Polymer Optical Fiber (POF) based Sensors for the Measurement of Elongation via Single Fiber

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Overview

1. **Motivation Fiber Optic Sensors**

2. **Technical Requirements for:**
   - Optical Transceivers and Signal Evaluation unit
   - POF Splitters
   - Optical Sensor Head

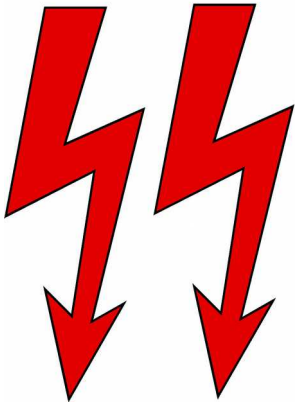
3. **Results and System Operation**
   - System installation
   - Elongation vibration of oscillating rod
   - Oscillation of a vacuum pump

4. **Further Applications and Conclusion**

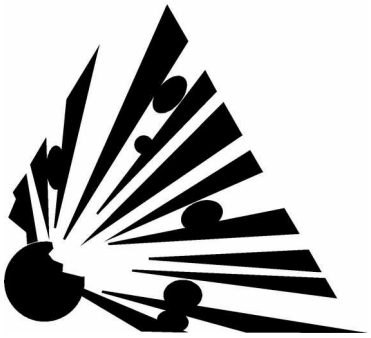
Motivation Fiber Optic Sensors

Measurement challenges in harsh environment include:

