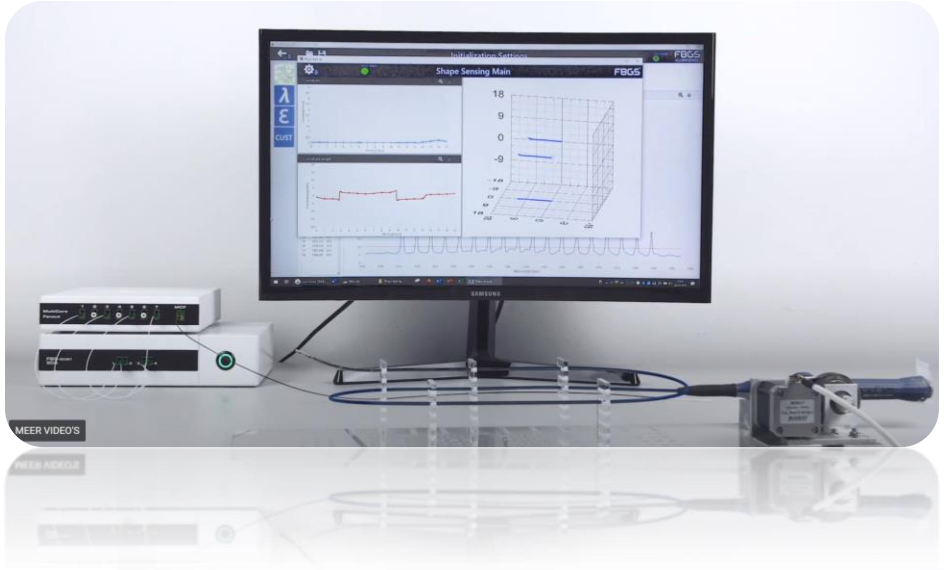
FBGS

# “Fiber optic sensing concepts for Minimally Invasive Surgery (MIS)”




**June 12, 2024**

Dr. Christian Voigtländer

R&D Manager
FBGS

# Outline

- **About FBGS**
- **Minimally Invasive Surgery (MIS)**
- **Catheter navigation**
    - 3D Shape Sensing of catheters
    - Navigation using pre-operative CT-imaging data
    - Absolute shape tracking using augmented reality

# Outline

- **About FBGS**
- **Minimally Invasive Surgery (MIS)**
- **Catheter navigation**
  - 3D Shape Sensing of catheters
  - Navigation using pre-operative CT-imaging data
  - Absolute shape tracking using augmented reality

## we are

a developer and manufacturer of fiber optic sensor components and fiber optic sensor solutions

We are vertical from raw materials to software

## we do

Temperature sensing

Shape sensing

Strain sensing

Force sensing

Pressure sensing

## for

**Medical**

Process Industry

Civil engineering

Transportation

Energy

Expert in tailored fiber optic sensors and interrogation devices

High level of applications know-how

Customer oriented

## we speak

18 languages and our team originates from 20 countries

# Locations

## FBGS North America (Montreal)

Sales (North American market)

## FBGS Belgium (Geel)

Sales and applications
Development and assembly of measurement systems (interrogators)
Sensing Solution Engineering and R&D Work

## FBGS Germany (Jena)

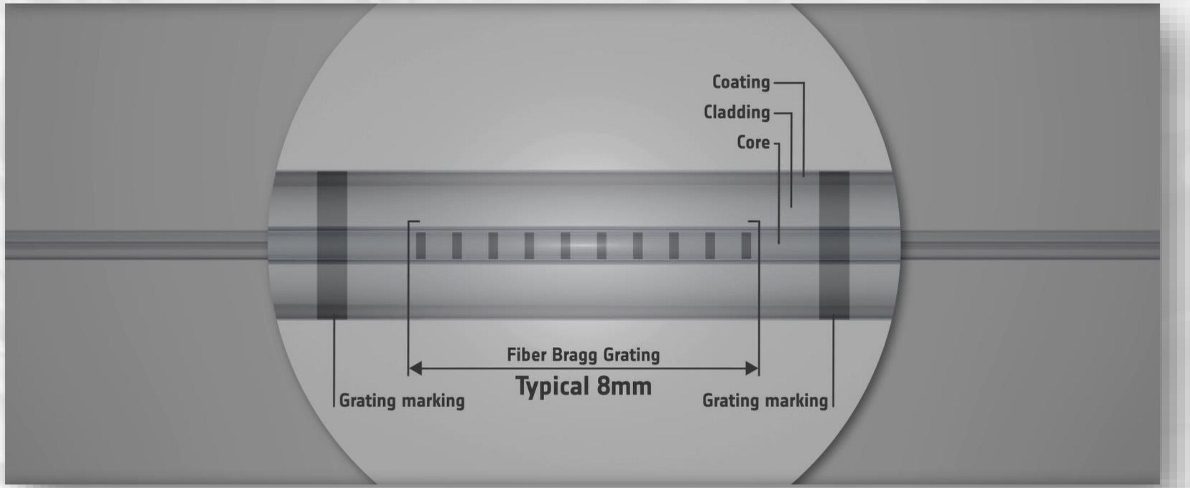
Company Headquarter
DTG® and FSG® production
R&D location for specialty fibers and FBGs

