

# Study on the Application of Fiber Bragg Grating Sensors

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**Abstract:** As a sensor with excellent performance, many kinds of sensors, such as uniform fiber Bragg grating and chirped fiber Bragg grating, have more applications. Through the principle of fiber Bragg grating internal writing, interference side writing, phase template writing and other manufacturing techniques, the principle of fiber Bragg grating sensor in the environment, stress and temperature changes and the dynamic magnetic field induction principle analysis, As well as the review of the applications of FBG sensors in composite materials, power system, oil and gas well and building structure, and illustrates the application of this kind of sensor in single-parameter sensing measurement, especially multi-parameter sensing measurement. Great room for development, it is worth further study.

## 1. Introduction

Since Hill KO first discovered the phenomenon of photo-gratings in germanium-doped fibers and created the world's first fiber grating in 1978, it has many unique advantages over traditional fiber-optic sensors. Therefore, in the field of optical fiber communication and fiber optics Sensing and other fields have broad application prospects. Most of the traditional optical fiber sensors are "light type" and "interference type." The former information reading is the measurement of light intensity, so the ups and downs of light sources, fiber bending loss, connection loss and detector aging and other factors will affect the measurement accuracy. The latter read the information to observe changes in the interference fringes, which requires interference fringes clear, and the interference fringes clear two interference light required light intensity equal. The FBG sensor based on fiber Bragg grating (FBG) has some special advantages. The most important thing is that the sensor signal has the advantages of wavelength modulation and multiplexing. The advantage of the FBG sensor is that the measurement signal is not affected by the optical fiber Bending loss, connection loss, fluctuation of light source and aging of the detector; avoiding the problems of ambiguous phase measurement of the interferometric optical fiber sensor; cascading a plurality of Bragg gratings onto an optical fiber, embedding the optical fiber (or adhering to) Structure under test, which can simultaneously obtain the information of several measurement targets, and can achieve quasi-distributed measurement. It can be said that FBG sensor is the most ideal sensitive element. For the above reasons, FBG sensors have become the research focus of current optical fiber sensors. With the progress of fiber grating manufacturing technology and performance improvement and the application of research and development of emerging, fiber grating sensor in the field of sensors will be more and more important.

## 2. Civil Engineering Structure of the Application

Structural monitoring in civil engineering is the most active area for fiber grating sensors. The state of the foundation structure and the measurement of the mechanical parameters are of crucial importance for the maintenance of bridges, dams, tunnels, high-rise buildings and stadiums. By measuring the distributional strain of the building, the state of the local loads can be predicted. Fiber grating sensors can either stick to the surface of an existing structure, or they can be embedded in the structure during casting to measure the structure in real time and monitor the formation and growth of structural defects. In addition, multiple FBG sensors can be connected in series to form a network for distributed detection of the structure. Sensing signals can be transmitted over a long

distance to the central control room for telemetry. Therefore, in civil engineering, fiber grating sensors become the most important means of structural monitoring. At present, the application of fiber grating sensors most areas when the number of bridges safety monitoring. The Beddington Trail Bridge near Calgary, Canada is one of the earliest bridges to be measured using fiber grating sensors. Sixteen FBG sensors are attached to prestressed concrete-backed steel bars and carbon fiber composite bars to provide long-term monitoring of the bridge structure, This was considered impossible before. In the summer of 1999, 120 FBG sensors were installed on a steel structure bridge at Las Cruces Interstate 10 in New Mexico, United States, creating the largest record of using FBG sensors on a single bridge at the time. The bridge, built in 1970, has experienced many fatigue cracks. FBG sensing systems not only detect and count standard vehicles, but also measure the speed and weight of the vehicle. With this system, it is possible to monitor dynamic loads Caused by the structural response, degradation and damage to understand the bridge's long-term changes in traffic response. In 1997, an all-composite bridge was constructed in Butler County, Ohio, USA. The composite was embedded with a fiber grating strain sensor in the fabrication process. Through the Internet, the bridge's load response can be regularly monitored and tracked Long-term performance. A team from the University of Vermont has used Fiber Grating sensors to remotely monitor the Waterbury Bridge in Vermont, transmit measured data to a central computer for analysis and publish on the Internet. The Horsetail fall bridge on the Columbia River in Oregon is an ancient bridge that was built in 1914 and was originally a concrete structure. The original design did not take into account the current traffic requirements. Later, the bridge was reinforced with fiber-reinforced plastic composites. To monitor the reinforcement The structure of the situation. The 28 FBG sensors are mounted on two concrete beams reinforced with composite materials and have been measured monthly with a portable spectrometer since 1998.

