons

- Remaining non-thermal and thermal phonon propagation possibilities
- Thermal contribution along path 1.2 (results in one decay time τₚₚₚ)
- Depend on the effective TES-to-gluco-area ratio
- Compensation between non-thermal and thermal contributions

Future experiments and developments

Future investigations for tailoring cryogenic composite detectors to the requirements of dark matter search experiments:

- Additional tests of the developed thermal composite detector model
- Determine TES-detector lifetime (rise and decay time)
- Inject thermal phonons only (via heaters) into the absorber
- Build composite detectors with well-defined different effective TES-to-gluco-area ratios to test the predictions of the model
- Optimise glue-to-TES-area ratio for CRESST-like detectors
- Improve reproducibility of TES production (transition temperatures)
- Add phonon collectors to the TES on the small substrate to support efficient phonon collection in the TES-detector