## FBGS China (Suzhou)

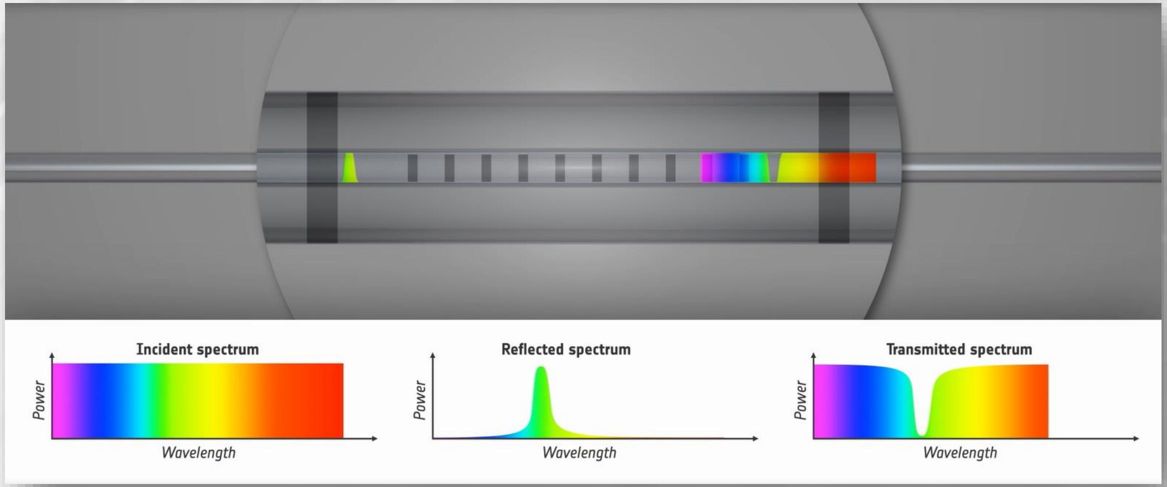
Sales and applications (Chinese customers)

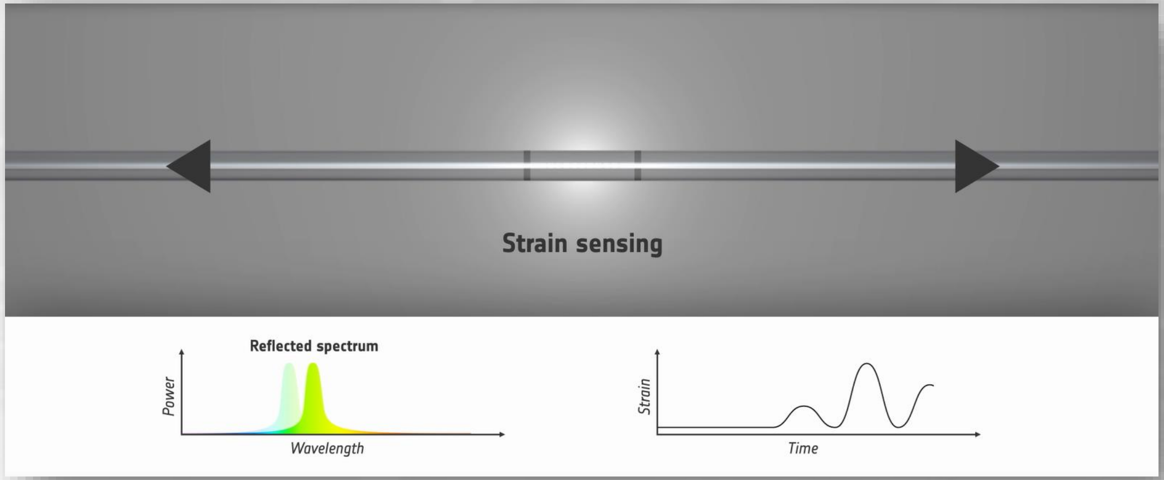
# Fiber Bragg Gratings

Permanent periodic modulation of the refractive index in the fiber core:




