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Research Article

Analysis of fiber bragg gratings for the elimination of realignment during the life of the system while FBG is spliced directly to the doped fiber

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Fiber brag grating, optical link, Wavelengths.

Abstract

Fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength-specific dielectric mirror. A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector.

1.Introduction

Fiber Bragg gratings are created by "inscribing" or "writing" systematic (periodic or aperiodic) variation of refractive index into the core of a special type of optical fiber using an intense ultraviolet (UV) source such as a UV laser. Two main processes are used: interference and masking. The method that is preferable depends on the type of grating to be manufactured. Normally a germanium-doped silica fiber is used in the manufacture of fiber Bragg gratings. The germanium-doped fiber is photosensitive, which means that the refractive index of the core changes with exposure to UV light. The amount of the change depends on the intensity and duration of the exposure as well as the photosensitivity of the fibre. To write a high reflectivity fiber Bragg grating directly in the fiber the level of doping with germanium needs to be high. However, standard fibers can be used if the photosensitivity is enhanced by pre-soaking the fiber in hydrogen. More recently, fiber Bragg gratings have also been written in polymer fibers, this is described in the PHOSFOS entry.

2. Fiber bragg gratings used in fiber lasers

Recently the development of high power fiber lasers has generated a new set of applications for fiber Bragg gratings (FBG's), operating at power levels that were previously thought impossible [1]. In the case of a simple fiber laser, the FBG's can be used as the high reflector (HR) and output coupler (OC) to form the laser cavity. The gain for the laser is provided by a length of rare earth doped optical fiber, with the most common form using Yb3+ ions as the active lasing ion in the silica fiber.

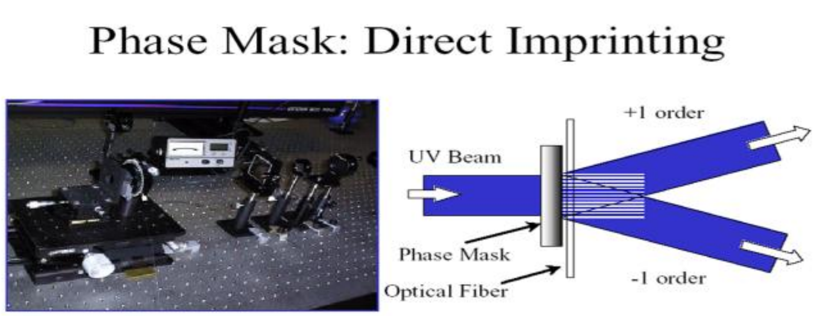

Figure1. Phase masking in case of fiber brag grating

These Yb-doped fiber lasers first operated at the 1 kW CW power level in 2004 based on free space cavities but were not shown to operate with fiber Bragg grating cavities until much later. Such monolithic, all-fiber devices are produced by many companies worldwide and at power levels exceeding 1 kW. The major advantage of these all fiber systems, where the free space mirrors are replaced with a pair of fiber Bragg gratings (FBG's), is the elimination of realignment during the life of the system, since the FBG is spliced directly to the doped fiber and never needs adjusting [2].

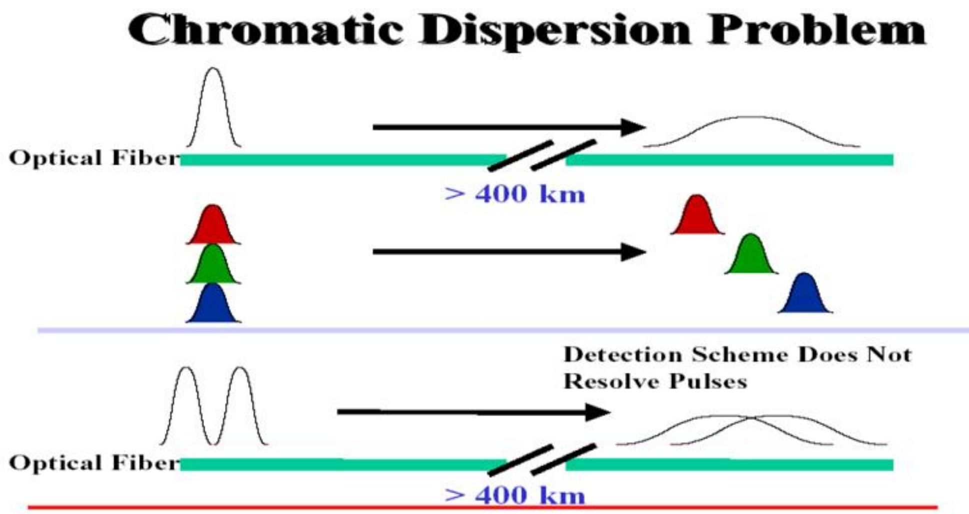

Figure2. Chromatic dispersion problem in fiber brag grating

The challenge is to operate these monolithic cavities at the kW CW power level in large mode area (LMA) fibers such as 20/400 (20 um diameter core and 400 um diameter inner cladding) without premature failures at the intra-cavity splice points and the gratings. Once optimized, these monolithic cavities do not need realignment during the life of the device, removing any cleaning and degradation of fiber surface from the maintenance schedule of the laser. However, the packaging and optimization of the splices and FBGs themselves are non-trivial at these power levels as are the matching of the various fibers, since the composition of the Yb-doped fiber and various passive and photosensitive fibers needs to be carefully matched across the entire fiber laser chain [3].

