Study and development of fiber Bragg grating sensors for advanced industrial applications

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Industrial environments impose harsh conditions on instrumentation, combining high temperature, mechanical stress, vibration, and electromagnetic interference that often challenge conventional sensors. Fiber Bragg grating (FBG) sensors have emerged as a powerful alternative for distributed and reliable measurements, offering multiplexing capability, immunity to electromagnetic noise, compactness, and resilience in extreme conditions. This thesis presents how FBG technology can be transformed into robust industrial instruments through the design, implementation, and validation of several customized systems.

The first part of the work addresses strain sensing through two complementary studies. The first demonstrates a textile-integrated FBG array, pre-strained and calibrated for repeatable quantitative deformation monitoring, opening perspectives for wearable and biomedical applications. The second focuses on the structural health monitoring of a 10-kW vertical axis wind turbine, where both externally bonded and packaged sensors were deployed. The results revealed distinct mechanical signatures related to aerodynamic loading, rotor imbalance, and tower resonance, contributing to a better understanding of wind turbine dynamics and providing practical recommendations for sensor positioning and operational monitoring.

The second part explores temperature sensing in industrial environments. FBG-based systems were designed and implemented in several Saint-Gobain facilities, including a glass furnace and cooling arches. A complete sensing chain was established, encompassing optical demodulation, three-dimensional visualization, and remote communication through industrial protocols such as Modbus TCP, MQTT, and OCP UA, while maintaining cybersecurity compatibility. A third study concerned a lamination tool operating under pressures up to 4 MPa and temperatures approaching 400 °C, leading to the development of a rugged and reusable sensor packaged in metallic tubing, capable of withstanding combined thermal and mechanical stress.

Finally, a novel slow-light FBG dosimeter was developed for the detection of low-dose gamma radiation. By combining calorimetric transduction with a Pound–Drever–Hall interrogation technique, the system achieved a resolution of $6\,\mathrm{mGy}/\sqrt{\mathrm{Hz}}$ within a sub-cm sensing region, representing one of the most compact and sensitive fiber-optic dosimeters reported so far.

In conclusion, this thesis demonstrates how the integration of optical fibers into carefully engineered, calibrated, and networked devices enables reliable measurements in some of the most demanding industrial conditions. The developed systems illustrate that FBG sensors can evolve from laboratory components into fully operational tools, paving the way toward smarter and more connected industrial infrastructures.