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Multi-point high temperature optical fiber sensor

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ABSTRACT

The ability to perform spatially resolved measurement of extreme temperatures, the order of 1000°C and above, would yield enormous benefit to many heavy industrial processes. While optical fibers can provide spatial information along their length through distributed and multi-point sensing techniques, operation at such temperatures is an area of ongoing research and development. A challenge is that conventional optical fibers, fabricated with a chemically doped core, suffer dopant diffusion at these high temperatures, ultimately limiting their operating lifespan. We can overcome this limitation by using specialty pure silica fibers, such as microstructured optical fibers. In this work we demonstrate the ability to use such fibers in a significantly multiplexed configuration with twenty fibre Bragg grating sensing elements written via femtosecond laser ablation.

Keywords: Fiber Bragg gratings, optical fiber sensor, temperature sensing

1. INTRODUCTION

Fiber Bragg gratings (FBGs) have found common use within structural health monitoring, but have also been employed in recent years for temperature sensing [1]. Typically FBGs written in conventional core:clad single-mode fibers (SMF) are limited to temperatures below 500°C, above which thermal annealing removes the refractive index modulations that make up the FBG [1, 2]. Specialty fibers and damage-type FBG writing techniques can expand this operating range, such as regenerated FBGs [3] and femtosecond written type II FBGs [4], which allow for sensing over 1000°C.

The use of single-material microstructured optical fibers is attractive for high temperature applications as dopant diffusion is avoided. Of particular interest is the simple to fabricate suspended core fiber (SCF) fiber geometry, which consists of three evenly spaced holes within a fiber creating a glass core in which the light confinement comes from the glass:air index contrast. Our previous work on SCFs has shown that a variety of temperature sensing techniques can be employed using these fibers, such as multimode interference [5] and femtosecond laser ablation gratings [6]. Through the latter approach, we have demonstrated the use of these fibers in sensing up to 1300°C [6], with long term (days) stability in annealed sensors shown to 1100°C [7].

In our previous work we demonstrated a limited multiplexing capability with three FBGs in a single fiber [6]. Here we report on the ability to dramatically expand this to twenty FBGs in a single fiber.

2. MULTI-POINT SENSOR

Twenty FBGs were written using a point-by-point fs-laser ablation technique on the core of a single in-house fabricated pure-silica SCF, with similar specifications as previously reported [6, 7]. Briefly, the FBGs were fabricated using wavelength-doubled (524 nm) femtosecond pulses (<250 fs, 100 nJ) at a pulse frequency of 1 kHz. The pulse energy was approximately 100 nJ. The laser pulses were focused through the cladding onto the core using a 50× microscope objective (Nikon MUE13500). The fiber was translated a length of 2 mm along its axis to produce an FBG with a pitch the order of 1 μm. Additional FBGs were written by re-mounting the fiber and writing with a different pitch to give a Bragg wavelength

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separation of 6 nm. The reflection spectrum of the FBG array was recorded using an optical fiber interrogator (Micron Optics si255) and is shown in Figure 1.

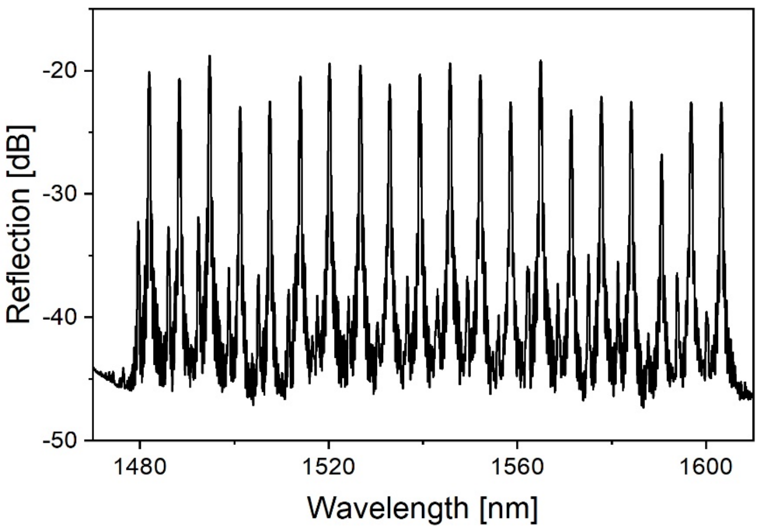

Figure 1. Reflection spectrum of a SCF with 20×2 mm FBGs with 6.5 nm wavelength spacing between adjacent gratings.

The grating array features high signal to noise ratio (> 10dB) and can be used to monitor temperature at twenty independent locations by separately tracking the shift of each peak.

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