Investigating luminescence characteristics of ultra-purified water and ice

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Production of luminescence

Luminescence characteristics:
- light yield
- emission spectrum
- decay kinetics

chemical reactions
radioactive radiation
electrical fields
light

energy transfer

atoms / molecules of the material

kinetic energy / vibrations
photon emission

luminescence
fluorescence
phosphorescence
Motivation

- Luminescence is produced in water and ice cherenkov detectors
  - Can be used as a new detection channel for particles that do not produce Cherenkov light, e.g. low-relativistic magnetic monopoles
  - Needs to be considered for the detector calibration
  → Therefore the luminescence characteristics of water and ice need to be known
Goals of our investigation

Lab measurements:
- Determining luminescence characteristics for water and ice in dependance of
  - temperature
  - pressure
  - charge
  - purity

In-situ measurements:
- Determining the luminescence characteristics of Antarctica ice on site
  → luminescence logger
Setup for light yield measurement

- Production of luminescence light with $\alpha$-particles from $^{241}$Am-source
Light yield results

![Graph showing light yield results vs. temperature]

**Light yield / \gamma / \text{MeV}**

Quickenden 1982/91
Steen 1972

**Temperature / °C**

-200 -170 -140 -110 -80 -50 -20 0 10 20 30

**Measurement**

IceCube
BAIKAL
Super-K
KM3NeT
SNO

**Radiation**

- $e^-$
- $\alpha$
- $\gamma$

**PRELIMINARY**

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Luminescence spectrum

- Motivation: identifying electronic transitions in molecules contributing to luminescence
- Only a few investigations have been performed so far

Quickenden, 1982 measured @ 88K
Choice of setup for spectral measurements

- Challenge: Very low detection rates due to low light yield
- Three different options were investigated concerning detection efficiency:
  - Transmissive grating → 0.37%
  - Monochromator → 0.077%
  - Linear variable filter → 0.46%
Experimental setup

- Linear module
- Aluminum holder
- PMT
- 0.2mm slit
- Ice probe
- Linear variable filter

[Image of experimental setup diagram]
Calibration of the setup

- Measurement of transmission curves at different positions
- Using a tunable light source with 10nm steps and a calibrated photodiode
Calibration of the setup - results
Calibration of the setup - results
Calibration of the setup - results

![Graph showing transmission in % vs wavelength (200 to 800) with error bars.](image-url)
Calibration of the setup - results
Calibration of the setup - results
Deconvolution of the signal

- Convolution of the unknown spectrum $s$ and the response function of the filter $A$

$$y(x) = \int A(x, \lambda)s(\lambda)d\lambda$$

- In this case discretized form is used $\vec{y} = A \cdot \vec{s}$

- First try: solve by inverting the response matrix $A$

- This is an ill-posed problem, uncertainties of $\vec{y}$ and $A$ lead to very high uncertainties in $\vec{s}$

$\rightarrow$ Regularisation is needed
Gold iteration

- Iteration of $\vec{s}$ using the recursion formula

$$s_{i}^{m+1} = s_{i}^{m}y_{i}' / \sum_{j=1}^{n} A_{ij}' s_{j}^{m}$$
Measurement of the emission spectrum

- First measurements show that the measured rate is still too low
  → New radioactive source with higher activity is needed
Outlook: Luminescence Logger

- **Goal:** Measure light yield and decay times of Antarctic ice in different depths in the SPICE hole
- **Production of luminescence with $^{36}\text{Cl}$-source that emits $\beta$-radiation**
- **Measurements will be performed in November 2018**
Summary

- Investigation of luminescence characteristics is ongoing
- Light yield and its temperature dependence has been determined in the temperature range $-40^\circ C$ to $20^\circ C$
- Setup for measurements of luminescence spectra has been developed and calibrated
- A new source is needed for measurements of luminescence spectra
- In November 2018, a device will be sent to the South Pole to measure luminescence characteristics of Antarctica ice on site
Jablonski diagramm

Absorption

Internal Conversion

Intersystem Crossing

Vibrational Relaxation

Phosphorescence

Fluorescence
Measuring principle

![Graph showing the relationship between Amplitude (mV) and Rate (Hz) with different categories labeled: X-ray and α radiation, X-ray, Water in front of PMT, and PMT dark rate. The graph includes a legend and axis labels for Amplitude (mV) and Rate (Hz).]
Temperature dependency of light yield

![Graph showing temperature dependency of light yield with plots for Signal, Glass Scintillation, and PMT Dark Rate. The x-axis represents temperature in °C, and the y-axis represents signal rate in Hz. The graphs illustrate the decrease in signal rate with increasing temperature.]