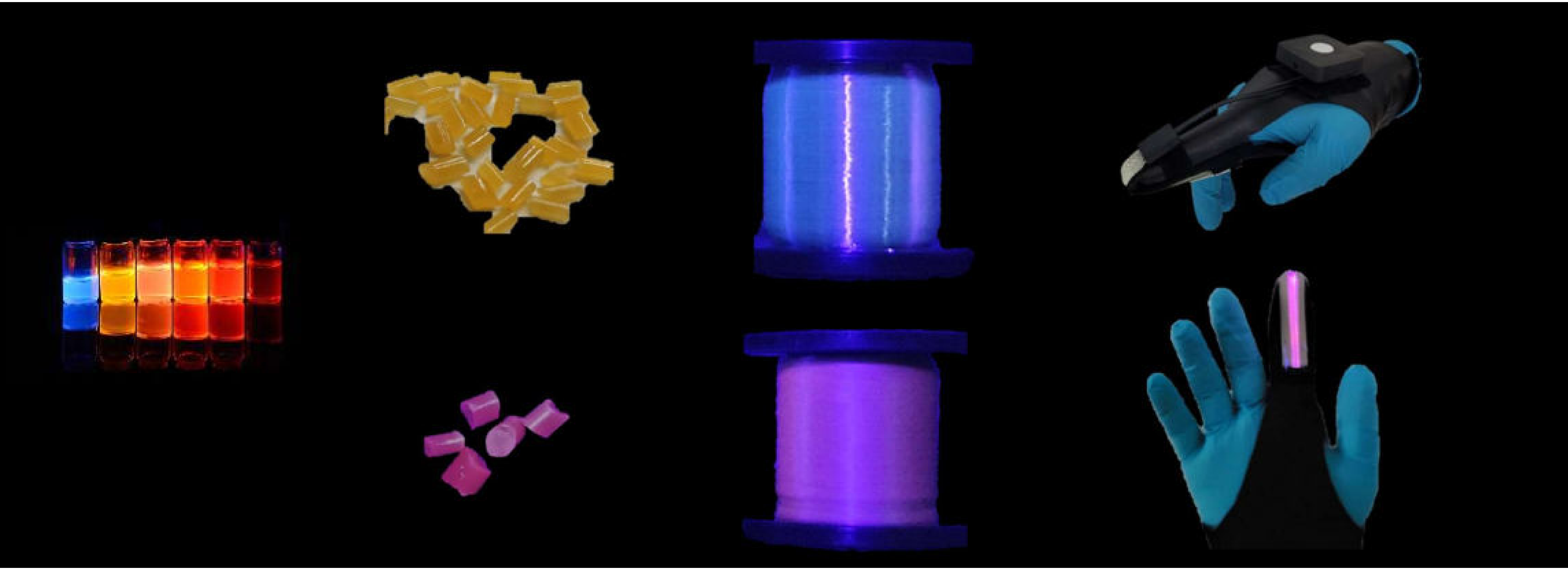

QDotFibreSense - Development of a rapid test system based on quantum dot functionalised filaments for explosive substances as a sensor glove for security forces

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1st Digital Smart Material Summit | 16th May 2023

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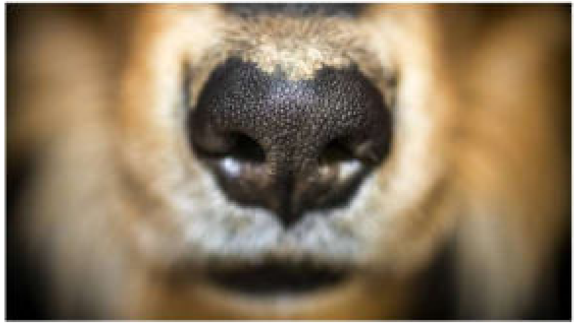
Introduction and Motivation

Security Checks

- Growing globalization lead to a steadily increasing number of travelers on airplanes
- Security checks at airports, stadiums or concert halls
  - Reduction of long queues
  - Quick and extensive implementation of security controls
- Current Methods for detection of hazardous substances:
  - Olfactory sensing by animals (e.g. sniffer dogs)
  - Swab tests in stationary spectrometry devices
    - → time-consuming and cost-intensive
    - → either long queues and/or inadequate checks at random
  - Other detection methods have been described, but not industrially implemented



"Itemiser 4DX" for explosives by Rapiscan Systems

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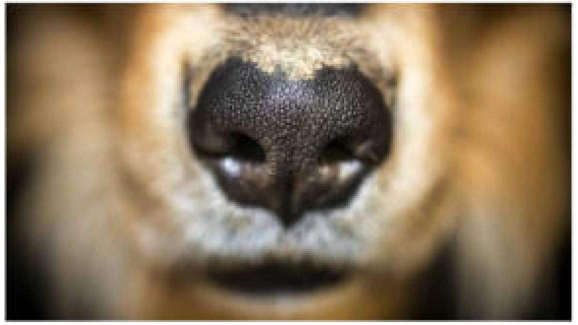
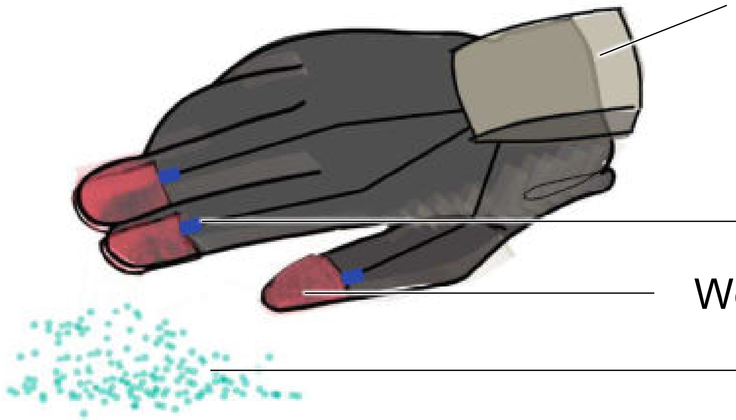
- Aim
  - Faster yet more comprehensive checks
  - Textile integrated low-investment sensor with swab tests