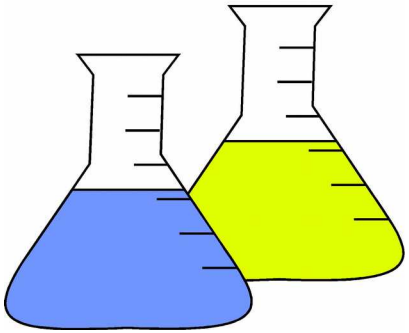
high voltage



explosive



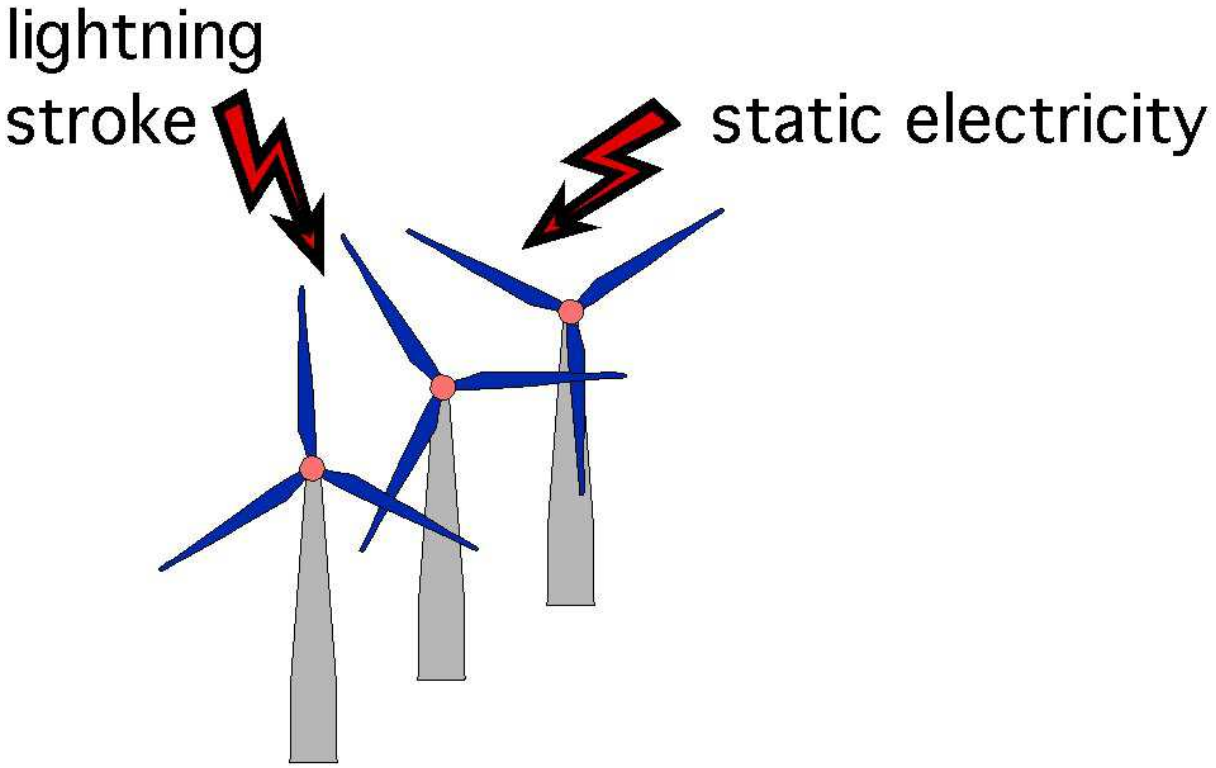
chemistry



Sensors heads and sensor data lines without metal parts or electrical current carrying parts are needed.

Motivation Fiber Optic Sensors

Example:

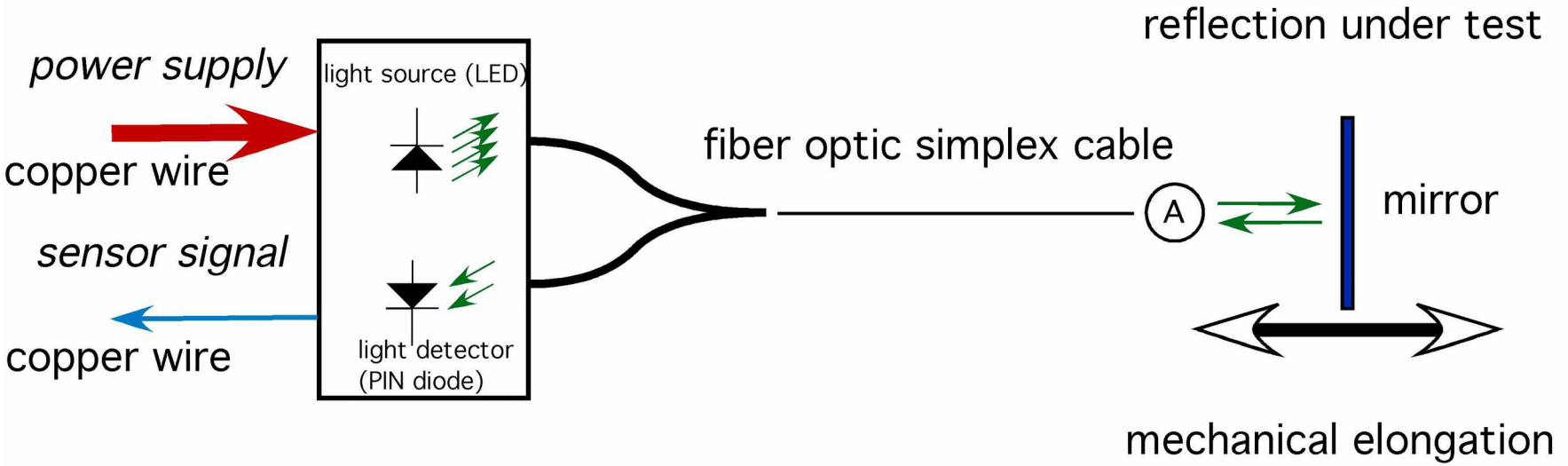


Consequence: Metal parts in the wings must be avoided.

Approach: POF based fiber optic sensor system with "non metal" sensor head

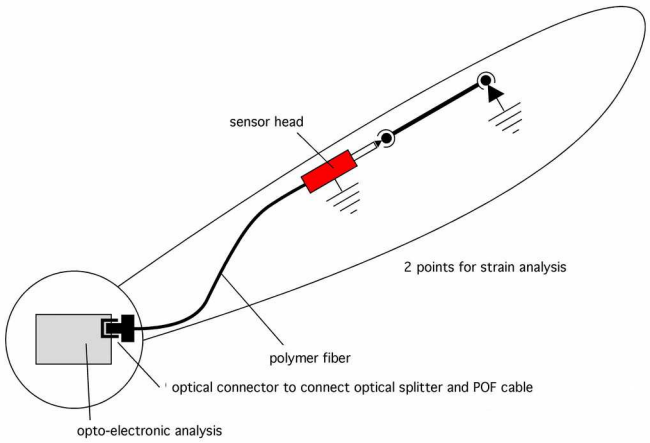
Motivation Fiber Optic Sensors

To avoid the high mechanic and electronic complexity of optical phase interrogation systems a POF based sensor system for fiber reflection measurement is investigated:

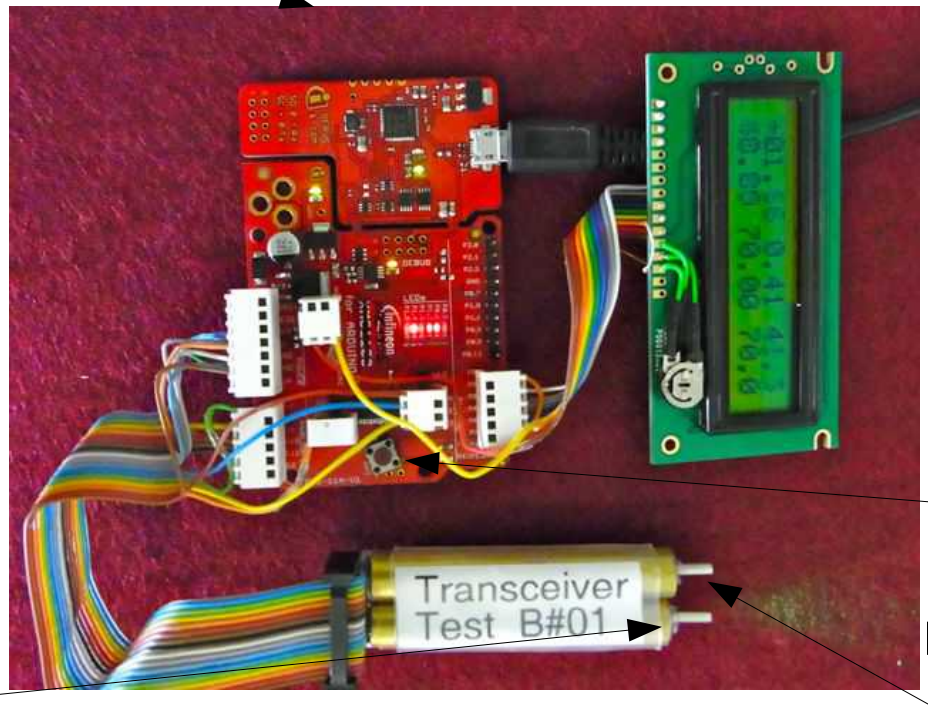


System requirements:

- stray light suppression
- high dynamic range of 60dB, to achieve fiber cable length of 200m,
- data acquisition to resolve 100Hz vibrations,
- zero calibration to avoid long term system aging,
- monitoring of transmit optical power



microcontroller generates LED on/off modulation at multiple kHz



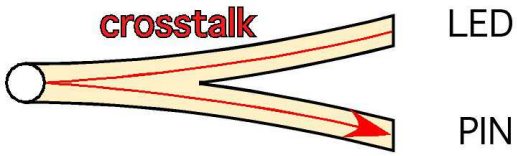
zero calibration

520nm LED transmitter (+5dBm) including monitor diode

receiver unit with variable gain (controlled by microcontroller)

Splitter design and crosstalk

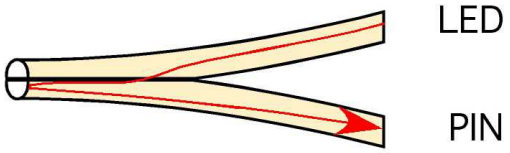
1x2 POF splitter design is crucial for satisfactory system operation. Splitter types:



splitter with common waveguide

-> crosstalk via endface reflection 15-20dB

- Not suitable for simplex sensor systems

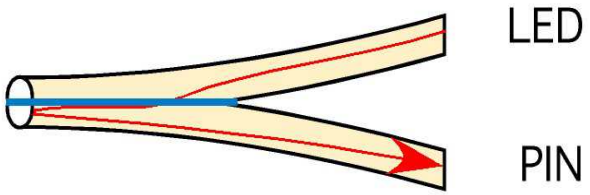


splitter with 2 separate unshielded waveguides

-> crosstalk 20-25dB

- Suitable only for low precision simplex sensor systems

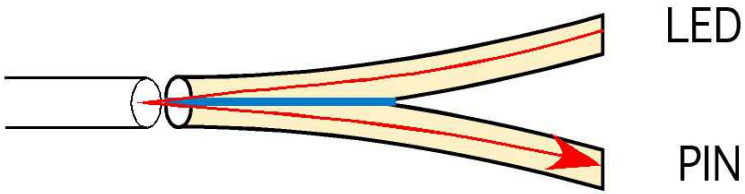
Splitter design and crosstalk



splitter with 2 separate shielded waveguides

-> crosstalk 40-60dB

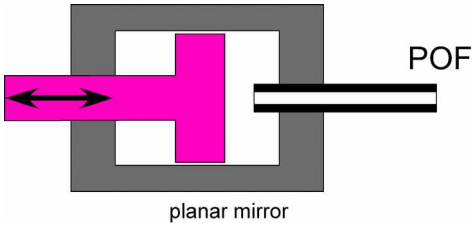
- Low crosstalk splitter for simplex sensor systems

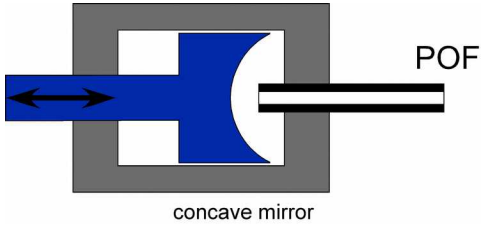


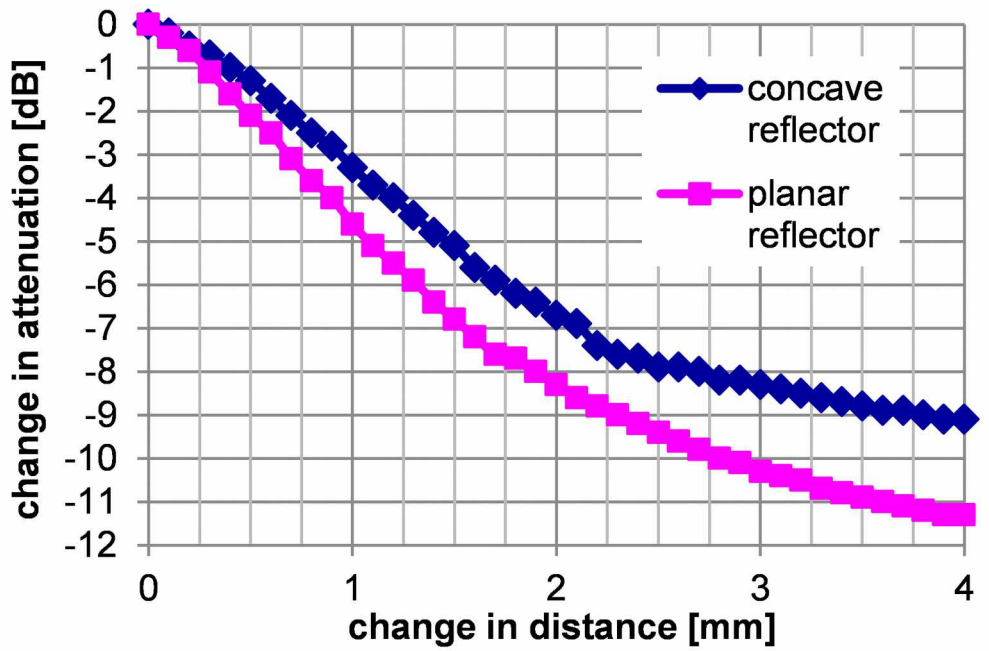
crosstalk via endface reflection
depends on surface and connector quality