**BRAGG CONDITION:** $\lambda_B = 2\,n\,\Lambda$

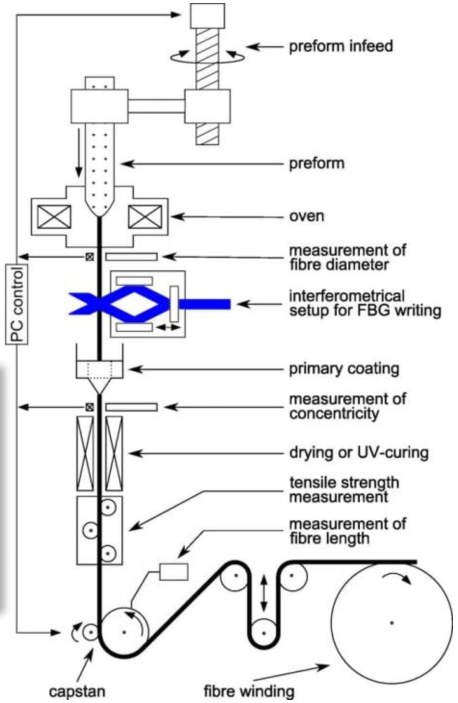


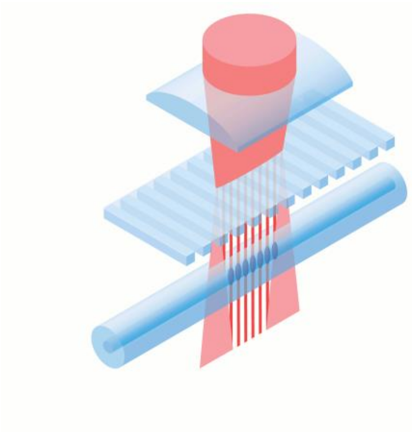

$$\lambda_B\,(T, \varepsilon) = 2\,n(T, \varepsilon)\,\Lambda(T, \varepsilon)$$

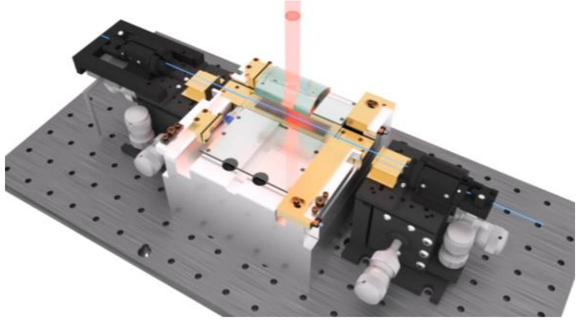
# FBGS base technologies

## Draw Tower Grating® technology




## FemtoSecond Grating® technology





## FBGscan interrogator platform


### Features

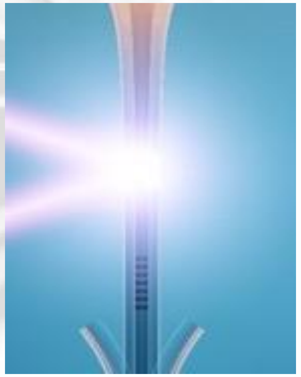
- Stand-alone FBG measurement system
- Up to 40 sensors per optical channel
- No need for time of flight corrections to maintain wavelength accuracy
- Depolarized light source to reduce birefringence induced noise effects
- High dynamic range ≥ 30dB
- Simultaneously detection of sensors belonging to the same optical channel
- Built-in processing board for calculating engineered data

# FBGS product line and technologies

| FBG sensor components | | | | Interrogators | Software |
|---|---|---|---|---|---|
| Draw Tower Gratings (DTG®) | FemtoSecond Gratings (FSG®) | All Grating Fibers (AGF®) | Sensors | Measurement devices | Software |

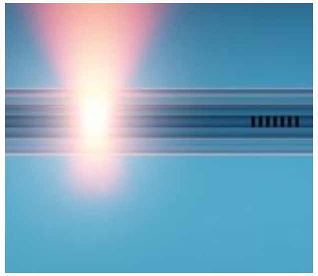
**Draw Tower Gratings (DTG®)**

- High-strength FBG sensors produced during the drawing of an optical fiber



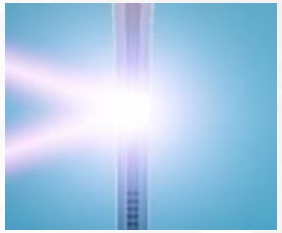
**FemtoSecond Gratings (FSG®)**

- High-strength FBG sensors produced by writing through the fiber coating



**All Grating Fibers (AGF®)**

- Optical fiber containing densely spaced low reflective DTG®s (R<0.1%)
- More than 95% of the fiber contains gratings



**Sensors**

- Variety of high-quality FBG sensors available for strain, force, temperature, pressure and shape measurements

**Measurement devices**

- High-precision measurement devices for all FBG sensors
- Available up to 15 optical channels
- For strain, force, temperature, pressure and shape

**Software**

- ILLumiSense software (embedded SW)
- Software for, data acquisition, processing and visualization
- Rest API
- Linux support

# Key advantages fiber optic sensors

## RELIABILITY

- Passive component
- Long lifetime (>20 years)
- No corrosion
- Stable over time (No calibration required)
- Cables and connectors are telecom grade


## IMMUNITY

- **Immune to electro-magnetic radiation & radio frequency interference**
- Immune to high voltage discharge
- Explosion safe

## SIZE

- Fiber is also the sensor
- **Lightweight & small diameter (< ¼ mm)**
- **High integration and embedding capabilities**

## PERFORMANCE

- **10’s, 100’s or 1000’s of sensors in 1 fiber**
- **Less cables**
- Easy installation
- High fatigue resistance
- Long distance measurements (20+ km)

## OMNI-FUNCTIONALITY

- Measurement of
  - Strain
  - **Temperature**
  - Vibration
  - Acoustics
  - **Pressure**
  - **Force**
  - **Shape**
  - Acceleration
  - Displacement
  - **Flow**
  - Liquid level

# Outline

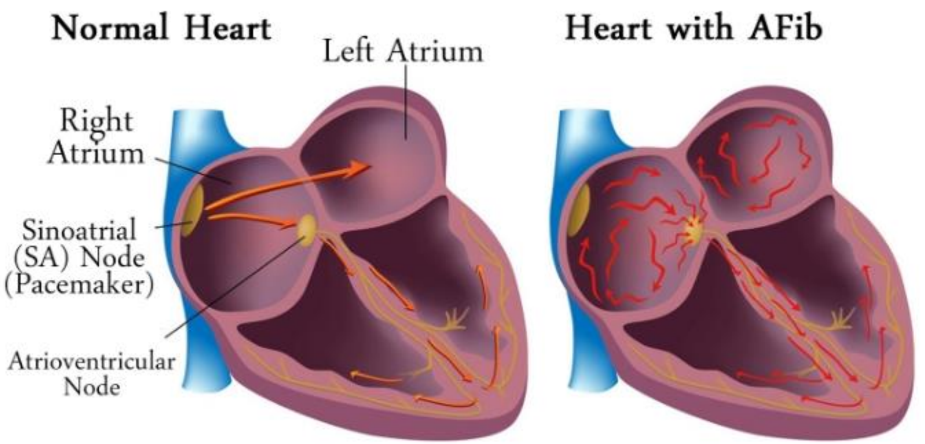
- About FBGS
- **Minimally Invasive Surgery (MIS)**
- Catheter navigation
  - 3D Shape Sensing of catheters
  - Navigation using pre-operative CT-imaging data
  - Absolute shape tracking using augmented reality

