DOMINO

Dikes and Debris Flows Monitoring by Novel Optical Fiber Sensors

Luca Palmieri
Thom Bogaard
Miguel Gonzalez-Herraez
Alessandro Pasuto

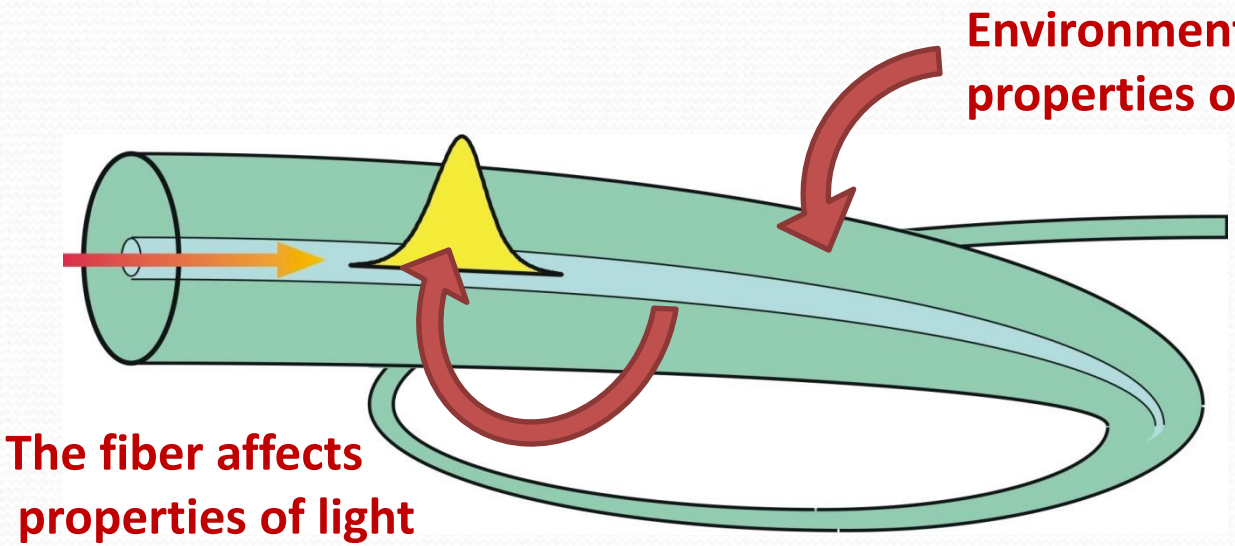
Water JPI
WaterWorks2014 Cofunded Call
18 May 2016, Rome

Consortium Description

ACRONYM	TOPIC	Coordination	Partners
DOMINO	**3**		
DIKES AND DEBRIS FLOWS MONITORING BY NOVEL OPTICAL FIBER SENSORS		**Dike; debris flow; fiber optic sensor; distributed monitoring; pressure; ground vibrations**	

PRINCIPAL INVESTIGATOR	INSTITUTION	COUNTRY
Luca Palmieri	**University of Padova**	**Italy**
Thom Bogaard	Delft University of Technology	The Netherlands
Miguel Gonzalez-Herraez	Universidad de Alcala	Spain
Alessandro Pasuto	National Research Council – Research Institute for Geo-Hydrological Protection	Italy

Optical Fiber Sensors



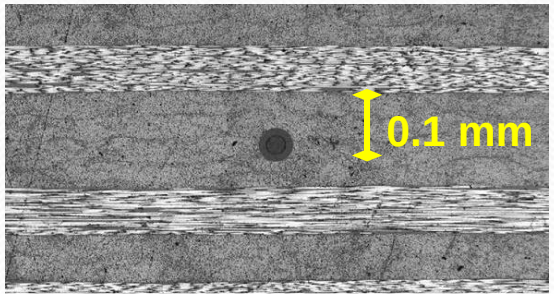
1. The properties of light propagating in the fiber depend on the optical properties of the fiber.

