

Projet First HE: FOTHERM

Exploration of failure localization techniques for Fiber Optic THERMal sensor

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1 : CERISIC, 2 : EMPHASE



1) Context

Our partner, EMPHASE Energy Management, is deeply involved in the development of a **low-cost thermal (and vibration) monitoring solution for gas and electricity power underground distribution infrastructure** in Belgium as a starting point. The main features can be summarized as follow:

- Reuse of existing telecommunication optical fiber;
- Distance range > 10km;
- Accuracy < 100m;
- Low-cost approach;
- With Alarming, monitoring and hot spot localization.



Fig. 1: Application examples - pipeline blast [1] and underground power cable failure [2]

A first low-cost prototype has been designed to detect temperature variations of an optical fiber, over distances greater than 10km and at a cost lower than the usual marketing techniques (distributed commercial systems rely mainly on Brillouin and Raman effects). The technique is based on intermodal interferometry and is able to detect a thermal variation on the fiber but without exact localization. **The FOTHERM project targets the localization of hot spots distributed on the optical fiber.**

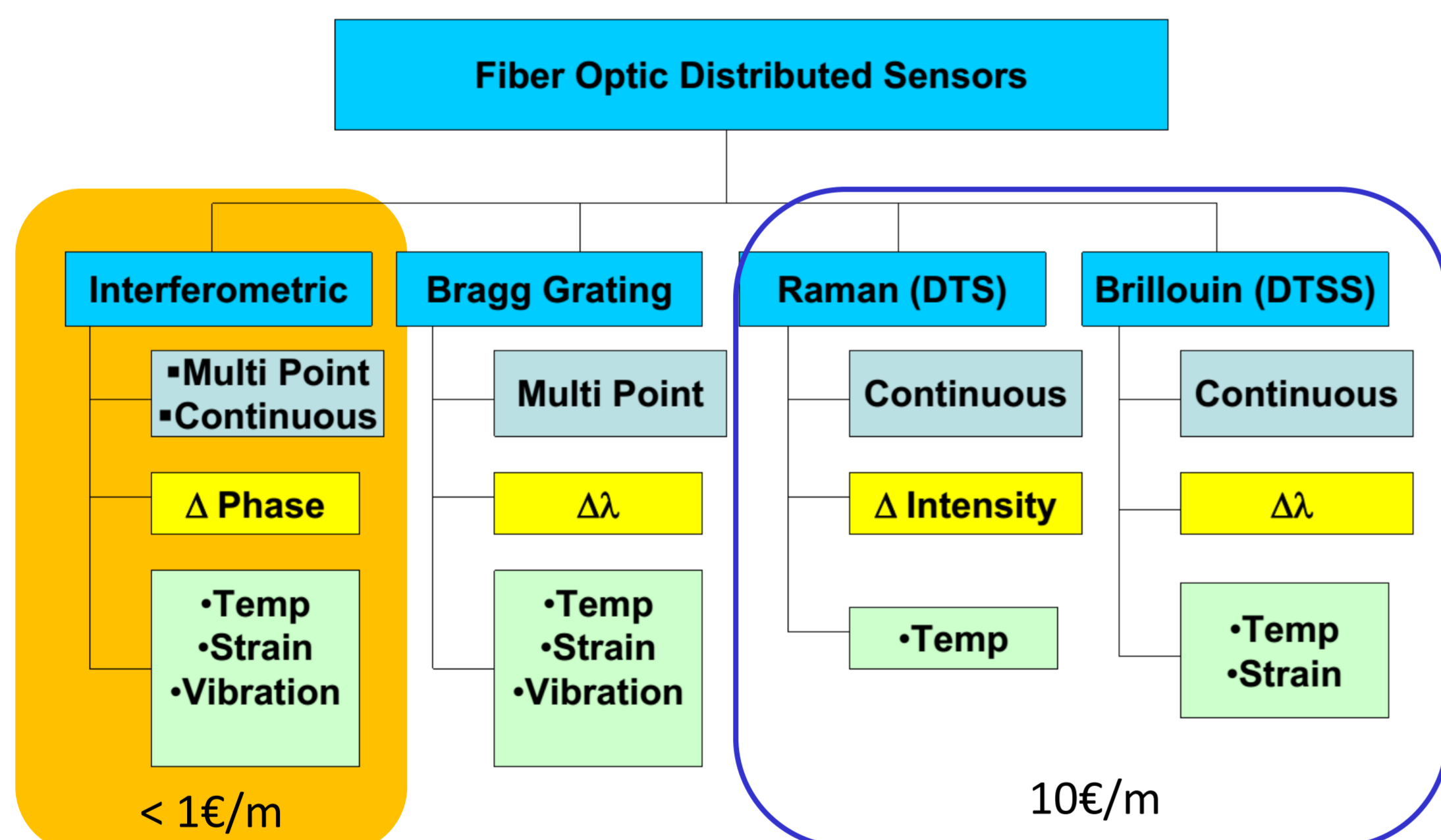