"Itemiser 4DX" for explosives by Rapiscan Systems

Concept of the sensor glove

- Textile glove with sensory areas at the tip of the fingers
- Custom-made electronics for power supply and control
- Exchangeable sensory ribbons



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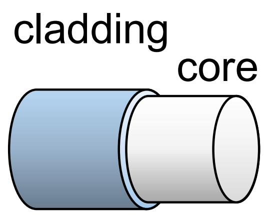
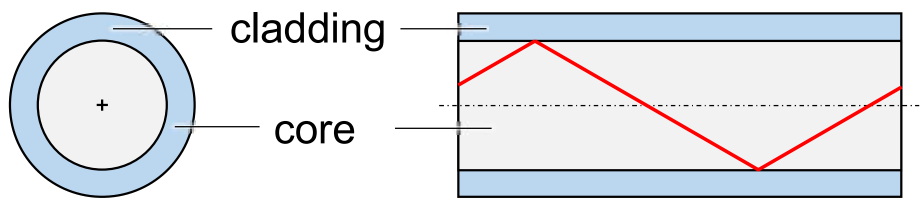
Introduction and Motivation

Polymer optical fibres

- Fiber Core:
- Cylindrical and highly transparent polymer
- Light conducting part of the fibre
  → Here: PMMA: Plexiglas 7N by Röhm GmbH, Darmstadt, Germany



- Fiber Cladding:
- Creates constant light conduction by means of total reflection
- Concentrically surrounded by a fibre cladding with a lower refractive index
  → Here: SiQD-doped PMMA by Applied Quantum Materials Inc., Edmonton, Alberta, Canada



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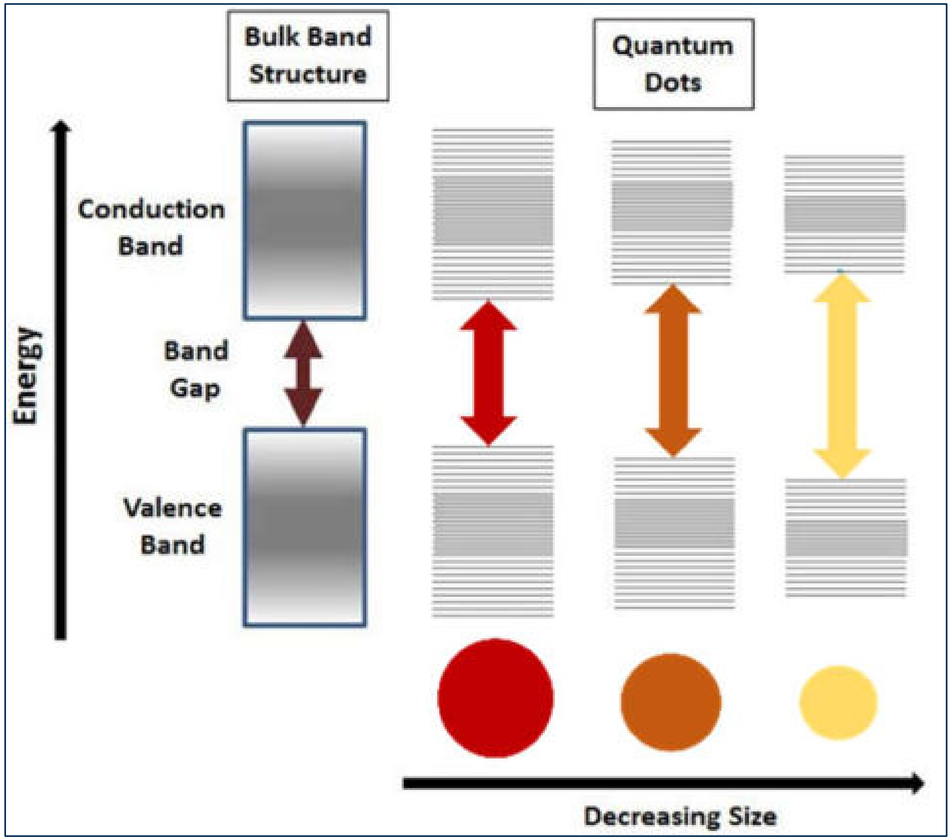
Introduction and Motivation

Quantum Dots

- QDs nanosized semiconducting material
- Diameters in range of 2-10 nm
- e- confinement and discrete energy level
- Decrease in size increase band gap