THE OPTICAL FIBER IS THE SENSOR !

to the external environment (temperature, strain, etc.).

3. Variation of the external environment may affect the properties of propagating light.

Optical Fiber Sensors



The optical fiber…

1. is intrinsically sensitive to several physical fields (most notably **temperature** and **strain)**
2. is small and lightweight (can be easily embedded)
3. operates from few to several hundreds of K (ideal for harsh environments)
4. allows signal propagation over huge distances (beyond tens of km)

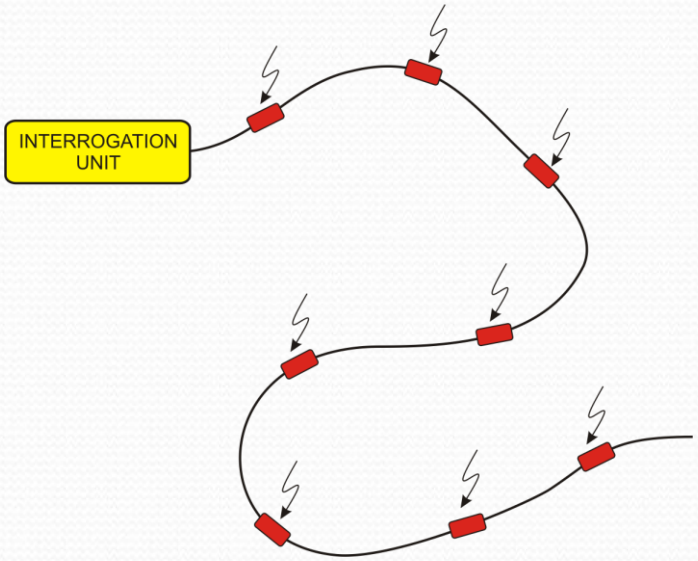
5. enables sensors multiplexing:

- **tens of concatenated sensors**
- **distributed sensors**

!

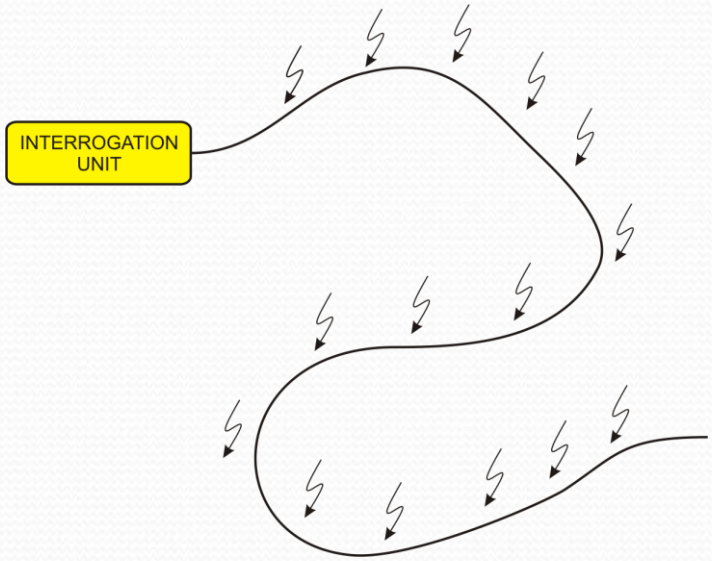
Optical Fiber Sensors

Quasi-distributed sensors



- Fiber Bragg gratings (FBGs).
- Tens of sensors concatenated along a single cable.
- Addressed by wavelength selection.