Fig. 3: Technology map for distributed temperature sensing using optical fiber [3] and estimating costs

2) Researching goals

The FOTHERM project targets the **localization of a given temperature variation on the fiber with a spatial resolution of 100m**. To achieve this purpose, four steps are scheduled:

1. Exploring Rayleigh backscattering as sensing technique;
2. Investigating Optical Time Dependent Reflectometry (OTDR) technique for localization purpose;
3. Prototyping & performance analyzing;
4. In-situ testing (ORES & AIR LIQUIDE plants).

3) Technical know-how

Used at wavelength below cut-off, fiber optic acts as multimode fiber and interferences occur between propagating modes in the same fiber. Fiber optic speckle refers to the pattern produced by these modal interferences who is sensitive to external constraints like temperature and vibration.

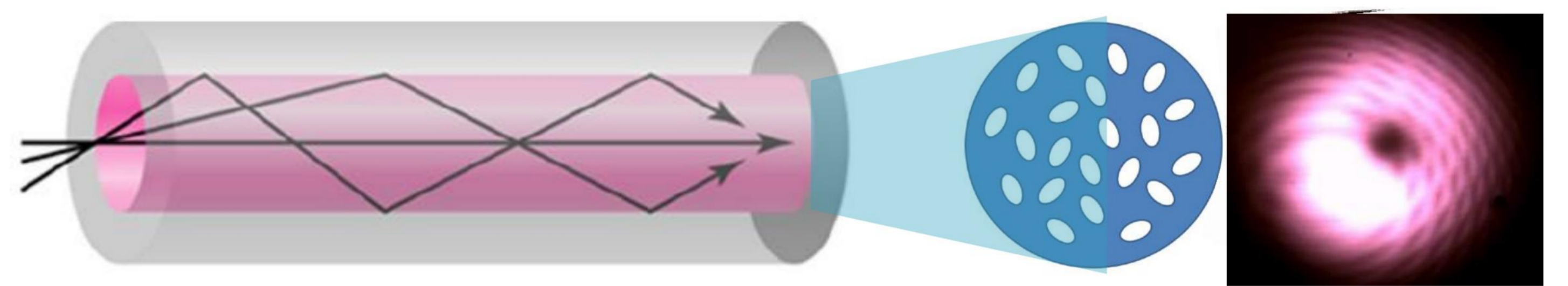


Fig. 4: Intermodal interference principle in a single mode optical fiber and its results on camera screen [4]

In few-mode configurations, it has been shown in [5] that temperature variation applied on the fibre results in a moving pattern. The blue arrows represent a rotation pattern while the black arrows symbolize a pulsation of intensity (beating) between both spots.