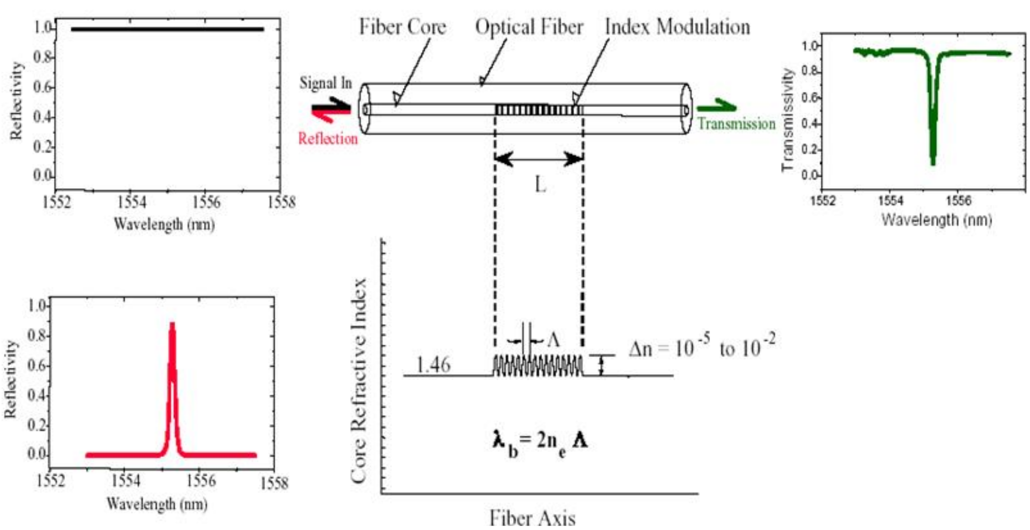

Figure3. Fiber brag grating principle

Although the power handling capability of the fiber itself far exceeds this level, and is possibly as high as >30 kW CW, the practical limit is much lower due to component reliability and splice losses. Process of matching active and passive fibers In a double-clad fiber there are two waveguides – the Yb-doped core that forms the signal waveguide and the inner cladding waveguide for the pump light. The inner cladding of the active fiber is often shaped to scramble the cladding modes and increase pump overlap with the doped core. The matching of active and passive fibers for improved signal integrity requires optimization of the core/clad concentricity, and the MFD through the core diameter and NA, which reduces splice loss. This is principally achieved by tightening all of the pertinent fiber specifications. Matching fibers for improved pump coupling requires optimization of the clad diameter for both the passive and the active fiber. To maximize the amount of pump power coupled into the active fiber, the active fiber is designed with a slightly larger clad diameter than the passive fibers delivering the pump power [4]. As an example, passive fibers with clad diameters of 395-um spliced to active octagon shaped fiber with clad diameters of 400-um improve the coupling of the pump power into the active fiber. An image of such a splice is shown, showing the shaped cladding of the doped double-clad fiber. The matching of active and passive fibers can be optimized in several ways. The easiest method for matching the signal carrying light is to have identical NA and core diameters for each fiber. This however does not account for all the refractive index profile features. Matching of the MFD is also a method used to create matched signal carrying fibers [5]. It has been shown that matching all of these components provides the best set of fibers to build high power amplifiers and lasers. Essentially, the MFD is modeled and the resulting target NA and core diameter are developed. The core-rod is made and before being drawn into fiber its core diameter and NA are checked. Based on the refractive index measurements, the final core/clad ratio is determined and adjusted to the target MFD. This approach accounts for details of the refractive index profile which can be measured easily and with high accuracy on the perform, before it is drawn into fiber.

Conclusion

The easiest method for matching the signal carrying light is to have identical NA and core diameters for each fiber. This however does not account for all the refractive index profile features. Matching of the MFD is also a method used to create matched signal carrying fibers. It has been shown that matching all of these components provides the best set of fibers to build high power amplifiers and lasers. Essentially, the MFD is modelled and the resulting target NA and core diameter are developed. The core-rod is made and before being drawn into fiber its core diameter and NA are checked. Based on the refractive index measurements, the final core/clad ratio is determined and adjusted to the target MFD.

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