# Minimally Invasive Surgery (MIS)

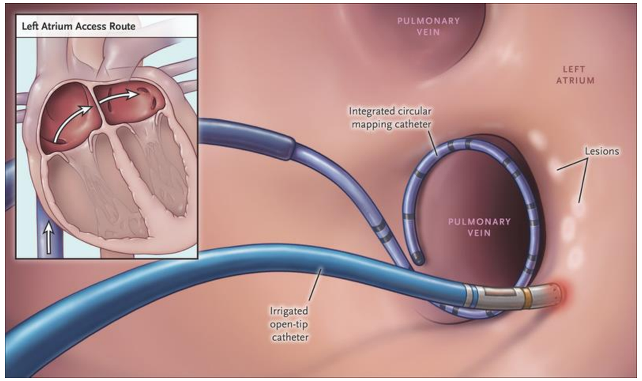
Minimally invasive surgery refers to **surgical procedures performed with minimal damage to the body's tissues**. These procedures are designed to minimize the size and number of incisions, reduce trauma to surrounding tissues, and promote faster recovery and reduced postoperative pain for patients

### Example: Atrial Fibrillation (AFib)

- Replacement of **regular** heart rhythm with an **irregular fibrillatory** heart rhythm
- Possible treatment:
  - **Catheter ablation** (interventional procedure)
- **Regions responsible for the irregularly generated electrical impulses are ablated to electrically insulate them**




Courtesy of the MAYO foundation for medical research and the U.S. National Library of Medicine



# Current challenges, limitations and opportunities

**① Patients**

- ❖ Overall instrument interaction
  - ➢ Vessel walls
  - ➢ Soft tissue
- ❖ Ablation tip contact forces
  - ➢ Perforation
  - ➢ Esophageal injury

**② Interventionalists**

- ❖ Ionizing radiation (fluoroscopy)
  - ➢ Cancer
  - ➢ Orthopedic injuries
- ❖ Limited visualization
  - ➢ 2D grey-scaled images

**③ Overall procedure**

- ❖ Safety and precision
- ❖ Sensing & visualization

**Opportunities of FO sensing in MIS**

- Provide 3D shape information of catheter(s)
- Assist with localisation/navigation of catheter inside body