Introduction and Motivation

Quantum Dots

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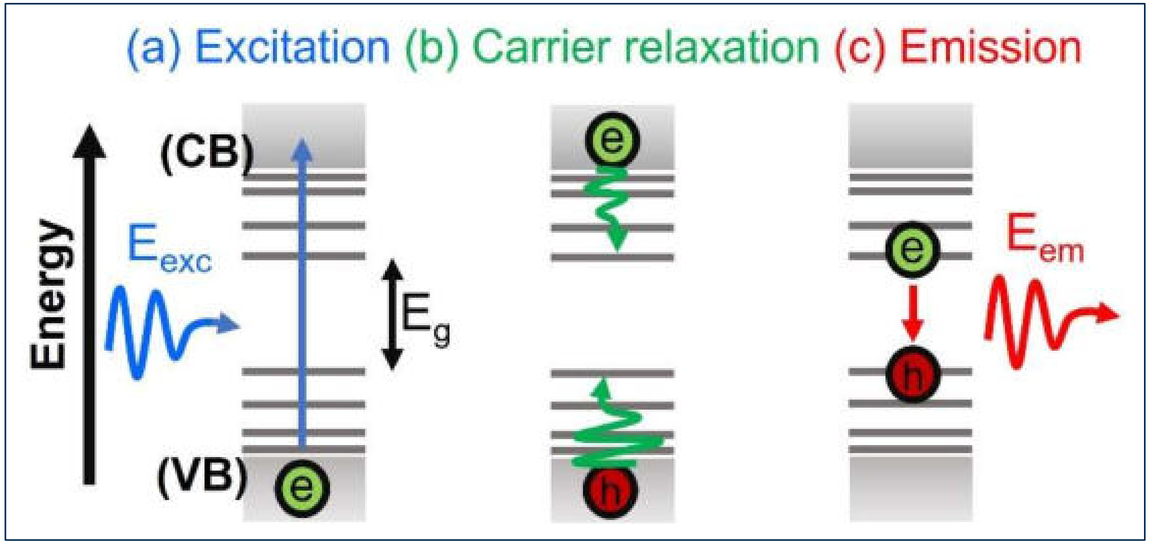
Photoluminescence (PL) Mechanism

- QDs absorbs UV radiation to excite e-
- e- de-excite to recombine with the hole
- Energy (band gap) emits in the form of PL



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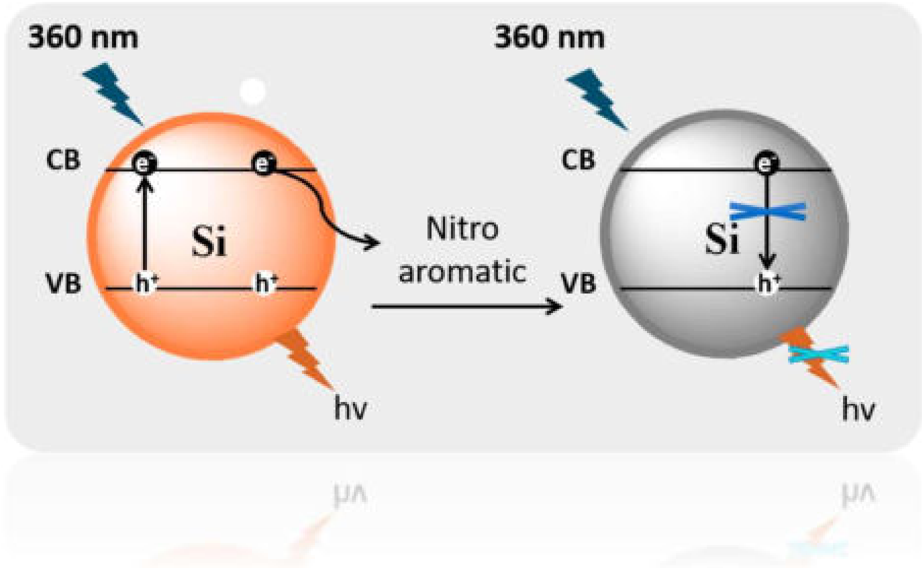
Quenching/Detection Mechanism

- QDs absorbs UV radiation to excite e-
- +ve of acceptor attract the –ve of donor
- e- doesn't de-excite back to hole
- Results in quenching of QD PL



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Introduction and Motivation

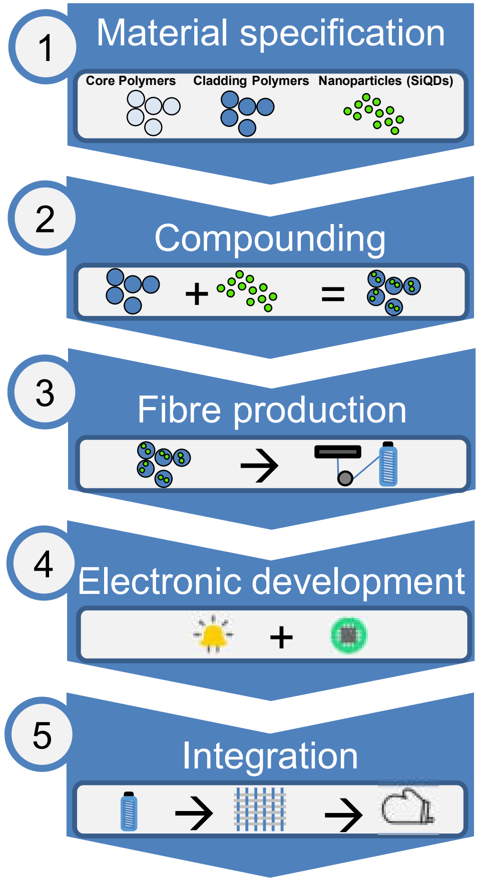
Steps of development

- Project QDotFibreSense
- Development consists of five steps

- Applied Quantum Materials Inc., Edmonton, Canada (AQM):
- Material specification/ SiQD production (Step 1)