Distributed sensors



- The fiber is a single sensing element.
- Arbitrary sections can be addressed by sending single optical pulses.
- Spatial resolution around 1 m.
- Tens of thousands of sensing points!
- **Provides a map of the physical field along the fiber.**

Water JPI

DOMINO Objectives

	Sensors to monitor the stability of dikes and embankments	Sensors to detect surge and monitor evolution of debris flows
Pressure	*Anomalous infiltration processes may lead to local increase of underground water level, i.e. hydrostatic pressure.*	*Debris flows composition and rheology can be studied by measuring the local pressure they exert while flowing.*
Vibration	*n.a.*	*Recording ground vibrations induced by debris flows is the most promising way to detect and analyze them.*

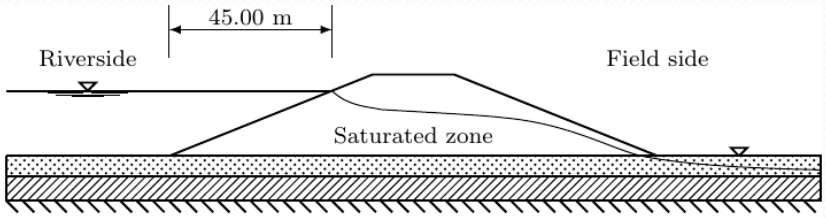
Dikes Monitoring

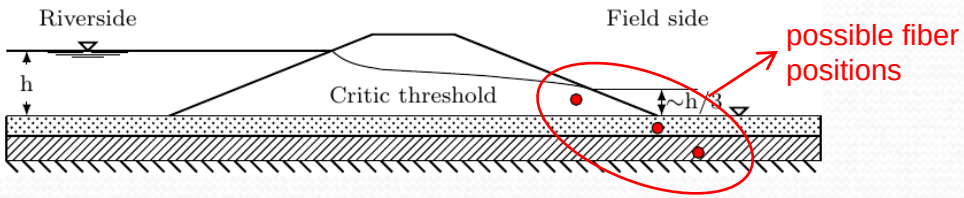
Dike collapse along Secchia river
(near Modena, northern Italy, 01/2014)

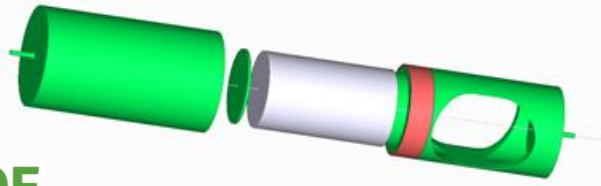
State of art

- Fiber sensors commonly used/studied are based on soil temperature and/or strain measurement.
- Usually fibers are embedded in geotextiles, which seem most befitted to newly built embankments.
- Data interpretation and system optimization are still critical.
- Changes of the hydrostatic pressure are at the base of several dike weakening mechanisms (backward-erosion piping, slope failure, etc.)
- Water pressure under a grass root layer is of importance in determining the initiation of failure of grass covers due to overflow.
- High sensitivity to pressure is required.

Dikes Monitoring







DOMINO proposal

Quasi-distributed pressure sensor (QDPS)

- Tens of single-point sensors concatenated along a single optical cable.
- Cable buried at some position inside the dike or at some depth at its foot; suitable for **retrofitting existing dikes**.
- Based on FBG technology.
- **Target specs:**
  - minimum pressure: 10-20 Pa
  - range: 10-50 km
  - number of sensors: < 50
- Will integrate other systems to improve dike stability assessment.
- Test performed at **Flood Proof Holland.**