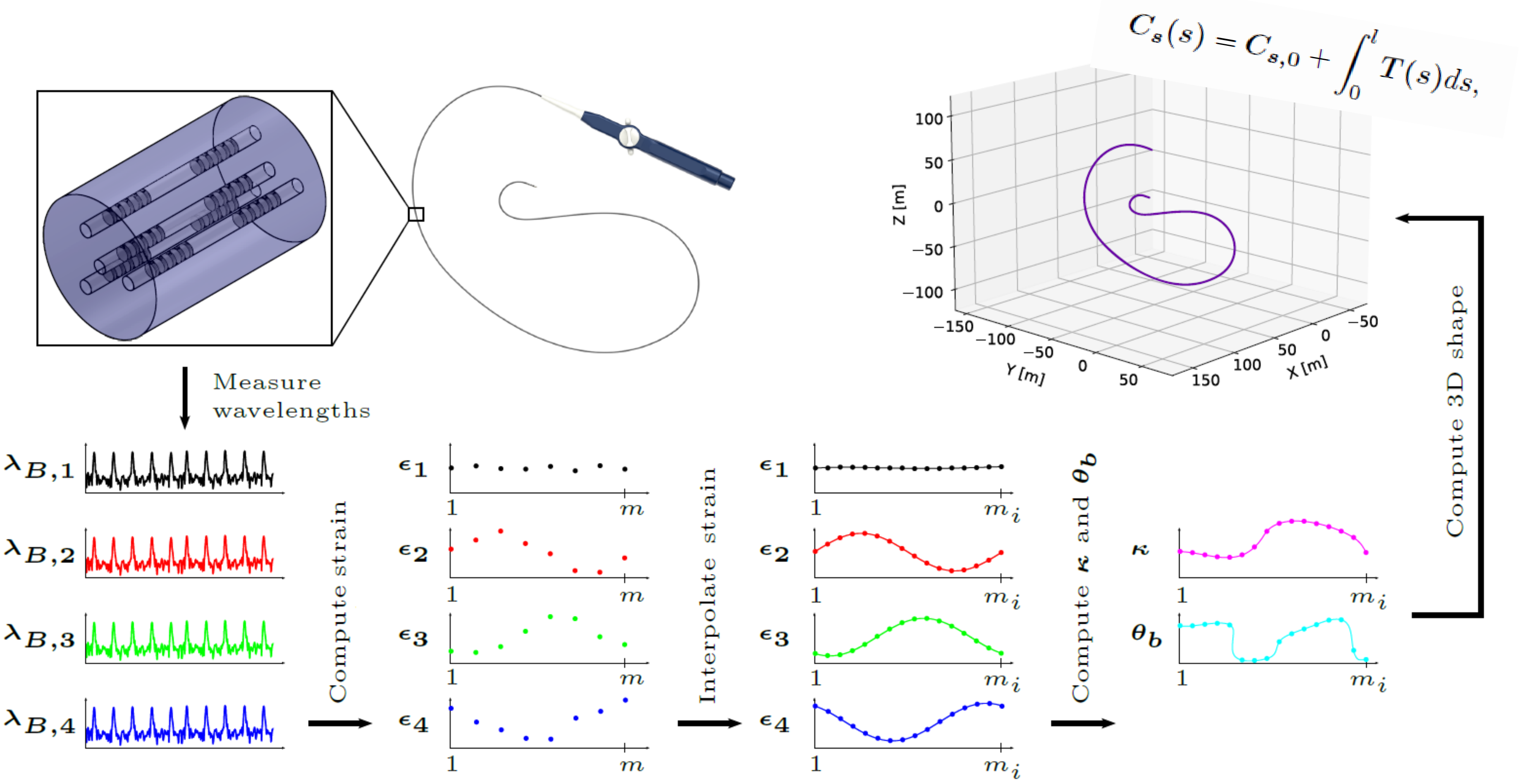
} Reduce exposure to ionizing radiation

- Measure intended or non-intended interaction forces between catheter and body

# Outline

- **About FBGS**
- **Minimally Invasive Surgery (MIS)**
- **Catheter navigation**
    - 3D Shape Sensing of catheters
    - Navigation using pre-operative CT-imaging data
    - Absolute shape tracking using augmented reality

# Shape sensing using MCF-DTG®




Differential Frenet-Serret formulae

$$\frac{dT}{ds} = \kappa N,$$

$$\frac{dN}{ds} = -\kappa T + \tau B,$$

$$\frac{dB}{ds} = -\tau N.$$

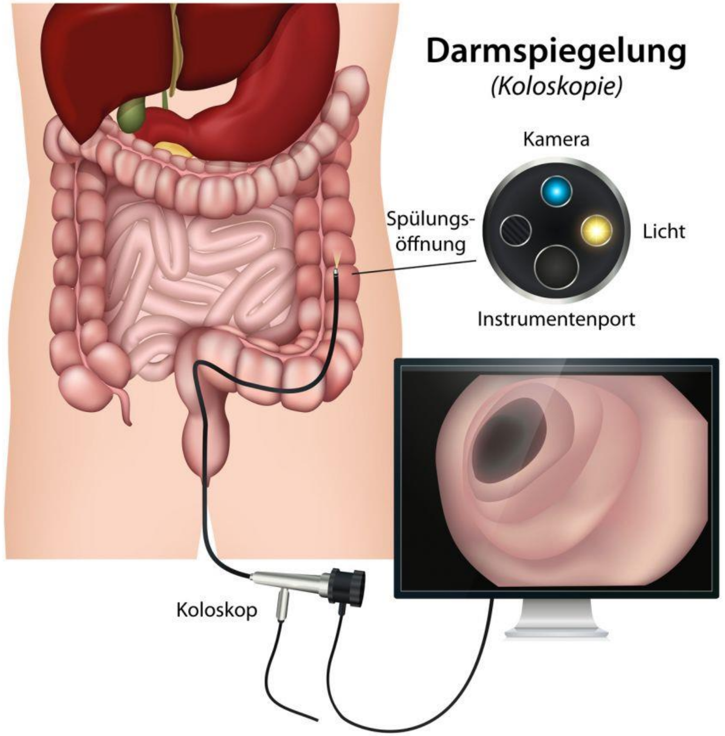
With $\tau = \frac{d\theta_b}{l_z},$

***Reference:*** *Al-Ahmad, O., Ourak, M., Van Roosbroeck, J., Vlekken, J., Vander Poorten, E. (2020). Improved FBG-Based Shape Sensing Methods for Vascular Catheterization Treatment. IEEE Robotics and Automation Letters, 5 (3), 4687-4694. doi: 10.1109/LRA.2020.3003291*

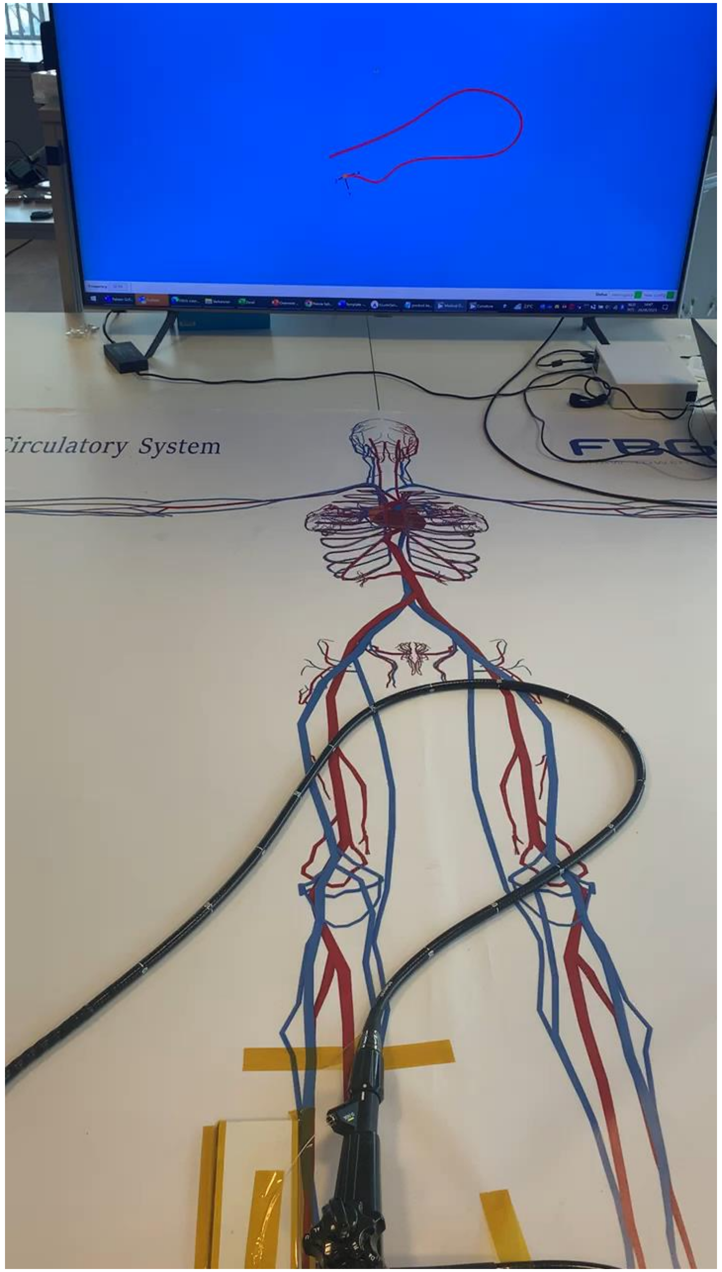
# Shape sensing for endoscope navigation

