Compact excimer lasers in FBG production

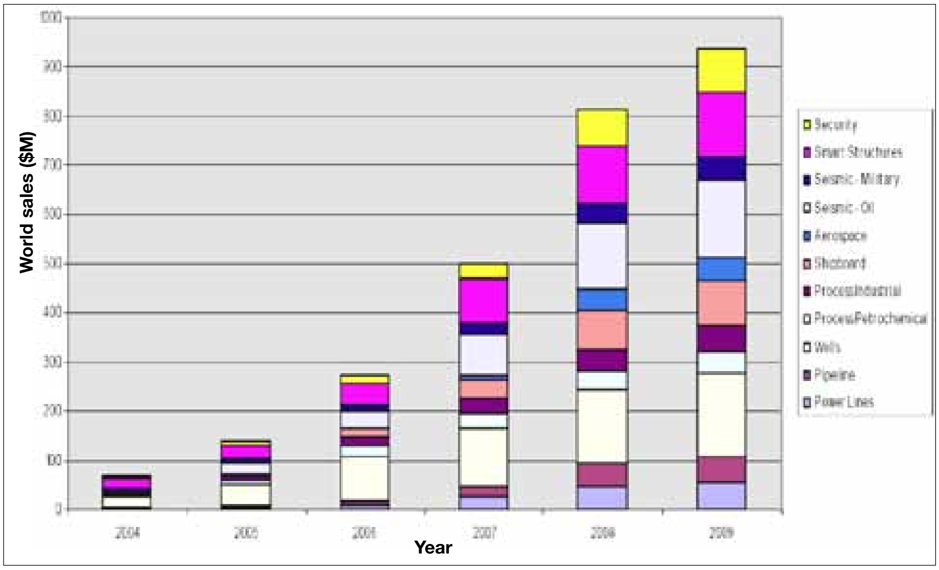

Figure 1: Total Fibre optic sensor market in million USD (Source: Lightwave Venture, LLC)

Fibre Bragg Gratings (FBGs) have found widespread use in optical telecommunications. They improve the performance of pump lasers in optical amplifiers, act as filters for gain flattening or for highly selective channel selection in wavelength division multiplexing.

Over the last decade, an increasing shift has occurred from optical communication toward optical sensing as shown in figure 1. Driven by global demand for strain, pressure and temperature monitoring in civil engineering as well as energy production and transmission, fibre optic sensor systems have emerged as an enabling technology, overcoming many of the limitations of electrical sensors.

The technical superiority of FBG based-sensor systems in these markets is in high sensor count, long strain range and low weight, plus they are chemically inert and not influenced by electromagnetic interference or harsh environments.

FBG sensor operation principle

A FBG is a form of periodic modulation of the index of refraction along the core of an optical Fibre as depicted in figure 2. When light from a broadband source interacts with the grating, a certain wavelength – the Bragg wavelength – is reflected whereas the remaining signal is transmitted. A mechanical force to the Fibre core spectrally shifts the reflected Bragg wavelength λ_r which is a function of the effective refractive index n_{eff} and the grating period Λ as indicated in figure 2. Hence, wavelength shifts as a result of grating periodicity and refractive index alterations induced by temperature, pressure or length changes can be used for optical sensing. To this end, an optical interrogation system such as a broadband light source or a narrowband fast tunable laser device is employed. The fibre containing the FBG has also to be embedded or otherwise contacted to the object, the strain or temperature changes of which is to be monitored.

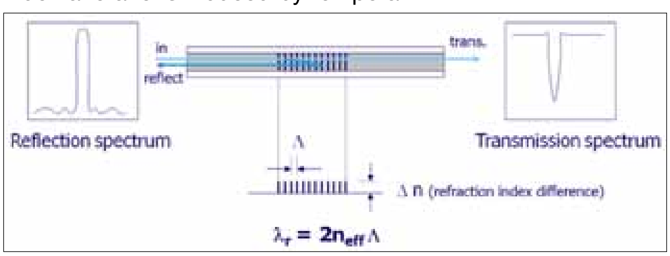

Figure 2: Principle of FBG-based fibre optic sensing

Commercial FBG sensors achieve a strain measurement accuracy of about 1µm/m and measure temperature changes as small as 0.2K. When using tunable laser interrogation schemes, fibre lengths of up to 30 km are overcome at sufficient signal-to noise ratio.

Phase-mask FBG writing

The common method in FBG production is phase-mask writing using 248 nm excimer lasers. When illuminated with the laser beam, the phase-mask generates the ±1st order beams thus creating a regular interference pattern.

Typically, the fibre and mask separation amounts to a few hundred microns, avoiding mechanical damage to the fibre material. Enhanced spatial coherence length of the excimer laser improves interference contrast behind the mask. To this end, excimer laser models used for FBG inscribing, use high coherence resonator optics that achieve a more than 1,000 µm (FWHM) coherence length.

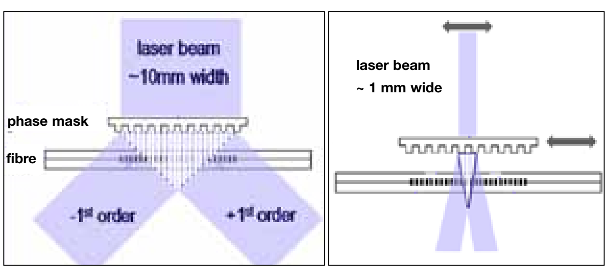

Figure 3: FBG writing with static, large beam (left) and scanning, small beam (right)

The fibre-phase mask assembly can be illuminated by a large beam covering the entire FBG structure of typically 10 mm length or by a small beam of typically 1 mm beam width which is then scanned relative to the phase mask in order to inscribe the FBG as indicated in figure 3.

The Fibre being in close proximity to the phase mask makes for a very stable mechanical system. With this method, the pattern recorded into the Fibre is a copy of the phase mask demagnified by a factor of ~2 which renders this technique well suited for automated production. Irregular grating profiles are obtained by using amplitude masks in front of a large illuminating beam or a controlled dither of the phase-mask with a scanning setup.

Today's compact excimer lasers offer billion shots tube lifetime, corresponding to 1 to 2 years tube and optics operation under FBG production conditions. Gas lifetime is of the order of 2 to 4 weeks, after which an automated new fill is performed in about 10 minutes.

Smart excimer lasers with output energies of some 10 mJ to 100 mJ per pulse have been established as affordable workhorses in phase-mask FBG manufacturing. These include (see figure 3) the Coherent COMPexPro 50 for static, large beam and the BraggStar Ind. for scanning, small beam fabrication.

Ralph Delmdahl Coherent GmbH
E: ralph.delmdahl@coherent.com
W: www.coherent.com/excimer