- Quality endfaces and connectors needed for simplex sensor systems

Sensor head



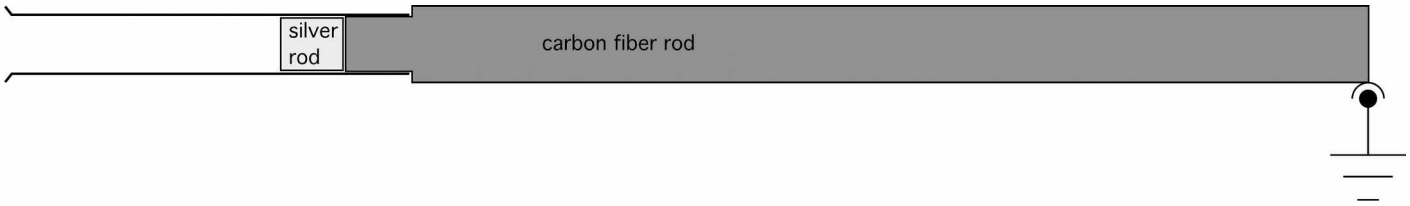




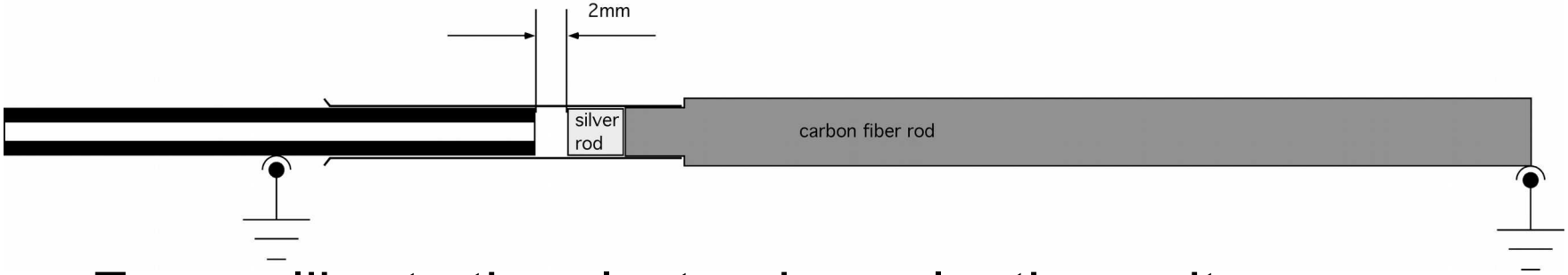
- Curved mirror designs can resolve about 4mm elongation distance.
- Concave mirrors show stronger reflectivity.
- Planar mirrors are easy to realize.

System installation

- Fix mirror rod to target.