## Endoscope navigation

- Navigation of endoscope in the body
- Avoidance of endoscope looping
- Insertion length measurement
- Tip torture detection




https://www.leading-medicine-guide.com/de/diagnostik/koloskopie-darmspiegelung

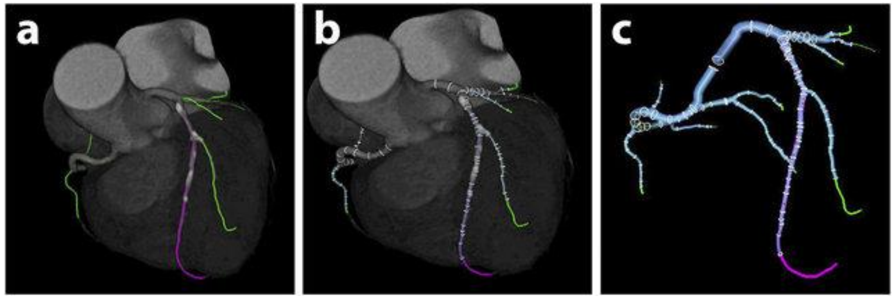


# Outline

- **About FBGS**
- **Minimally Invasive Surgery (MIS)**
- **Catheter navigation**
  - 3D Shape Sensing of catheters
  - Navigation using pre-operative CT-imaging data
  - Absolute shape tracking using augmented reality

# Navigation using pre-operative CT-imaging data

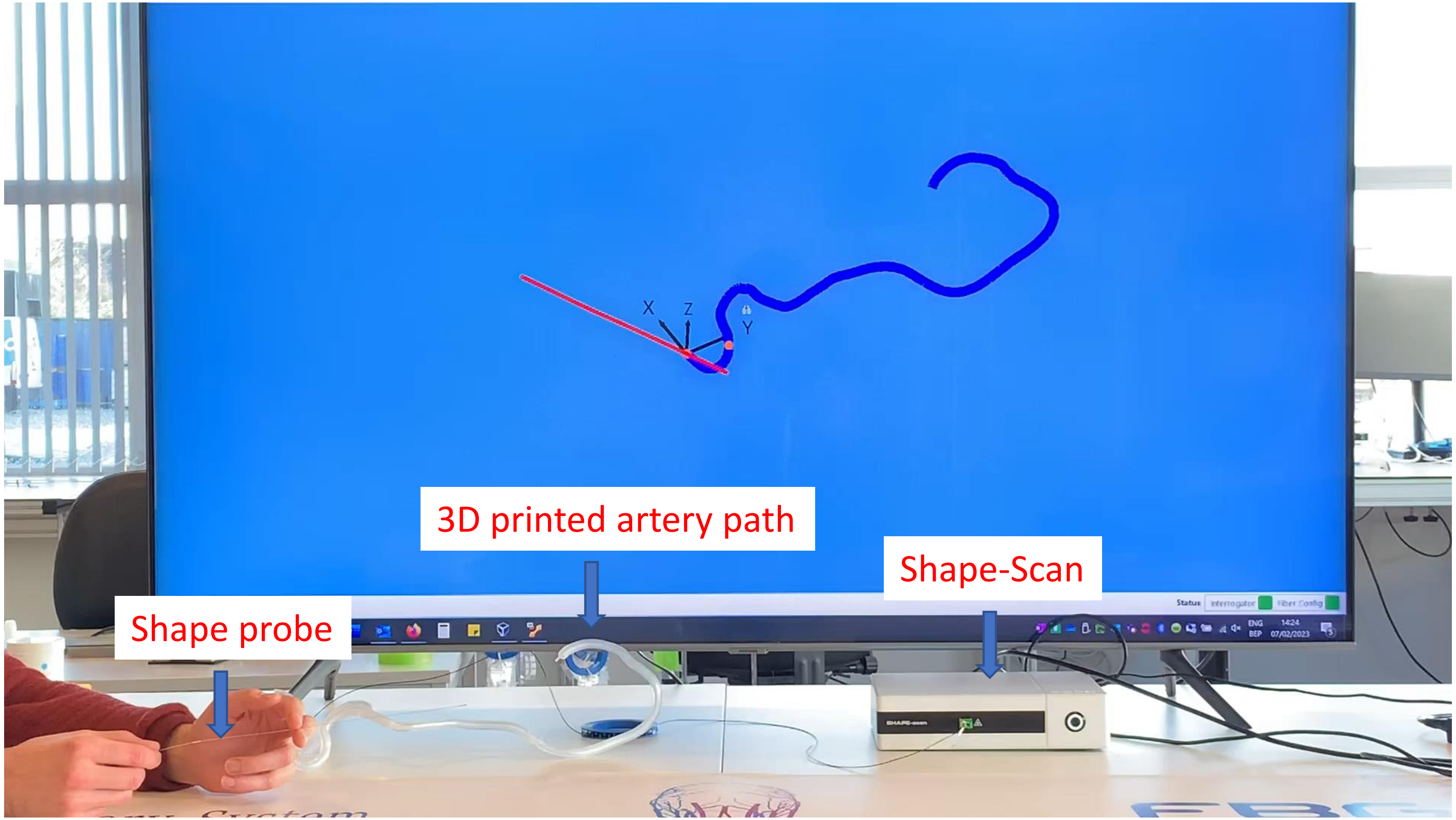
- **Computed Tomography scan (CT-scan)**, is a medical imaging technique that uses X-ray technology and advanced computer processing to create detailed 3D images of the body, including the bones, muscles, organs and blood vessels
- Segmentation technologies can be used to extract 3D shape information of e.g. blood vessel