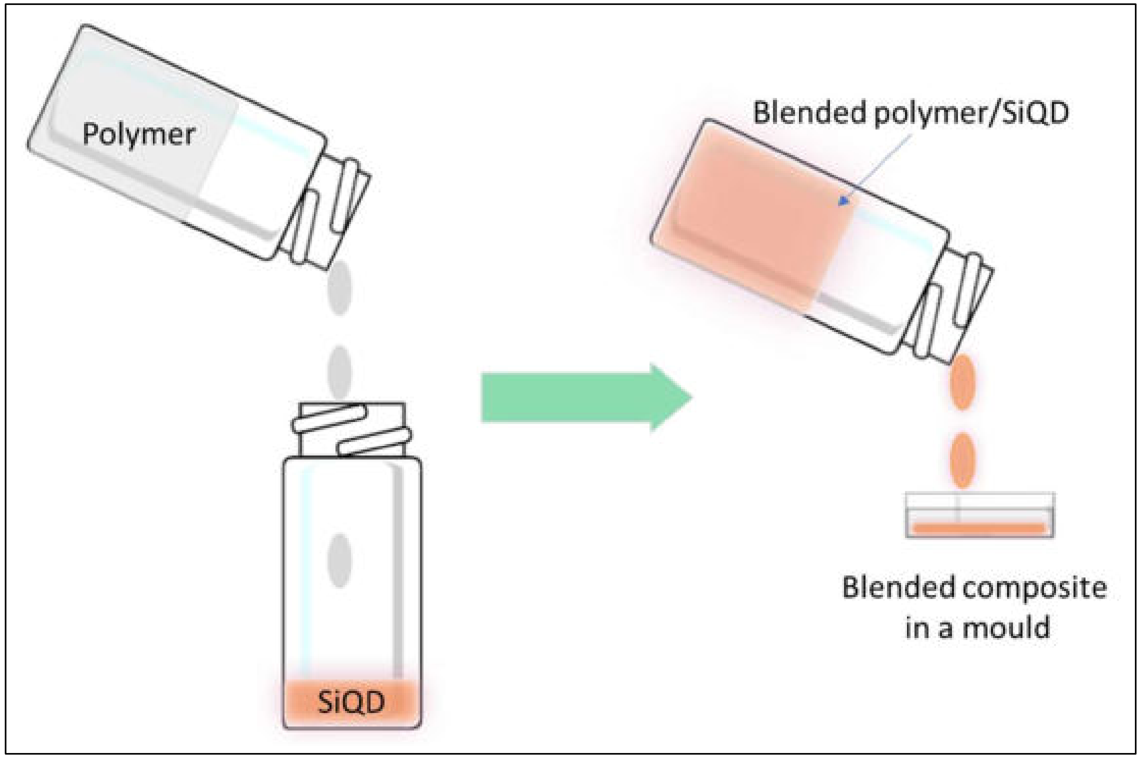
- Institut für Textiltechnik of RWTH Aachen University (ITA):
- Compounding (Step 2)
- Fibre production (Step 3)

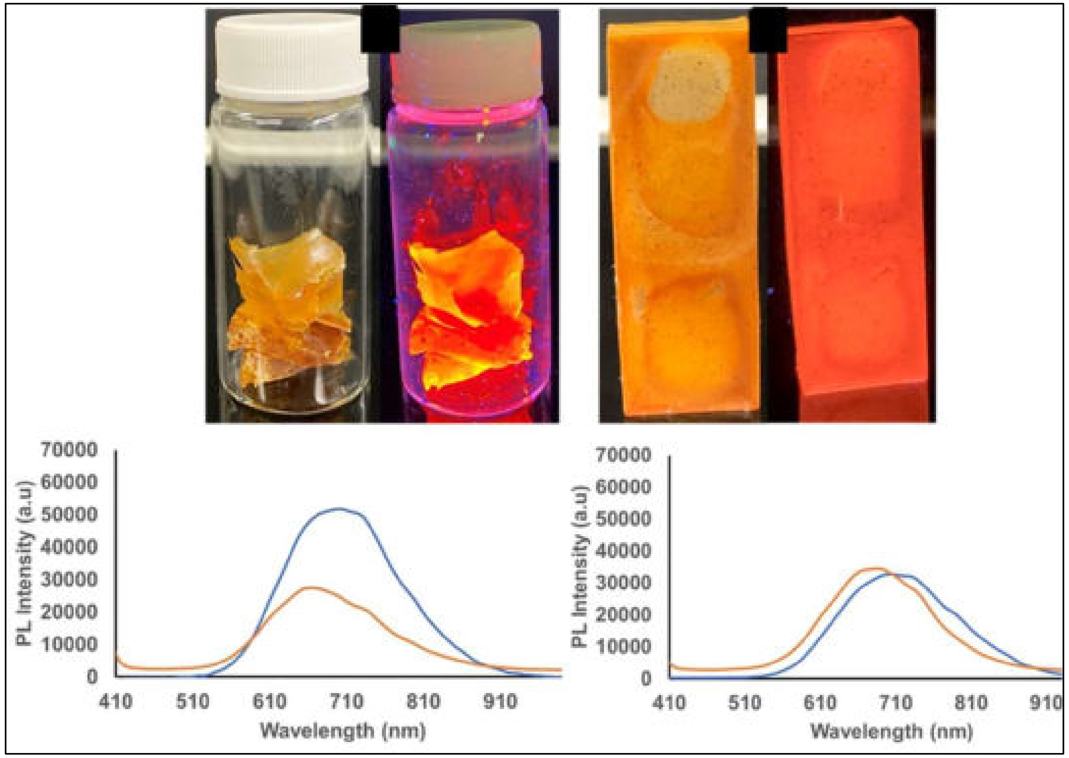
- ITP GmbH, Weimar, Germany (ITP):
- Electronic development (Step 4)
- Integration (Step 5)