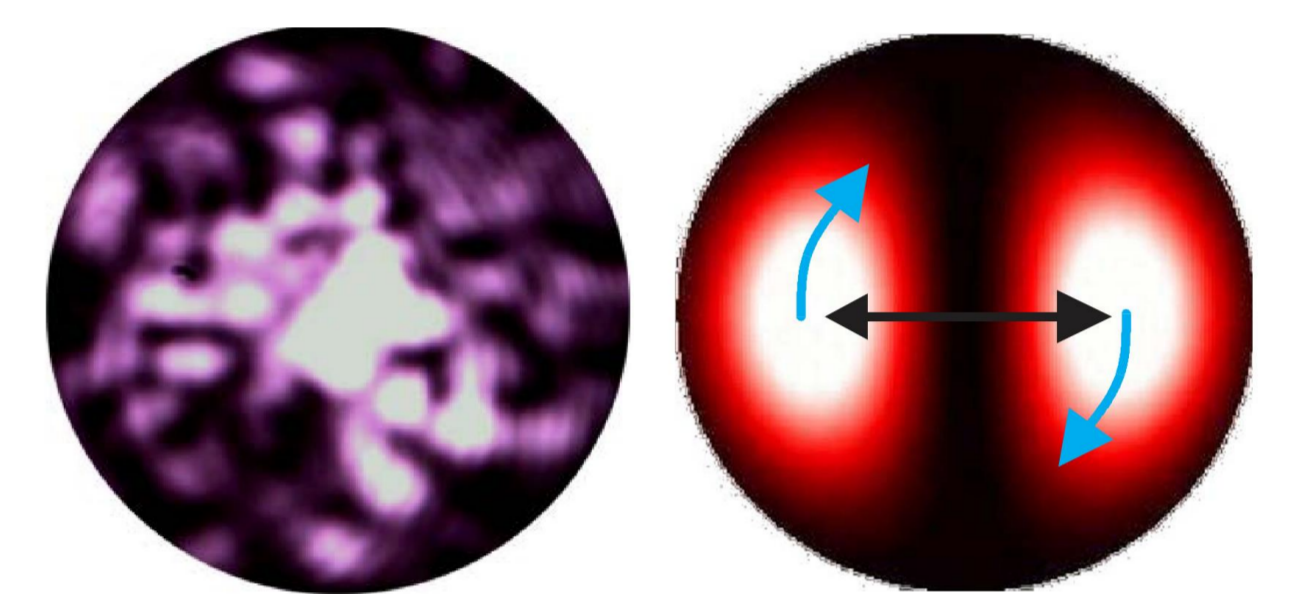


Fig. 5: Moving interference pattern [5]

4) Exploration of the localization using OTDR

Based on the measurement of Rayleigh backscattering, it measures the time delay between the launching of a pulse in the fiber and its multiple reflections distributed along the optical link under test. As the light velocity in the fiber is known, the distances of the reflective event can be determined. The following setups including OTDR technique will be investigated:

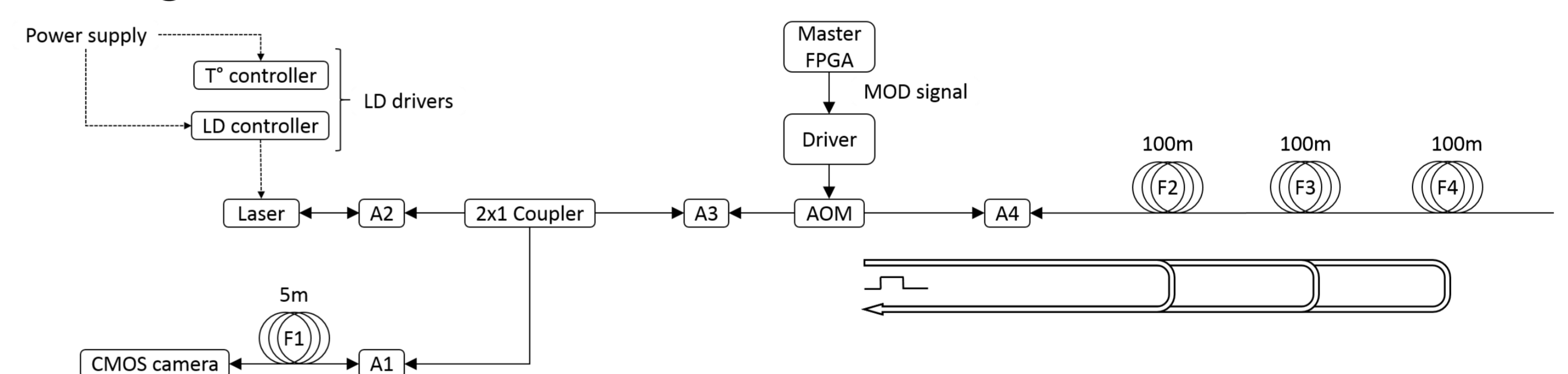


Fig. 6: First implementation using an acousto-optic modulator (AOM) and 2X1 coupler

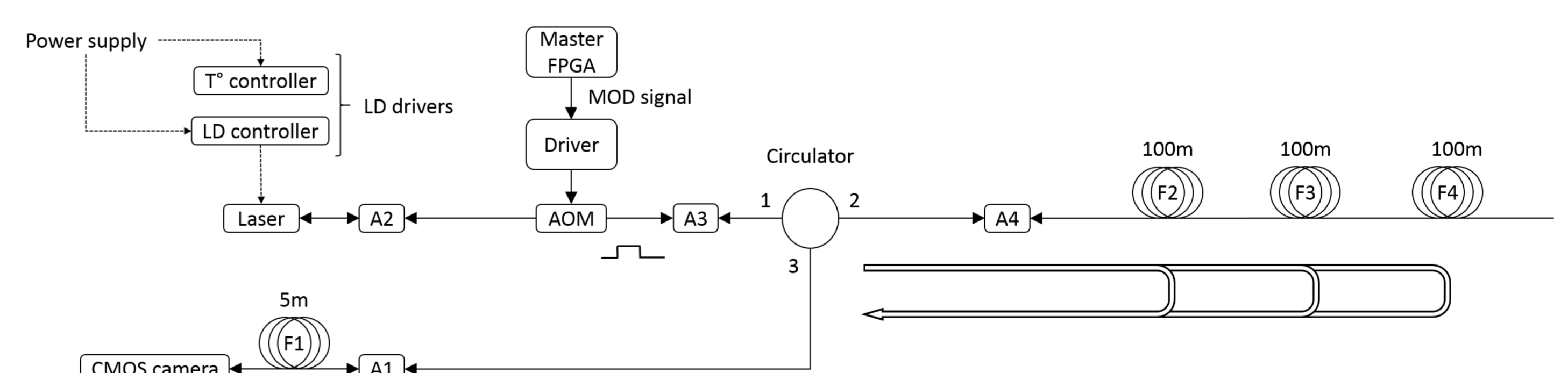


Fig. 7: Second implementation using an acousto-optic modulator (AOM) and a circulator

References:

- [1] MailOnline (2010). 'The moment workmen accidentally blew up a Texas gas pipeline, leaving one dead and seven injured'. Available from: <http://www.dailymail.co.uk/news/article-1284880/Texas-gas-pipeline-explosion-kills-worker-injures-seven.html> [24 February 2015]
- [2] Electrical Engineering Portal (2012). 'The Good, The Bad and The Ugly Cable Insulation'. Available from: <http://electrical-engineering-portal.com/the-good-bad-ugly-cable-insulation> [16 February 2015]
- [3] Krohn, D. (2010). 'Overview of Fiber Optics Sensors', Industrial Laboratory
- [4] Musin, F. (2014). 'Fiber Optic Temperature Sensor Based on Image Processing of Intermodal Interference Pattern'. Presented at the Journée d'Etudes 'Will be smart by 2020', Chaire académique Ores - UMONS 'Smart Grids - Smart Metering', Mons, Belgium.
- [5] Musin, F., Mégret, P. and Wuilpart, M. (2014) 'Fiber optic temperature sensor based on image processing of intermodal interference pattern', Paper presented at IEEE Sensors 2014 Conference, Valencia, Spain.

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