Example of Coronary segmentation from CT-scan image
(Courtesey: Adriaan Coenen, Medical Center, Rotterdam)

- CT scans are frequently used as part of preparation for surgery or treatment.
- **3D shape information from CT-scan can be used as a reference shape to localize the catheter**

# Navigation using pre-operative CT-imaging data

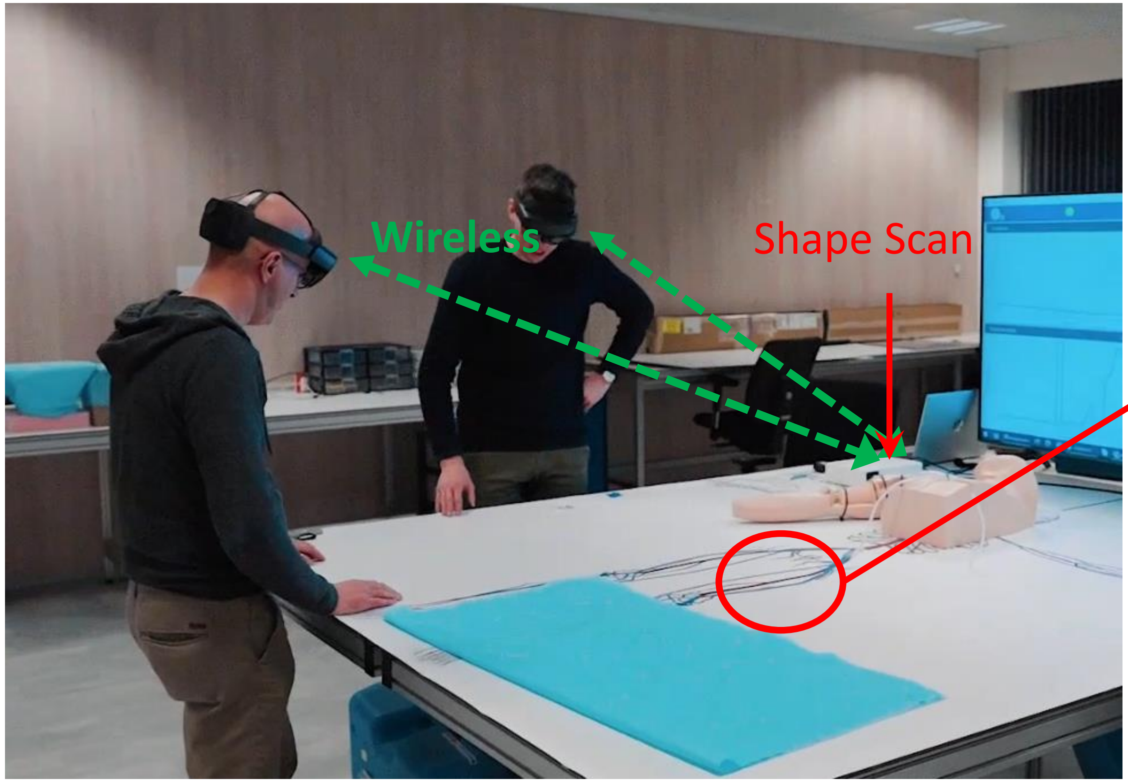


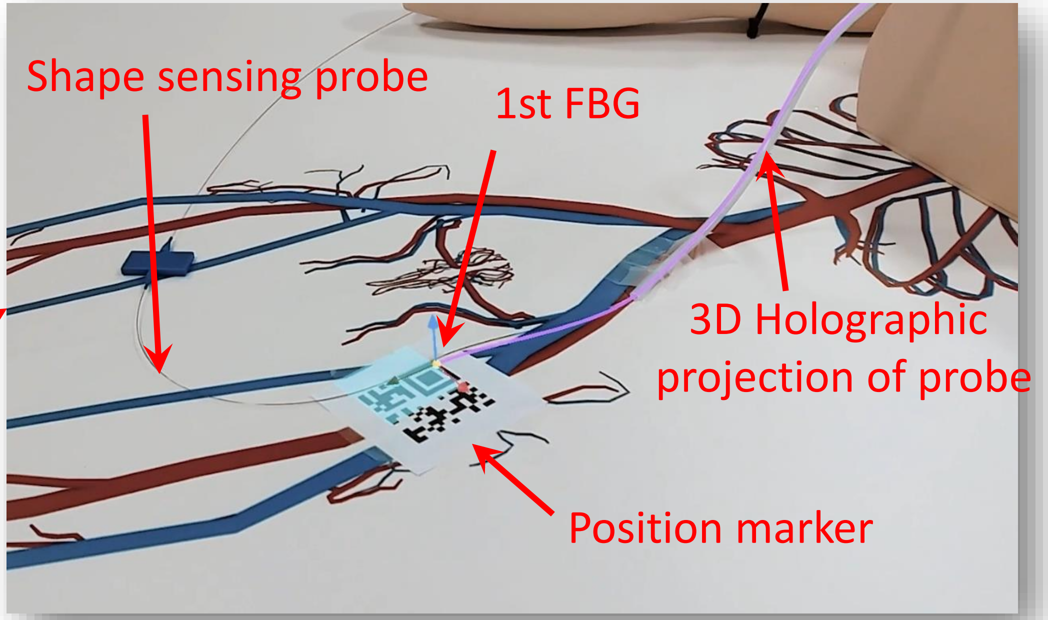

***Patent application:*** *Determining position or insertion length of an elongated device (US 18/164,817 and EP20707122.6).*