Material specification/ SiQD production (Step 1)

Blending of QD with Polymer





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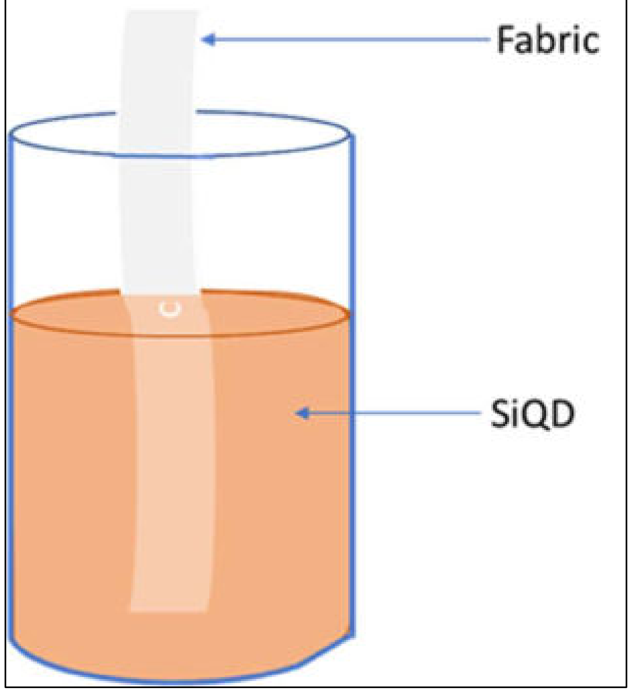
Material specification/ SiQD production (Step 1)

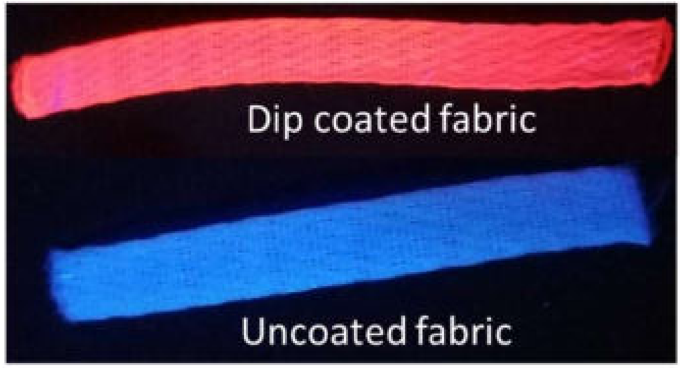
Coating Process

Spray coating

Dip coating



Dip coating was the best method for even coating of sensors



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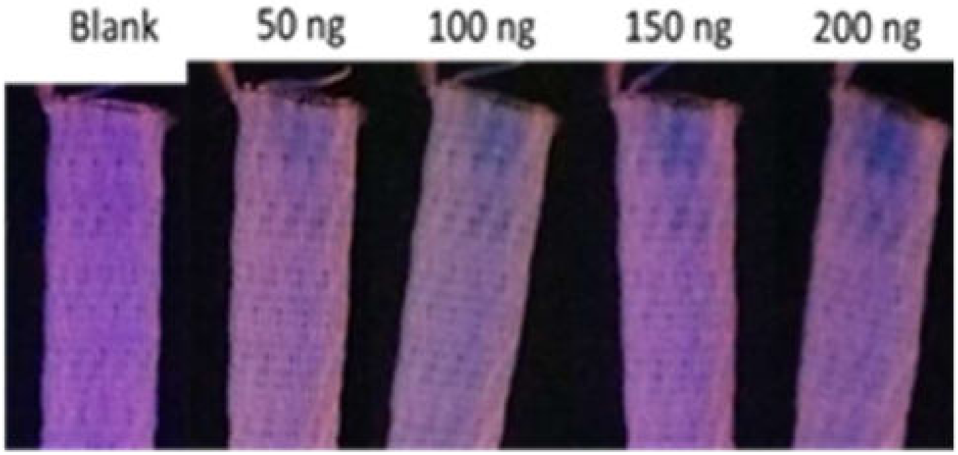
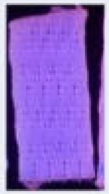
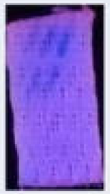
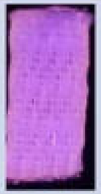
Material specification/ SiQD production (Step 1)

Quenching Test

Quenching detected for 50 ng TNT



Fabric could be washed and reused for further detection of TNT

(365 nm)	Before	After Quenching	After 24 hours	After Quenching (2)
Negative Control				
Positive Control				
Washing Study				

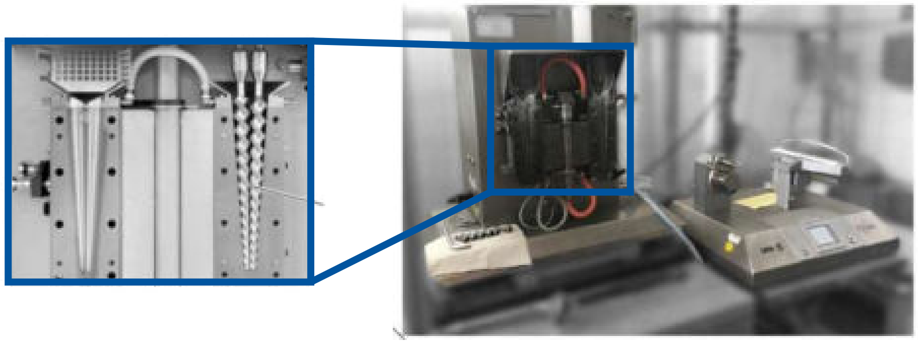
Compounding (Step 2)