### **3. Aerospace Industry Applications**

The aerospace industry is a sensor-intensive place where more than 100 sensors need to be used by an aircraft to monitor pressure, temperature, vibration, fuel level, landing gear condition, wing and rudder position, etc. The sensor's Size and weight become very important. Fiber grating sensors have only one fiber and the sensing elements (gratings) are made in the core. Few sensors can be compared in terms of small size and light weight. Therefore, the aerospace industry attaches great importance to fiber grating sensing technology, and only Boeing Co., Ltd. has registered several patents on fiber grating sensors. The use of advanced composite materials to make aerospace structures such as wing components is an inevitable trend. Advanced composites are more resistant to fatigue, lighter weight, better strength-to-weight ratio, more complex shapes than metal and corrosion resistant, and are especially prone to embedding in the manufacture of composite structures Fiber grating sensors provide real-time health and performance monitoring of airborne sensing systems during aircraft operations, reducing aircraft weight, inspection time and maintenance costs while improving performance. Smart Fibers Ltd offers compact deformable composite structures with fiber grating sensors embedded in aircraft and spacecraft to facilitate health and service monitoring, structural damage detection, design information gathering, manufacturing aids, smart controls and structural dimension monitoring. NASA attaches great importance to the application of FBG sensors. They installed a fiber grating sensing network that measures strain and temperature on the Space Shuttle X-33 to provide real-time health monitoring of the space shuttle. The X-33 is a prototype designed for round-trip flights to the International Space Station. Ames Research Center Helicopter rotors are measured with a nondestructive, sensitive pressure sensor that buries a fiber grating sensor in a specially designed casing with a tube thickness of less than 1.6 mm to provide two-dimensional, real-time Sensing data. Helicopter rotor pressure sensing is currently drilling holes in the wing, the pressure sensor into the hole for measurement. This compromised method requires special design and manufacture of the rotor, costing more than a million dollars. They also applied fiber grating sensors to the measurement of tail rotor loads, the role of the rotor and fuselage, the aerodynamics of the rotor in the machine, the rotor-rotor interaction in the tilted rotor, the aerodynamics of the rotor shaft, and the wake and tail

interaction. Langley Research Center and Hampton University are collaborating on the development of fiber grating shear stress monitoring sensors for aerodynamic devices.

#### 4. Power Industry Applications

Most of the power industry equipment in a strong electromagnetic field, the general electrical sensors can not be used. In many cases, the measurement needs to be carried out in high voltage, such as on-line monitoring of high-voltage switch, high-voltage transformer winding, generator stator and other parameters such as temperature and displacement of real-time measurement of these places require sensors with good insulation properties, Small size, and passive devices, fiber grating sensors are the best choice for these measurements. Some power equipment is often located in hard-to-reach places such as barren hills, transmission cables in desert wilderness and relay substations, and the telemetry capability of distributed fiber grating sensing systems can greatly reduce equipment maintenance costs. Therefore, the application of FBG sensor in power industry has a good prospect. Fiber sensors using the Faraday effect have been used for high-current measurements at high voltages in the distribution industry, but the problems due to linear birefringence, temperature and vibration have limited the application of this technique. An alternative approach is to use an integrated system of conventional current transducers, piezo-electric elements, and fiber gratings to indirectly measure high currents, which convert the current into a voltage that changes the piezoelectric element by Fiber grating sensor measurement. Another improved method to further improve the resolution, the method of fiber grating sensor based on the fiber grating grating-based method to replace.

Knowing the local temperature distribution in high-voltage, high-power equipment such as generators and transformers is crucial to understanding their working status and to identifying new or repaired product quality. Defects or deterioration of the device can be detected by continuously monitoring the temperature change of the coil windings. Hammon et al. Demonstrated the use of fiber grating sensors to measure the winding temperature of high voltage transformers. The accuracy of long-term monitoring has reached  $\pm 3^\circ\text{C}$ . If you use WDM technology for this system, you can make real-time multi-point measurements. Siemens, Germany, is using fiber grating sensors for measuring the stator temperature of air-cooled turbine generators. They use epoxy to embed the fiber grating in the stator. The fiber grating is specially encapsulated to ensure a vacuum of  $4 \times 10^5\text{ Pa}$  Under the no deformation and is not sensitive to chemical and physical changes in the epoxy resin at  $160^\circ\text{C}$ . Their goal is to continuously measure the range from  $20^\circ\text{C}$  to  $160^\circ\text{C}$  with a measurement accuracy of less than  $1^\circ\text{C}$ . At the same time, they also measured high currents in the same generator.

At present, wind turbine generators are getting bigger and bigger, from MW to MW. A wind farm that outputs 1.5 MW requires 70 m of blades and a tower height of 100 m. The next generation of wind turbine generators will reach 5 MW or more and require more than 100 m of blades, which are necessary for real-time monitoring of these blades. Smart Fiber Ltd prepares composite blades, buries fiber grating sensors into the composite during manufacturing, and monitors wind turbine generators for real-time, on-the-ground monitoring in real time. In this application, FBG sensors can overcome the electromagnetic interference of electrical sensors, afraid of lightning shortcomings.

#### 5. Conclusion

Compared with traditional sensors, FBG sensors have the following characteristics: high precision, good sensitivity, high reliability, anti-electromagnetic interference, corrosion resistance, simple structure, small size, suitable for many occasions. Researchers at home and abroad have done a lot of research on fiber grating sensors and applied this new technology to many projects on fiber grating sensors. Believe in the near future FBG sensor is bound to replace traditional sensors in many fields.

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