# Outline

- **About FBGS**
- **Minimally Invasive Surgery (MIS)**
- **Catheter navigation**
  - 3D Shape Sensing of catheters
  - Navigation using pre-operative CT-imaging data
  - Absolute shape tracking using augmented reality

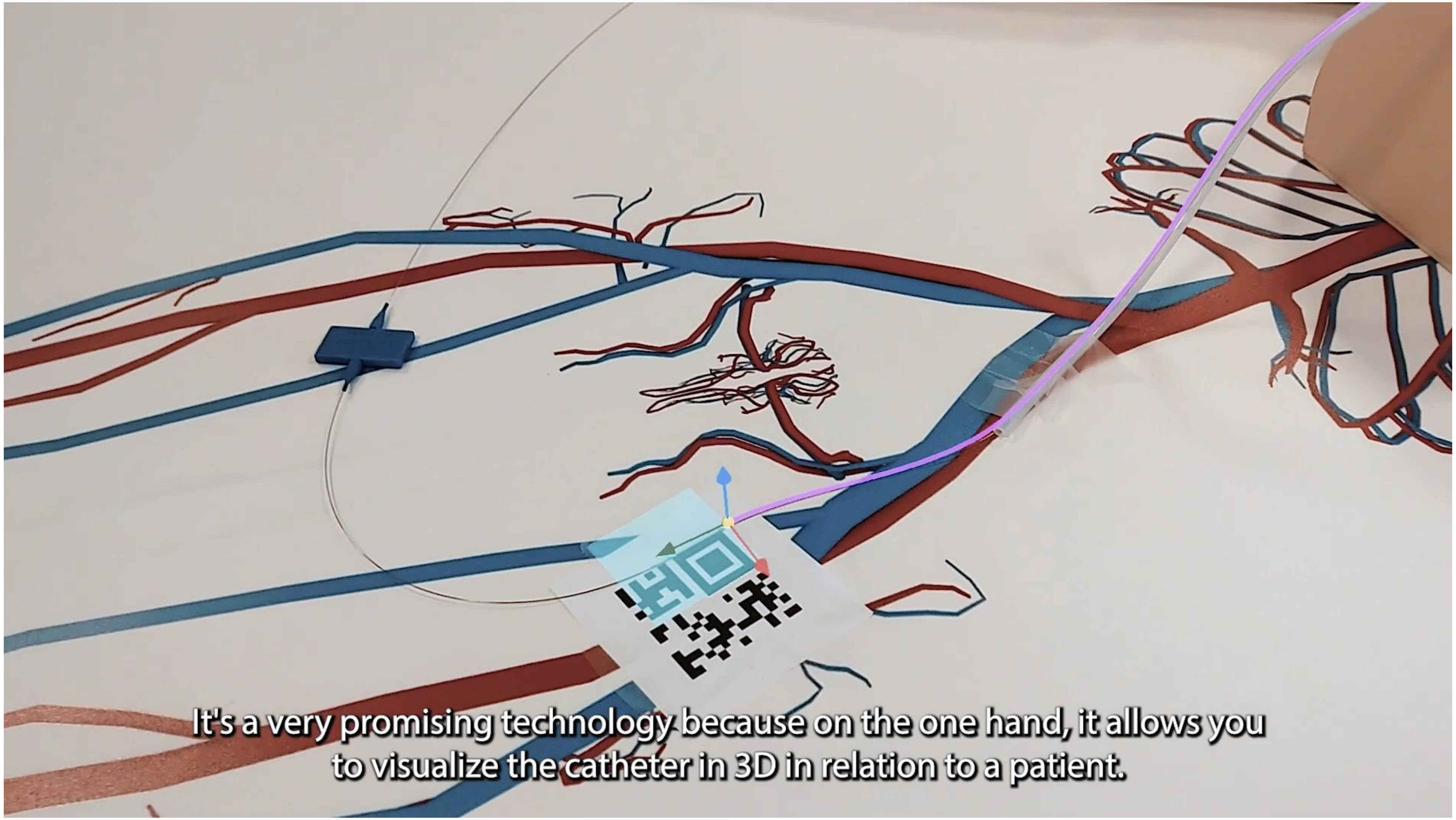
# Absolute shape tracking using augmented reality




- **The depth camera allows to perform spatial mapping**
  = the ability to create a **3D map of the environment** and is an inherent part of augmented reality technology.
- Spatial mapping makes it possible to place objects on real surfaces.
- Relative position in 3D space calculated from position markers robe
- **Hologram of the shape probe is projected in space matching the physical presence of the shape probe.**

# Demonstration absolute shape tracking using augmented reality



# Questions?


**Dr. Christian Voigtländer (R&D Manager)**

- cvoigtlaender@fbgs.com
- www.fbgs.com

- **FBGS International NV**
  Bell-Telephonelaan 2H
  2440 Geel (Belgium)
- **FBGS Technologies GmbH**
  Franz Loewen Str. 3
  07745 Jena (Germany)