→ **Dilute the SiQD compound to desired concentration**

- Weighing and mixing the SiQDs with the corresponding polymer
- Drying the SiQD-polymer-mixture in a vacuum drying oven to the desired moisture content
- Compound the
- Granulation of the cooled extrudate to 5 mm long polymer granules

Polymer with ~14 % SiQDs

Polymer with 1 % SiQDs each



Micro compounder

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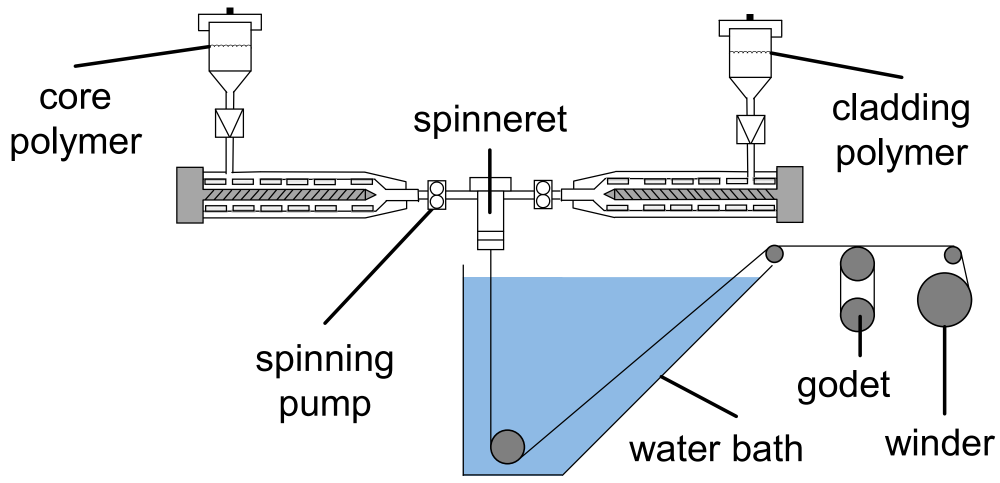
Fibre production (Step 3)

→ **Production of a circular functionalised POF with a total fibre diameter of 300 µm with a cladding thickness of 10 µm**

- Bicomponent monofilament meltspinning
- Melting the pure polymer in the core extruder
- Melting the SiQD-polymer-compound in the cladding extruder simultaneously
- Cooling the bicomponent fibre in a water bath
- Finally winding the POF on a bobbin



Schematic illustration of the bicomponent spinning process

Fibre production (Step 3)

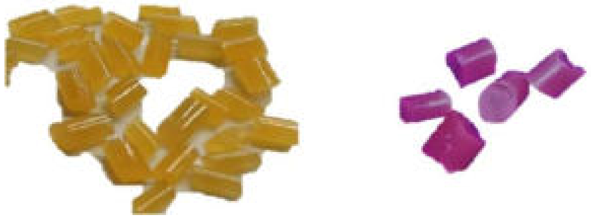
Investigations at the polymer level

- TGA analyses:

→ concentration of 1 % SiQDs, no significant effect

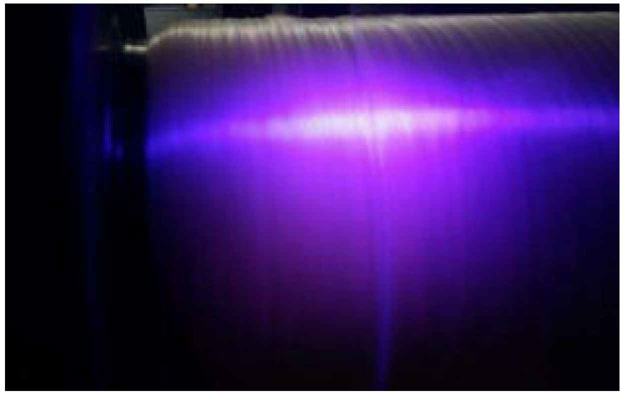
- DSC investigations:

→ glass transition temperature, slightly reduced.