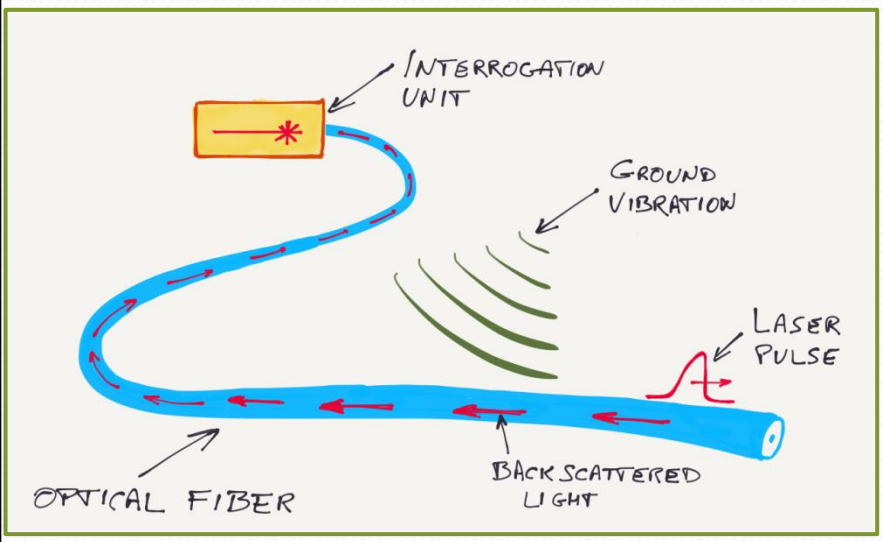
Debris Flows Monitoring

Debris flow near Cortina d'Ampezzo
(north-eastern Italy, 09/2015)

State of art

- Monitoring is crucial for:
  - hazard assessment,
  - civil protection planning.
- "Standard" sensors include:
  - ultrasonic sensors,
  - trip wires,
  - geophones.
- The accuracy is generally poor:
  only surge detection and velocity estimation.
- Monitoring of **ground vibrations**:
  one of the most promising approaches.
- Measurement of **pressure**:
  useful to characterize content and dynamic.
- Application of optical fiber sensors is
  at a **very early stage**.

Debris Flows Monitoring

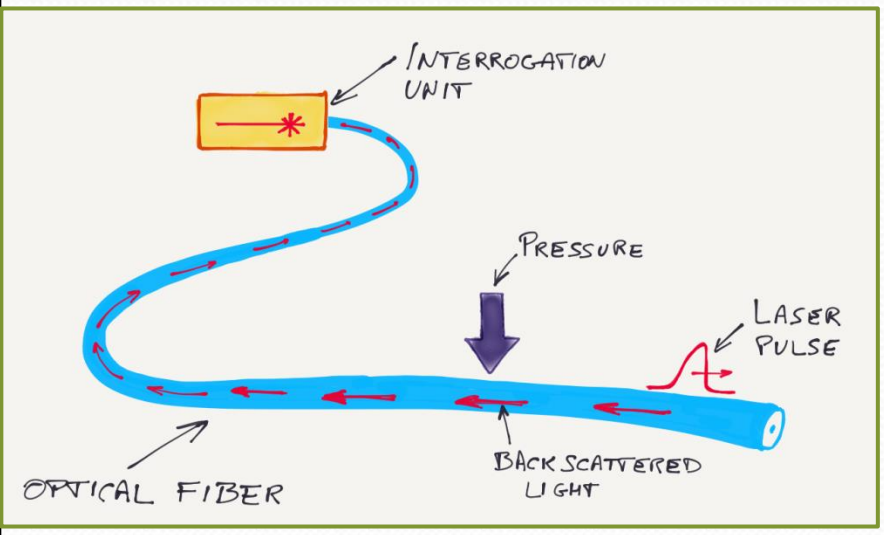


DOMINO proposals

1) Distributed vibration sensor (DVS)

- Optical cable installed along channels and ravines; interrogation unit at a distant and safer place.
- Cheaper and affordable implementation of existing technology (DAS).
- Based on coherent fading of Rayleigh backscattering.
- **Target specs:**
  - frequency: 5-500 Hz
  - range: 5 km
  - spatial resolution: 1-10 m
- Detects surge and monitors evolution (early warning, debris flow characterization).
- Tests performed on an artificial flume.

Debris Flows Monitoring



DOMINO proposals

2) Distributed pressure sensor (DPS)

- Optical cable installed along channels and ravines; interrogation unit at a distant and safer place.
- Based on polarization properties of Rayleigh backscattering.
- **Target specs:**
  - minimum pressure: about 1 kPa
  - range: 1 km
  - spatial resolution: 5-10 m
- Enables characterization of debris flow content and rheology.
- Tests performed on an artificial flume.