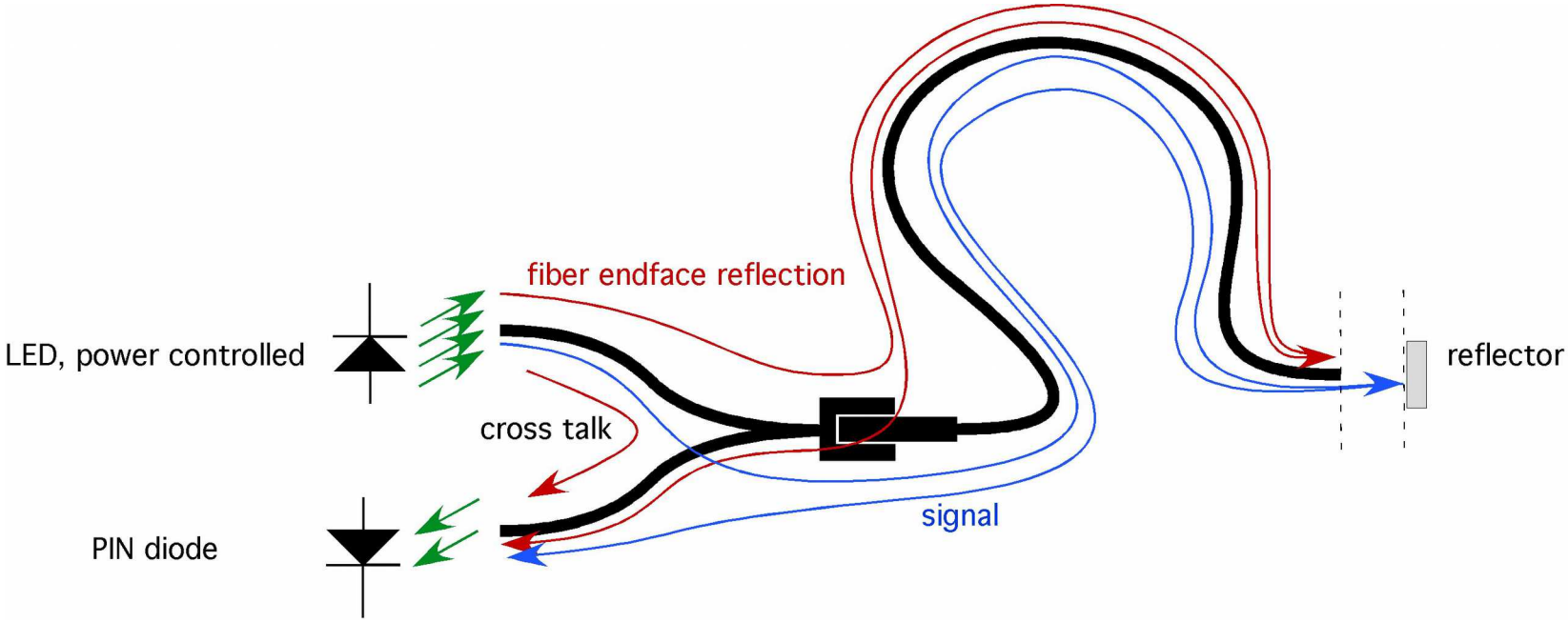


- Introduce POF to mirror ferrule up to stop, retract it about 2mm and fix it to target.



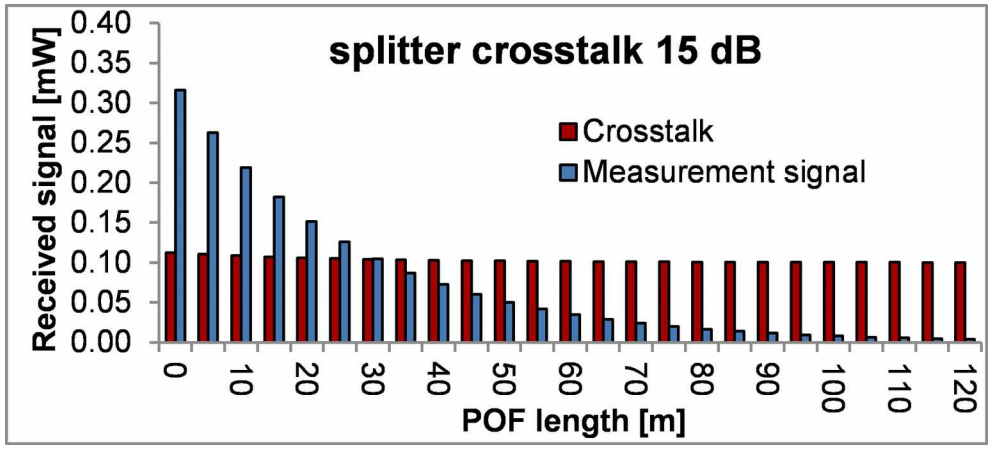
- Zero calibrate the electronic evaluation unit.
- Start measurement.

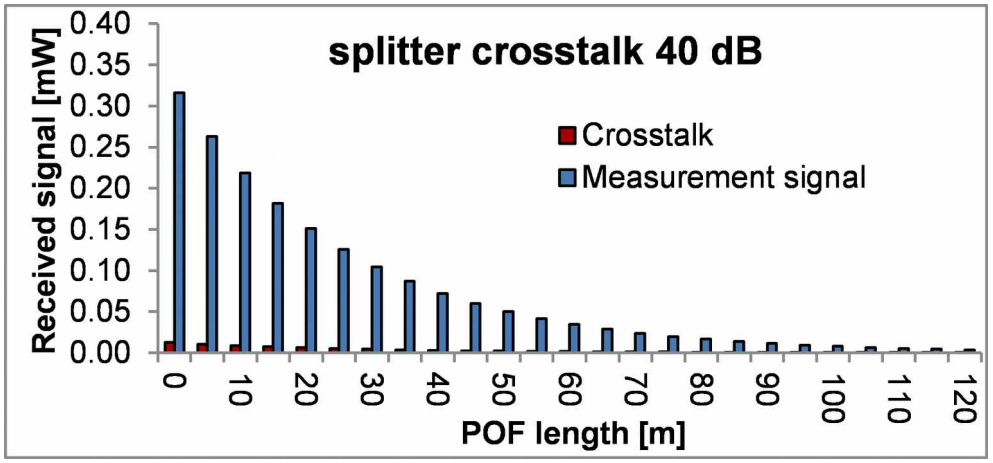
System operation under crosstalk influence



The desired signal (blue light path) is covered by splitter crosstalk and far endface reflection (red light paths).