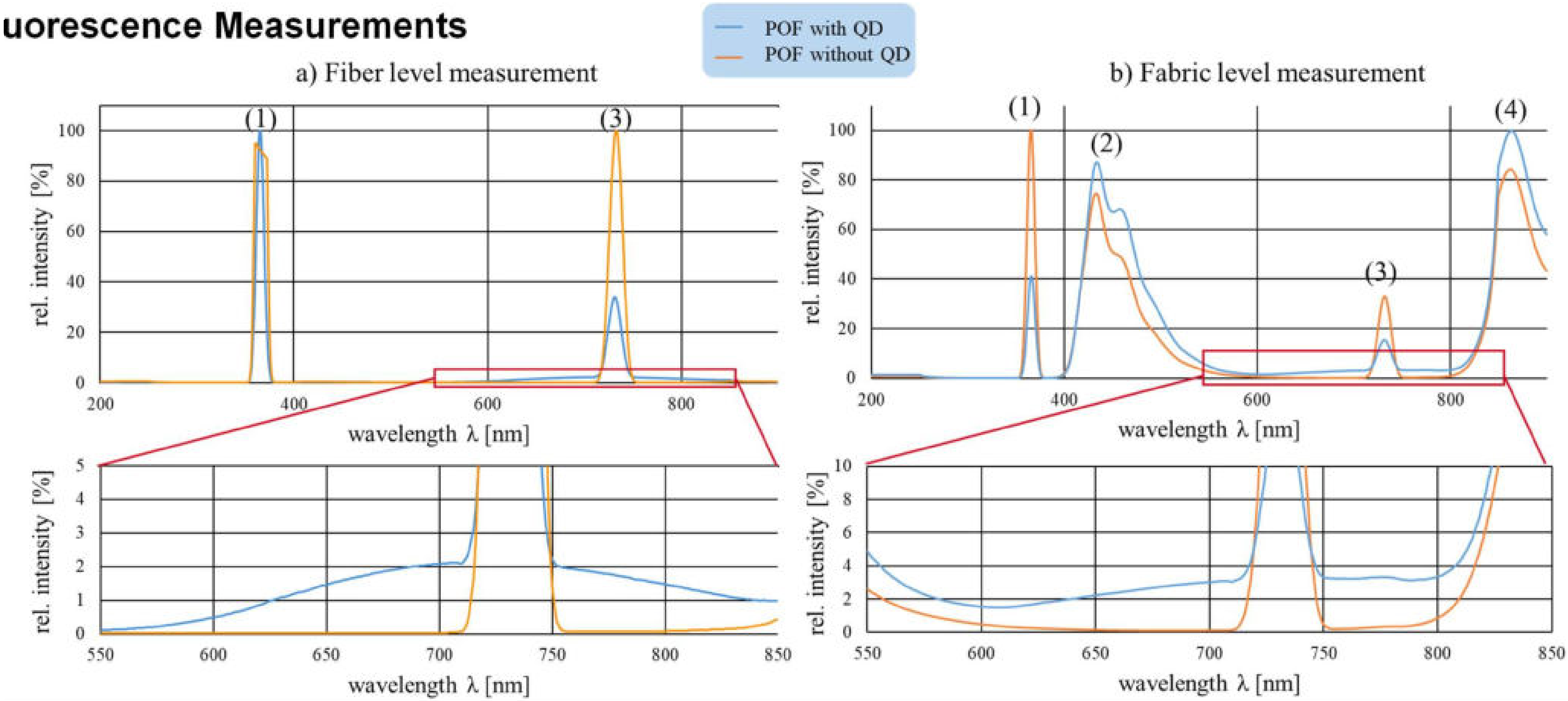
Investigations at the fiber level

- Tenacity of SiQD-POF, reduced by around 22 %
- Attenuation, heavily increased (factor >7)



Fibre production (Step 3)

Fluorescence Measurements



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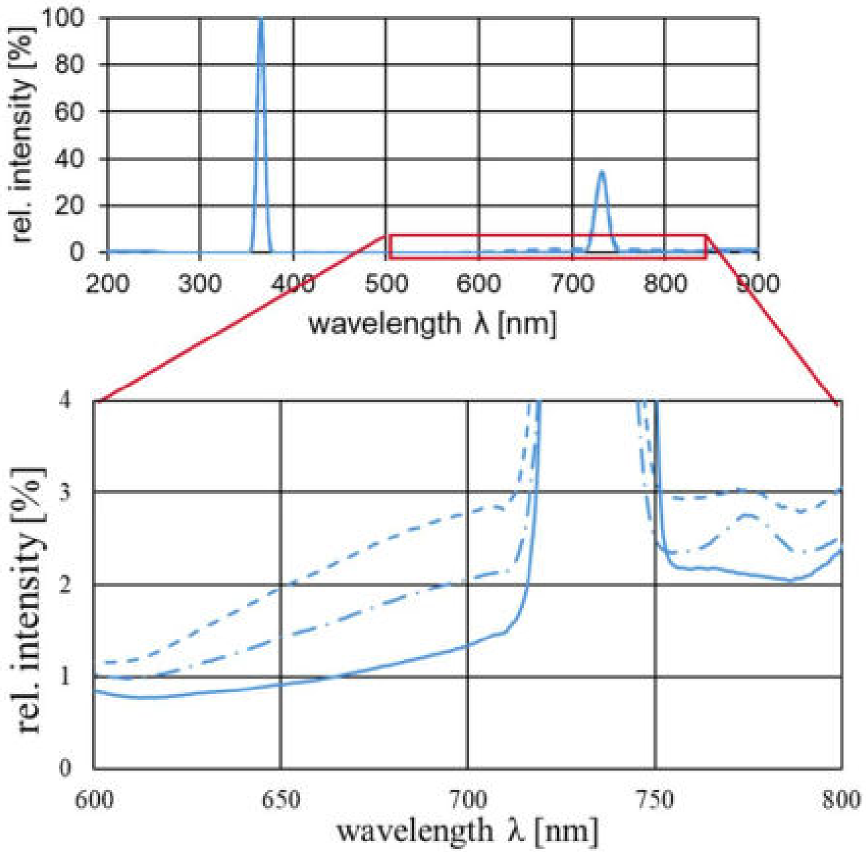
Fibre production (Step 3)

Quenching Trials

- Wipe test of the fibre with following mixture:
  - TNT
  - Acetonitrile
  - Methanol
- Coated aluminium strips are used as a backing.