The Consortium

Università degli Studi di Padova

Italy

Expertise

Optical fiber technology for communication and sensing. Distributed polarization measurements and sensors.

http://peg.dei.unipd.it/

Main responsibilities

- Project coordination
- Development of quasi-distributed pressure sensor
- Participation to development of distributed pressure sensor
- Participation to large-scale experiments

TU Delft

Netherlands

Expertise

Large water cycle, both natural and artificial. Extreme weather, flooding, science and engineering of delta areas.

http://www.watermanagement.tudelft.nl/

Main responsibilities

- Modelling of dikes hydrology
- Organization of large-scale test on dike monitoring
- Analysis of data from large-scale dike monitoring

Universidad de Alcalá

Spain

Expertise

Optical fiber sensing. Brillouin- and Rayleigh-scattering distributed sensing.

http://grifo.depeca.uah.es/

Main responsibilities

- Development of distributed vibration sensor
- Development of distributed pressure sensor
- Participation to large-scale experiments

irpi

Istituto di Ricerca per la Protezione Idrogeologica

Italy

Expertise

Hydro-geological risk, monitoring and modelling of landslide and debris-flow.

http://www.irpi.cnr.it/

Main responsibilities

- Modelling of debris flows seismic activity
- Development of small-scale testbeds
- Organization of large-scale debris flow tests
- Analysis of data from large-scale debris flow tests

The Consortium

Università degli Studi di Padova

Italy

Expertise

Optical fiber technology for communication and sensing. Distributed polarization measurements and sensors.

http://peg.dei.unipd.it/

Main responsibilities

- Project coordination
- Development of quasi-distributed pressure sensor
- Participation to development of distributed pressure sensor
- Participation to large-scale experiments

TU Delft

Netherlands

Expertise

Large water cycle, both natural and artificial. Extreme weather, flooding, science and engineering of delta areas.

http://www.watermanagement.tudelft.nl/

Main responsibilities

- Modelling of dikes hydrology
- Organization of large-scale test on dike monitoring
- Analysis of data from large-scale dike monitoring

Universidad de Alcalá

Spain

Expertise

Optical fiber sensing. Brillouin- and Rayleigh-scattering distributed sensing.

http://grifo.depeca.uah.es/

Main responsibilities

- Development of distributed vibration sensor
- Development of distributed pressure sensor
- Participation to large-scale experiments

irpi

Istituto di Ricerca per la Protezione Idrogeologica

Italy

Expertise

Hydro-geological risk, monitoring and modelling of landslide and debris-flow.

http://www.irpi.cnr.it/

Main responsibilities

- Modelling of debris flows seismic activity
- Development of small-scale testbeds
- Organization of large-scale debris flow tests
- Analysis of data from large-scale debris flow tests

The Consortium

Università degli Studi di Padova

Italy

Expertise

Optical fiber technology for communication and sensing. Distributed polarization measurements and sensors.

http://peg.dei.unipd.it/

Main responsibilities

- Project coordination
- Development of quasi-distributed pressure sensor
- Participation to development of distributed pressure sensor
- Participation to large-scale experiments

TU Delft

Netherlands

Expertise

Large water cycle, both natural and artificial. Extreme weather, flooding, science and engineering of delta areas.

http://www.watermanagement.tudelft.nl/

Main responsibilities

- Modelling of dikes hydrology
- Organization of large-scale test on dike monitoring
- Analysis of data from large-scale dike monitoring

Universidad de Alcalá

Spain

Expertise

Optical fiber sensing. Brillouin- and Rayleigh-scattering distributed sensing.

http://grifo.depeca.uah.es/

Main responsibilities

- Development of distributed vibration sensor
- Development of distributed pressure sensor
- Participation to large-scale experiments

irpi

Istituto di Ricerca per la Protezione Idrogeologica

Italy

Expertise

Hydro-geological risk, monitoring and modelling of landslide and debris-flow.

