Chirped Bragg Grating for Beam Combining and Moiré Spectral Filtering

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Abstract: Chirped Bragg Grating (CBG) at tilted incidence is shown producing wavelength-dependent transverse beam stretching allowing for spectroscopy and spectral beam combining. Moiré patterned CBG at normal incidence is shown producing spectral comb filter.

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Chirped Bragg Gratings (CBGs) constitute a class of reflective Volume Bragg Gratings (VBG) [1]: the class, in which the spatial frequency of refractive index modulation changes along the propagation direction. CBG in fibers are successfully used for stretching and compressing of short pulses in the Master Oscillator ─ Power Amplifier schemes of a laser [2]. In the work [3] volume variant of CBG was demonstrated to perform the same function, with the advantage of much higher tolerance to large power densities of radiation. Schematics of pulse transformation and reflection spectrum for reflecting CBG is presented in figure 1. Particular parameters of numerically modeled CBG for the graph Figure 1b are as follows: total thickness of the grating $L = 0.1\ m$, chirp parameter $d\lambda_{\text{resonant}}/dz = -96\ pm/cm$, middle-to-top modulation of refractive index change $n_1 = 10^{-4} \equiv 100$ parts per million, central wavelength $\lambda_0 = 1.06\ \mu m$, and thus "strength" $S = \pi L n_1/\lambda_0$=30, diffraction efficiency at spectral plateau is about $\eta \approx 0.975$.

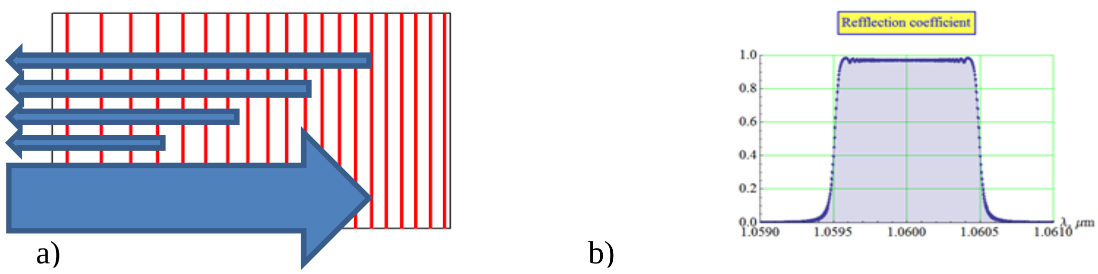

Figure 1. a) Chirped Bragg Grating (CBG) and its action; b) reflection spectrum of CBG.

In this talk we describe the modeling of the optical performance of two variants of CBG.

The first variant is CBG at Tilted incidence (TiCBG), where the incident ray constitutes an angle θ with the normal to Bragg planes, θ being measured inside the medium. Polychromatic incident beam composed of discrete spectral components is separated into transverse-shifted group of those components, Figure 2a. Crude interpretation of the process is that different wavelengths find different depth inside TiCBG, where they are reflected according to Archimedes' Law. We have actually modeled the process of reflection by TiCBG for each individual spectral component by Fourier expansion of transverse profile of the beam, calculation of complex reflection amplitude for each Fourier harmonic, and subsequent recombining of Fourier harmonics into spatial profiles of reflected beams. Details of equations for coupled waves and technique of their solution were previously presented by us in [4], [5]. The main technical novelty of calculations here is to properly elucidate the detuning form Bragg condition for each individual transverse Fourier harmonic. The particular formulae for that detuning may be found e.g. in [6]. An example of the results of such modeling is presented at the Figure 2c. Particular incidence angle was taken θ = 30°, transverse size of our TiCBG $\Delta x = 6.7\ cm$, transverse size of incident Gaussian beam $w_0(\text{FWe}^{-2}\text{IM}) = 4mm$ was chosen in such a way that the beams with depicted wavelengths do not overlap.

The same device may be used for spectral beam combining, if all the beams are reversed, Figure 2b. Actual transverse size of the beams may be made much smaller, if residual absorption of high power density does not harm the optical properties of TiCBG.

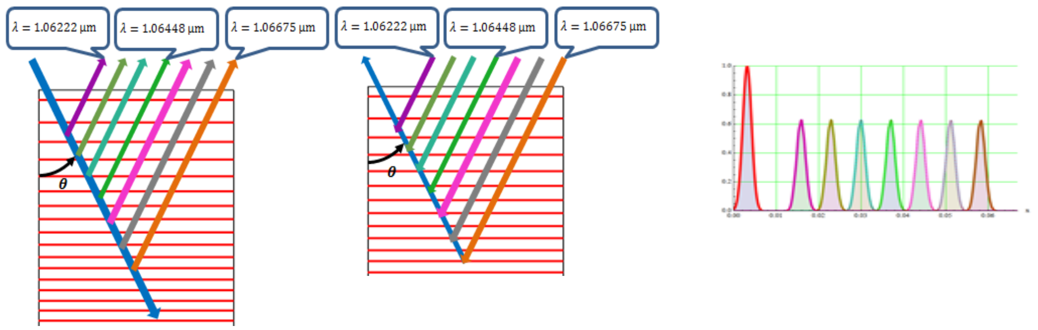

Figure 2. a) Separation of polychromatic beam into transverse-sifted components at Tilted incidence (TiCBG), b) Combining of several beams into one by TiCBG, c) Calculated transverse patterns of the beams.

Another novel variant of CBG is the one, when simultaneously two chirped gratings are recorded into the same volume with the same value of $d\lambda_{\text{resonant}}/dz$, but with slight longitudinal shift with respect to each other. A Moiré pattern of CBG (MCBG) thus is implemented; compare to Moiré VBG without chirp, studied in details in [7,8]. Figure 3a shows a particular example of the refractive index modulation profile in MCBG. Spectral dependence of reflection coefficient for such MCBG was numerically modeled by us by the technique from [4], and is presented at the Fig. 3b.

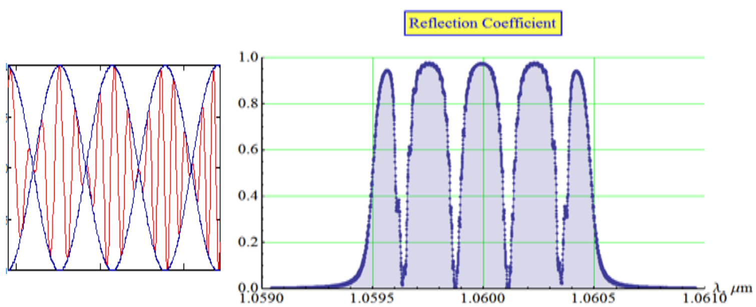

Figure 3, a) Example of refractive modulation in a Moiré CBG, b) Corresponding spectral dependence of reflection coefficient for the normal incidence.

Generally the spectrum of reflection is a comb, with the number of reflection zeros coincident with the number of zeros in Moiré pattern. The width values of the transmission comb may be made very narrow, if the strength of MCBG is large enough.

To conclude, we suggested and modeled numerically two novel variants of the use of Chirped Bragg Gratings: Tilted incidence at CBG (TiCBG), and Moiré CBG at normal incidence (MCBG), and suggested their possible applications.

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