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#04-161 Confocal chromatic sensor for displacement monitoring in research reactor

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Confocal chromatic microscopy is an optical technique allowing measuring displacement, thickness, and roughness with a sub-micrometric precision [1]. Its operation principle relies on a wavelength encoding of the object position. The light emitted by a polychromatic source is transported by an optical fiber up to an optical system, called optical pen only composed of passive components and presenting a strong chromatism. That means that the various wavelengths will be focused at different positions by the optical system on the optical axis. The surface of the object under test will reflect all the wavelengths but only a small fraction of the reflected spectrum will be focused back on the cleaved end of the optical fiber and then will be able to be guided towards an optical analyzer.
The change in the spectral properties of the analyzed signal provides an information about the distance of the interface located within the measuring range of the sensor. Historically, this class of sensors has been first developed in the 90's by the company STIL based in the south of France.

Of course, this sensor can only operate in a sufficiently transparent medium in the considered spectral domain. But it presents the advantage of being contactless which is a crucial advantage for some applications such as the one of measuring displacement in the core of nuclear research reactor: cladding swelling measurement for instance.

The extreme environmental conditions encountered in a nuclear reactor -high temperature, high pressure, high fluency irradiations, strong vibrations and surrounding turbulent flow- can affect the performances of those optical system and mitigation techniques need to be put in place to optimize the sensor response for this specific environment. Another constraint concerns the small space available between the rods to be monitored, implying the challenge to conceive a very small sensor able to operate under these constraints.
This development is made in the framework of a PHD at the Commissariat à l'Energie Atomique (CEA) -in collaboration with the Laboratoire Hubert Curien (LabHC) of the University of Saint-Etienne and also the company STIL.

Among various scientific and technological locks, the first to be considered is the Radiation Induced Attenuation (RIA) phenomenon of the fiber and of the bulk optical components constituting the optical system. Indeed, glasses and fibers tends to darken when exposed at high neutron fluencies decreasing the light transmission efficiency. In the state of the art, it has already been shown that some spectral regions show huge RIA levels under high level of mixed gamma/neutron irradiation. In the visible, the absorption band peaking at 630 nm and caused by the Non-Bridging-Oxygen Hole Centers (NBOHCs) can strongly alter the sensing as well as the growing of the vibration band at 1380 nm of hydroxyls that could appear when NBOHCs are passivated by hydrogen. Basic mechanisms at the origin of the RIA are known [1, 2] but still only a few experimental data at the very high fluency associated with the application (neutron fluency about $10^{19} n/cm^2$ with gamma doses of more than one GGy, and also high temperature) are available, making difficult to really assess the RIA impact of the sensor performances.

However, RIA is not the only scientific lock; elevated temperature can also affects the optical system. Indeed, if the sensor exploits the chromatism, related to the refractive index dependence to the wavelength, the temperature is also able to modify the refractive index causing a direct shift of the probing spectral range but also dilatation of the lenses and optical aberrations. Irradiations too can alter the well behaviour of the sensor -because of compaction. We also have to stay cautious about water under pressure with turbulent flow and vibrations.

We will present the detailed specifications and a preliminary analysis of the constraints, with a special focus on the RIA at high fluency.

[1] http://www.stil-sensors.com/?lang=EN
[2] D. L. Griscom, « γ and fission-reactor effects on the visible-range transparency of aluminium-jacked, all-silica optical fibers », J. Appl. Phys., vol. 80, no.4, pp. 2142-2155, Aug. 1996.
[3] S. Girard et al. "Radiation Effects on Silica-Based Fibers, « Recent Advances and Future Challenges», IEEE Trans. Nucl. Sci., vol 60, no. 3, pp. 2015-2036, June 2013.

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