http://www.irpi.cnr.it/

Main responsibilities

- Modelling of debris flows seismic activity
- Development of small-scale testbeds
- Organization of large-scale debris flow tests
- Analysis of data from large-scale debris flow tests

The Consortium

Università degli Studi di Padova

Italy

Expertise

Optical fiber technology for communication and sensing. Distributed polarization measurements and sensors.

http://peg.dei.unipd.it/

Main responsibilities

- Project coordination
- Development of quasi-distributed pressure sensor
- Participation to development of distributed pressure sensor
- Participation to large-scale experiments

TU Delft

Netherlands

Expertise

Large water cycle, both natural and artificial. Extreme weather, flooding, science and engineering of delta areas.

http://www.watermanagement.tudelft.nl/

Main responsibilities

- Modelling of dikes hydrology
- Organization of large-scale test on dike monitoring
- Analysis of data from large-scale dike monitoring

Universidad de Alcalá

Spain

Expertise

Optical fiber sensing. Brillouin- and Rayleigh-scattering distributed sensing.

http://grifo.depeca.uah.es/

Main responsibilities

- Development of distributed vibration sensor
- Development of distributed pressure sensor
- Participation to large-scale experiments

irpi

Istituto di Ricerca per la Protezione Idrogeologica

Italy

Expertise

Hydro-geological risk, monitoring and modelling of landslide and debris-flow.

http://www.irpi.cnr.it/

Main responsibilities

- Modelling of debris flows seismic activity
- Development of small-scale testbeds
- Organization of large-scale debris flow tests
- Analysis of data from large-scale debris flow tests

WPs and Management

WP#	Title	Coordinator
WP0	Coordination	Luca Palmieri
WP1	Distributed fiber optic sensors	Miguel Gonzalez-Herraez
WP2	Quasi-distributed fiber optic sensors	Luca Palmieri
WP3	Geophysical numerical modelling	Thom Bogaard
WP4	Small- and large-scale physical models and tests	Alessandro Pasuto
WP5	Communication and dissemination	Andrea Galtarossa

- Monthly meetings of the Management Committee (WPs' coordinators)
- Twice-a-year general meetings
- Involvement of stakeholders and relevant authorities
- Endorsement letters already received from:
  Valorisation Programme Delta Technology and Water (Netherlands), *Provincia Autonoma di Bolzano* (Italy), *Regione del Veneto* (Italy), *Focus SL* (Spain)

Scheduling

DOMINO started on May 1st, 2016

Deadlines		Main Milestones
M9	Jan 2017	Release of numerical models Definition of sensors' specifications
M18	Oct 2017	Release of the DVS system
M21	Jan 2018	Release of the QDPS system
M27	Jul 2018	Release of the DPS system
M30	Oct 2018	Dike monitoring large-scale tests in execution
M30	Oct 2018	Debris-flow monitoring large-scale tests in execution

Expected Results and Exploitation

- New and improved numerical models to increase knowledge about dike failure mechanisms and debris flow rheology.
- An engineered QDPS to improve monitoring of dike stability.
- An affordable DVS specifically designed to address debris flows monitoring.
- A DPS to characterize content and rheology of debris flows.
- Both pressure and vibration sensors may find application in other fields (most notably the oil and gas industry).
- Establishing a research group beyond the project duration. **Collaborations are welcome!**
- Contribute to the public awareness by pervasive dissemination actions and constant involvement of the relevant authorities.

Acknowledgements

MINISTERO DELL'ISTRUZIONE DELL'UNIVERSITA' E DELLA RICERCA

MINISTERIO
DE ECONOMÍA
Y COMPETITIVIDAD

Netherlands Organisation for Scientific Research

http://domino.dei.unipd.it

luca.palmieri@unipd.it