Signal and crosstalk

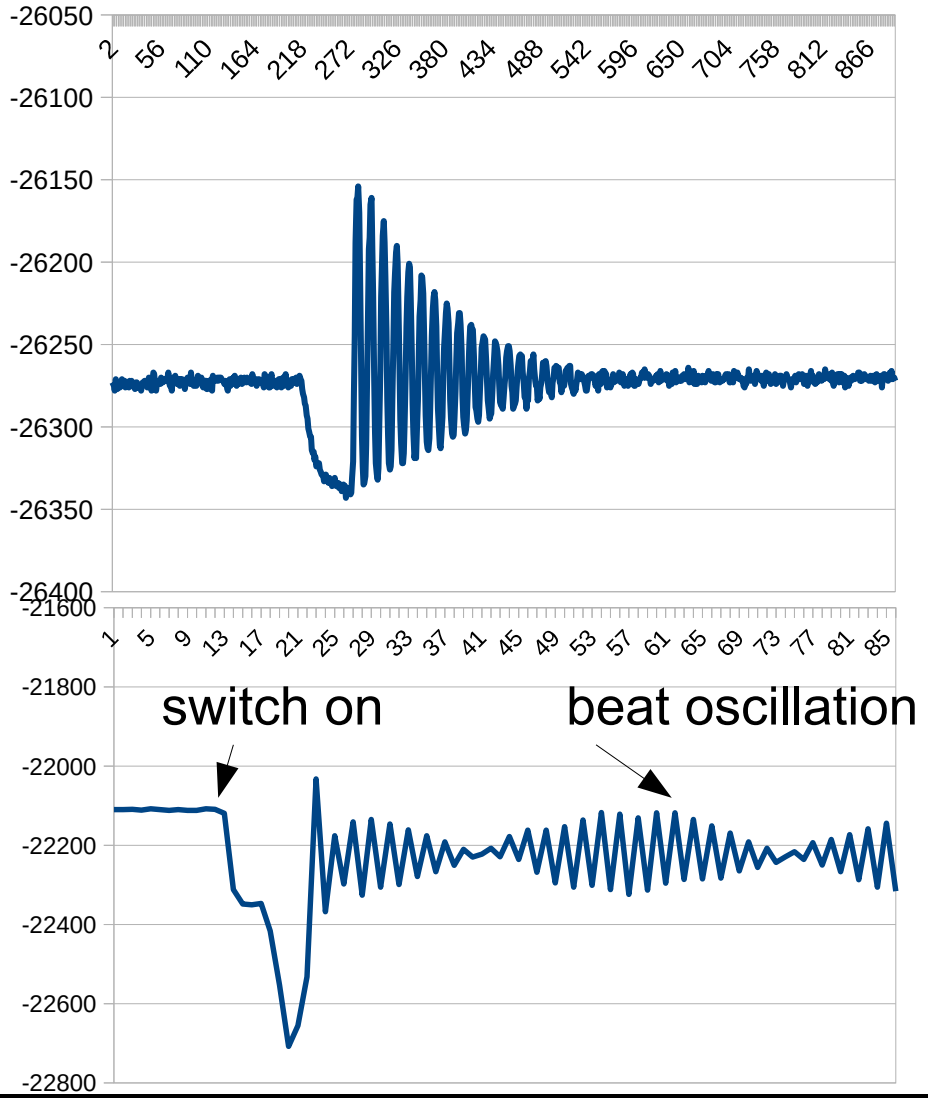




- High crosstalk splitter limit fiber cable distance to a few m.
- Low crosstalk splitter (40dB crosstalk attenuation) allow measurement distances of >70m.

System performance

- Oscillating rod, 70m POF, 520nm
- Vacuum pump vibration, 30m POF, 520nm



Further POF cable sensor applications

- **POF simplex systems**
  - elongation sensors
  - acceleration sensors
  - fiber optic switches
  - length and rotation encoder sensors
  - distance sensors (in combination with suitable optics)
- **POF duplex systems**
  - POF cable quality control
  - fiber optic light barriers
- **POF simplex multi wavelength (WDM) systems**
  - fiber optic color measurement for
    - print products
    - ph value of chemicals
    - temperature
    - ...

Conclusion

- The reported POF based elongation sensor allows to solve a great number of various measurement challenges.
- It is low cost in fabrication and system installation.
- Its key element is the 1x2 POF splitter.
- Splitter crosstalk defines the quality of the measurement system.