Applying the TNT solution

Soaking the sample



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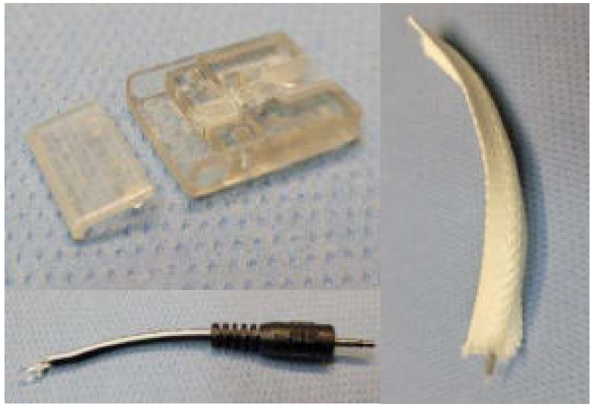
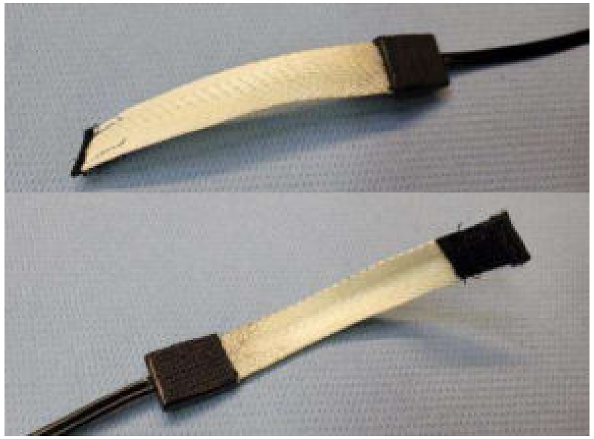
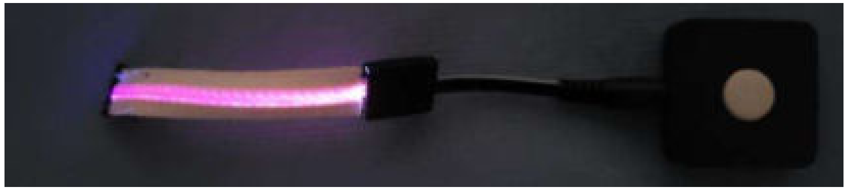
Electronic development (Step 4)

Sensor Ribbons

- Polyester weaving with five integrated PMMA fibres
- Coated with Quantum Dots
- Combined with LED in an adapter piece
- Exchangeable, can be saved as evidence or further analysis
- Fixation points on adapter and end part of the ribbon



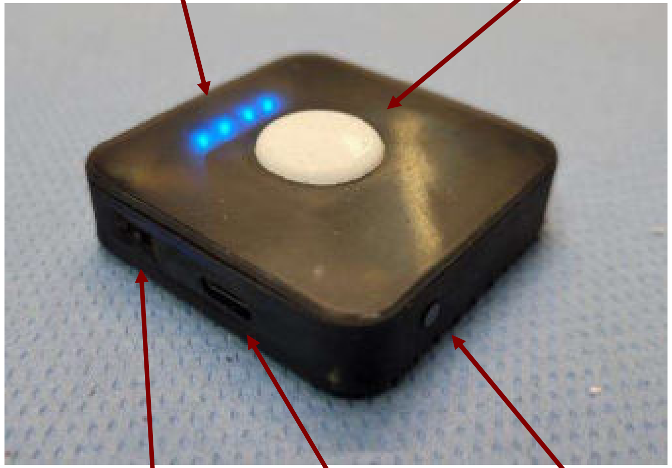




Electronic development (Step 4)

Electronics

- 2-way-safety: ON/OFF-Switch and separate POWER switch for LEDs
- LED is timed: 20 s until automatically switching off
- Chargeable via micro-USB, capacity of 0.9 Wh
- Charge indicator with four LEDs, can be activated via a separate button



Integration (Step 5)

Prototype

- Fingerstall with hook-and-loop-fastener for fixation of further components
- Electronics for control and power supply (ca. 1 working shift)
- Excitation wavelength: UV-A (390 nm)
- QD-coated sensory ribbons, exchangeable

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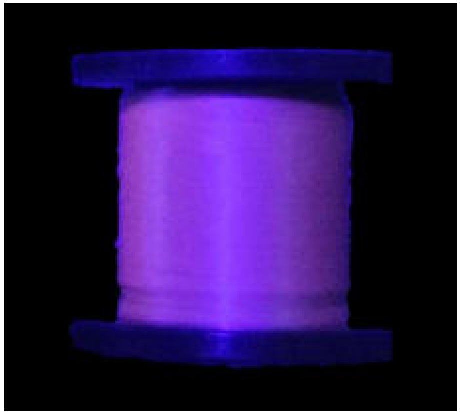
Summary and Outlook

Summary

- AQM:
  - SiQD production
  - Quenching Test
  - Blending SiQDs into Polymers



- ITA:
- Compounding
- Fibre production an Testing

- ITP:
- Smart glove design
- Design of the electronic components

Outlook

- Further development to a market maturity sensor system
- Field test via established contacts to:
  - State Office of Criminal Investigation Thuringia (LKA Thüringen)
  - Royal Canadian Mountain Police

Project Consortium

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SPONSORED BY THE
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ACKNOWLEDGMENT
The project on which this report is based was funded by the Federal Ministry for Economic Affairs and Climate Action under the funding number ZF4558958AW9 and ZF4111306AW9. The authors are responsible for the content of this publication.

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